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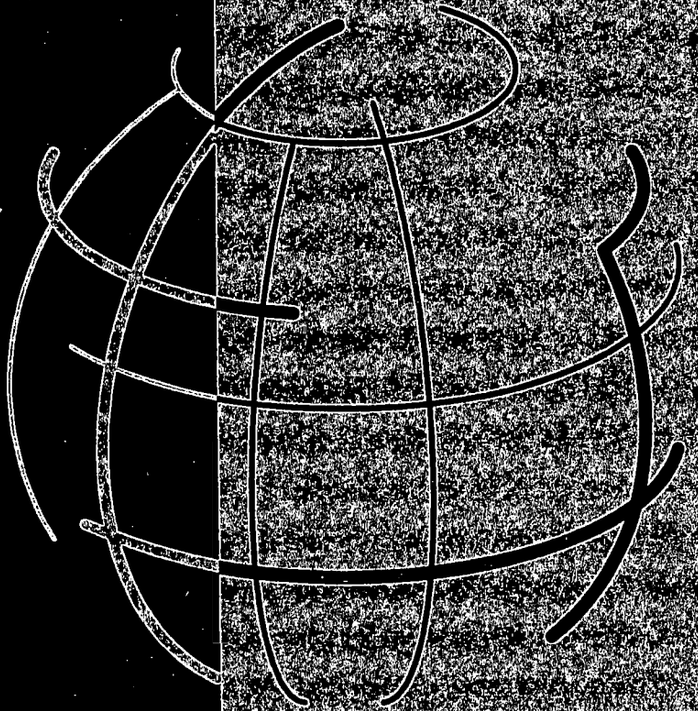
2/18/2000

# United States

# TAKING ACTION ON CLIMATE CHANGE



October 1999

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# EXECUTIVE SUMMARY

Climate change threatens the United States and all nations. To help address this threat, the United States is taking significant new steps to reduce greenhouse gas emissions. During the past year, President Clinton launched initiatives on bioenergy, wind and solar energy, and Federal energy efficiency. In addition, a growing number of state and local governments and private companies are stepping forward to address climate change with prudent, creative, cost-effective strategies to reduce greenhouse gas emissions. At the same time, the United States continues to invest more than $1 billion per year in research and development on technologies that will help reduce greenhouse gas emissions. In short, from city council chambers to corporate boardrooms, the United States is mobilizing against global warming—the greatest environmental challenge of the 21st century.

## New Initiatives

In 1999, the Clinton Administration launched four initiatives that will help reduce greenhouse gas emissions in the United States:

- ***Bioenergy.*** In August 1999, the President signed an Executive Order to accelerate the development of bio-based industries. The President set a goal of tripling U.S. use of bioenergy and bioproducts by 2010. This would reduce annual greenhouse gas emissions by an amount equal to as much as 100 million metric tons of carbon (MMTCE).

- ***Federal energy.*** In June 1999, President Clinton issued an Executive Order requiring each Federal agency to reduce greenhouse gas emissions from energy use in buildings by 30 percent below 1990 levels by 2010.

- ***Wind Powering America.*** This new U.S. Department of Energy (DOE) initiative seeks to supply 5 percent of U.S. electricity through wind technologies by 2020, which would avoid emissions of 35 MMTCE.

- ***Brightfields.*** DOE announced a program aimed at using former industrial sites contaminated with toxic waste for producing pollution-free solar energy.

These new Federal initiatives on climate are set forth in the first section of this report.

## U.S. States, Localities, and Companies Moving Forward

In addition to actions at the Federal level, many states, cities, industries, and sectors of the U.S. economy are moving forward on their own to address climate change, understanding that the threat is real and prudent action is called for.

These actions are described in more detail in Parts II and III of this report.

## Ongoing Federal Efforts

The foundation of President Clinton's environmentally and economically sound plan for reducing U.S. greenhouse gas emissions remains the Climate Change Technology Initiative (CCTI)—a vigorous five-year, $6.3 billion program of tax incentives and investments focusing on energy efficiency and renewable energy technologies. Last year, in Fiscal Year 1999, President Clinton and Vice President Gore secured more than $1 billion in CCTI funding. These CCTI investments already are yielding real results and real emissions reductions. For example:

- Federal *energy efficiency standards for equipment and appliances*, such as heating and cooling equipment, water heaters, lighting, refrigerators, clothes washers and dryers, and cooking equipment will avoid cumulative emissions of more than 225 MMTCE by 2010.

- Federally led voluntary programs, such as *ENERGY STAR®* labeling for high efficiency products and buildings, already have resulted in more than $3 billion in technology investments by U.S. companies, consumers, and state and local organizations. These investments will deliver emissions reductions of almost 40 MMTCE over the next decade.

- Federal efforts focused on *non-$CO_2$ greenhouse gases* have locked in emissions reductions of well over 100 MMTCE through 2010. In so doing, they are expected to maintain methane emissions at or below 1990 levels through 2010. Not counting applications to replace ozone-depleting substances, they will also maintain industrial emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$) at or below 1990 levels through 2010.

Other CCTI investments have a more long-term R&D focus and can be expected to yield even greater reductions in the decade ahead. Among these are: the *Partnership for a New Generation of Vehicles*, a government-industry effort to develop cars that achieve up to three times the fuel efficiency of today's cars; the *Partnership for Advancing Technology in Housing*, which aims to improve the energy efficiency of new homes by more than 50 percent and to retrofit 15 million existing homes to make them 30 percent more energy efficient within a decade; and *research partnerships* for key renewable energy technologies such as wind, photovoltaics, geothermal, and biomass.

In addition to the CCTI, other important elements of the President's October 1997 plan include a proposal to restructure the electricity industry by introducing competition that will provide incentives for

energy efficiency; a wide range of industry consultations with key energy-intensive industry sectors to improve energy use and reduce emissions; a commitment to work with the U.S. Congress and industry on legislation to reward companies that take early action to reduce their emissions; reducing the Federal government's own greenhouse gas emissions; and a strong program of scientific research to further our understanding of human and naturally induced changes in the Earth's environment and assess the likely consequences of global warming.

These ongoing Federal programs and policies to address climate change are set forth in more detail in Part IV of this report.

## Part of a Larger Three-Stage Plan

The programs and policies set forth in this report are part of the United States' longer-term response to the challenge of climate change. In 1993, following the U.S. ratification of the UN Framework Convention on Climate Change, President Clinton launched the Climate Change Action Plan (CCAP), emphasizing a series of win-win voluntary initiatives for reducing greenhouse gases. These efforts were expanded significantly in October 1997, prior to the Kyoto conference, when the President outlined his more comprehensive, three-stage plan for reducing U.S. emissions. The three stages of the plan are:

- *Stage 1:* **Priming the pump** through R&D investments and tax incentives aimed at increasing energy efficiency and spurring the broader use of renewable energy; working with industry and others to promote sensible solutions; and employing market-based mechanisms to ensure cost-effective reductions. ***All of the materials included in this report are part of Stage 1 of the President's plan.***

- *Stage 2:* **Review and evaluation** in preparation for a domestic emissions trading system. Under the President's plan, the United States will review its progress beginning around 2004 and evaluate next steps as it moves towards a market-based permit trading system for carbon emissions. Emissions trading will harness the power of the market to achieve a national greenhouse gas target at the lowest possible cost. The United States is using emissions trading successfully to reduce the pollution that causes acid rain, exceeding environmental objectives while reducing the costs to 50 percent below the expected level.

- *Stage 3:* **Binding targets through a domestic emissions trading program.** Beginning in 2008, an emissions trading program would be implemented to cut emissions in the major greenhouse gas-emitting sectors of the U.S. economy: buildings, transportation, industry, and electricity.

The President's three-stage plan recognizes the long-term nature of efforts to address climate change. It allows us to

monitor our progress and re-assess our success in reducing emissions, the state of scientific knowledge, and the response of the U.S. economy. The plan's graduated approach to emissions reduction will allow the United States to exploit the opportunities that exist for win-win reductions that both help the environment and save money for consumers, businesses, and governments.

## 1998 Emissions

In 1998, greenhouse gas emissions in the United States grew only slightly (0.4 percent) despite strong U.S. economic growth (3.9 percent). Although there were several one-time contributing factors (including mild weather that reduced the demand for heating fuel), the 1998 emissions figures are encouraging. Clearly, these numbers demonstrate that economic growth and emissions need not move in lockstep. The 1998 figures are consistent with a long-term movement in the U.S. economy toward the lower-emitting service and high-technology sectors.

## The Way Forward

At the same time, we realize that it is far too soon to conclude that the 1998 emissions figures represent a trend, and there is certainly no room for complacency. Reducing emissions will continue to be an uphill climb—both for the United States and the entire world.

In the long run, the President's balanced approach to the challenge of climate change will allow the United States to continue to grow our economy and protect the environment at the same time.

As President Clinton has said: "One of the big ideas the world has to abandon is the idea that the only way to build a modern prosperous economy is with the industrial energy use patterns of a former era. It is not true."

# PART I: NEW FEDERAL INITIATIVES

Over the past year, the Clinton Administration introduced a series of new Federal initiatives to address the challenge of climate change. They include:

- **Executive Order on Bio-Based Products and Bioenergy**
- **Executive Order on Federal Energy Efficiency**
- **Wind Powering America Initiative**
- **Brightfields Initiative**

This section discusses each of these initiatives in turn.

## Measuring Greenhouse Gas Emissions and Emissions Reductions

Greenhouse gas emissions can be expressed either in terms of metric tons of carbon equivalent (MTCE) or in metric tons of carbon dioxide equivalent. This report uses MTCE or million MTCE (MMTCE). To convert carbon equivalents to carbon dioxide equivalents, multiply by 3.67.

Because of the interaction effects of programs designed to reinforce each other, it would not be appropriate to add together emissions reductions for all programs listed in this report to arrive at an estimate of total U.S. reductions. Furthermore, estimates from government agencies and industry sectors rely on different baselines and cannot be directly compared. There is a substantial amount of uncertainty associated with any of these projections because the estimates attempt to quantify projected technology adoption more than a decade into the future.

# THE PRESIDENT'S NEW EXECUTIVE ORDER ON BIO-BASED PRODUCTS AND BIOENERGY

On August 12, 1999, President Clinton announced new steps to spur bio-based technologies that can help grow the U.S. economy, enhance U.S. energy security, and meet environmental challenges, including global warming. The President issued Executive Order 13134 coordinating Federal efforts to accelerate these 21st century technologies—which can convert sustainably grown crops, trees, and other "biomass" into fuels, power, and products. He also set a goal of tripling U.S. use of bioenergy and bioproducts by 2010. Meeting this goal could create $15 to $20 billion in new income for farmers and rural America, and reduce annual greenhouse gas emissions by an amount equal to as much as 100 million metric tons of carbon (MMTCE)—the equivalent of taking more than 70 million cars off the road.

## What the Executive Order Does

Scientific advances in agriculture, forestry, and other biological sciences are making bioenergy and bioproducts technically feasible and economically viable. Recent reports and studies concluded that U.S. government support for research is essential to realizing the full economic and environmental potential of bio-based industries. The new Executive Order:

- Establishes a permanent council consisting of the Secretaries of Energy and Agriculture, the Environmental Protection Agency Administrator, the Director of the National Science Foundation, and other agency heads

### Biomass: Clean Renewable Energy for the 21st Century

The term *biomass* refers to trees, crops, and agricultural, forestry, and other organic waste materials that can be used to make fuels, chemicals, and electricity. Biomass is a clean and renewable source of energy. It can be used to fuel cars, power factories, and create a host of chemicals and other everyday products. Energy from biomass sources—mostly from wood and wood waste—currently accounts for about 3 percent of the total U.S. energy supply. Since biomass crops absorb carbon during growth, their use for energy and other applications results in near-zero net carbon release. Thus, substituting sustainably grown biomass for fossil fuels can dramatically reduce greenhouse gas emissions that contribute to global warming, while also reducing emissions of nitrogen oxides ($NO_x$), sulfur oxides ($SO_x$), and other pollutants. In addition, the deep-rooted plants commonly used for biomass, such as poplar, willow, and switchgrass, are helpful in controlling erosion, filtering chemicals from water runoff, and slowing floodwaters.

to develop a detailed research program to be presented as part of the annual Federal budget.

- Instructs the council to review major agency regulations, incentives, and programs to ensure that they are effective in promoting the use of bioproducts and bioenergy. The council's plan will be reviewed by an outside advisory group with representatives from bio-based industries, agriculture and forestry sectors, universities, and environmental groups.

- Directs the U.S. Department of Energy (DOE) and the U.S. Department of Agriculture (USDA) to establish a National Bio-based Products and Bioenergy Coordination Office to manage the preparation of interagency budgets and provide a convenient point of entry for anyone interested in Federal work in bio-based products and bioenergy.

The Executive Order also builds on the Administration's record of strong and consistent support for bio-based industries, as indicated by: (1) the electricity restructuring bill introduced by the Administration earlier in 1999 requiring that 7.5 percent of all U.S. electricity come from renewable resources by 2010; (2) Executive Order 13101, signed in September 1998, instructing Federal agencies to make use of bio-based products; (3) new proposed tax credits for bio-based electricity production; and (4) increased research funding for DOE, USDA, and the National Science Foundation.

## Bioenergy and Bioproducts Are Here Today

Clean bioenergy and bioproducts are very much here and now. Already DOE and USDA are participating in partnerships on a number of breakthrough bioenergy and bioproducts projects, including:

***Biomass-to-Ethanol Demonstration Projects.*** During the autumn of 1998, BC International Corporation broke ground in Jennings, Louisiana, for the first commercial plant to produce ethanol from the cellulose in agricultural waste—in this case, sugar cane bagasse. A number of other demonstration projects to convert municipal solid waste to ethanol are under development.

***Biorefinery for Chemicals.*** Cargill Corporation, one of the largest privately held companies in the United States, built a prototype biorefinery in Blair, Nebraska. This new facility will use corn to produce a stream of chemical products and also a biodegradable polymer, polylactic acid, used in manufacturing films, fibers, rigid materials, and coatings.

***Co-Firing Technologies.*** A number of projects are underway to explore ways to use biomass such as switchgrass and short-rotation wood crops like willows to make electricity by co-firing them with coal. Two of the most prominent studies—the Iowa Chariton Valley initiative and

the New York Salix project—also will investigate the technical and economic aspects of biomass gasification, in which biomass is made into a fuel gas that can be used for heat or power production.

***Biomass to Energy.*** In the United States, more than 270 landfill gas-to-energy projects use the gas from decomposing waste as an energy source.

## Economic Potential of Using Biomass for Energy and Products

Using biomass for energy and products is not only good for the environment, it also promises real economic opportunities for farmers, the forest products industry, energy producers, and chemical manufacturers. In rural areas, a fast-growing bioenergy market will increase the demand for energy crops, agricultural and forest residues, and wastes of all types. By creating high-tech jobs and new economic opportunities, meeting the President's goal of tripling U.S. use of bioenergy and bioproducts could add $15 to $20 billion in new income for farmers and many rural communities, ensuring that they are an integral part of a prosperous 21st century global economy. The President's Committee of Advisors on Science and Technology noted in a recent report, "Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation," that investments in bioenergy technologies, infrastructures, and markets can play a crucial role in helping the world meet its future energy needs in an environmentally sustainable way.

## The Administration's Fiscal Year 2000 Budget on Biomass

The President's Fiscal Year 2000 budget request contains $242 million for investments in biomass research, development, and deployment, including:

***Advanced Biomass Power and Fuels***—funding for DOE and USDA to continue developing, testing, and demonstrating high-yield, low-cost biomass feedstocks; processes for co-firing biomass with coal to produce electricity; advanced technologies for biomass gasification using paper industry by-products; and continued work on producing alternative fuels, such as cellulosic ethanol, from biomass.

***National Biomass Partnership***—funding for DOE, USDA, and other Federal agencies and their private partners to launch a national partnership to develop advanced integrated biomass technologies.

The President also proposed a package of ***biomass tax credits***, which would add an extension of five years to the current tax credit of 1.5 cents per kilowatt-hour for electricity produced from biomass. In addition, the proposal expands the types of biomass eligible for the credit to include certain forest-related, agricultural, and other resources. Finally, the package includes a 1.0 cent per kilowatt-hour tax credit for electricity produced by co-firing biomass in coal plants.

# THE PRESIDENT'S NEW FEDERAL ENERGY EFFICIENCY EXECUTIVE ORDER

On June 3, 1999, President Clinton issued Executive Order 13123 that will help meet the challenge of global warming by requiring each Federal agency to reduce greenhouse gas emissions from energy use in buildings by 30 percent below 1990 levels by 2010. This will reduce annual greenhouse gas emissions by 2.4 million metric tons of carbon equivalent (MMTCE)—the equivalent of taking 1.7 million cars off the road—and save U.S. taxpayers more than $750 million a year. The order also will expand markets for renewable technologies, reduce air pollution, and serve as a powerful example to U.S. businesses and consumers who can reap substantial benefits from energy improvements.

## Aggressive New Goals

The Federal government is the largest energy consumer in the United States. Its annual energy bill runs more than $8 billion, including $4 billion to heat, cool, and power 500,000 buildings. Federal agencies already have reduced energy consumption 17 percent per square foot relative to 1985 levels. The Executive Order builds on that progress, extending current energy efficiency goals and setting new targets for greenhouse gas reductions, renewable energy use, and water conservation.

***New Greenhouse Gas Reduction Goal.*** The order requires each Federal agency to reduce greenhouse gas emissions that result from energy use in its buildings by 30 percent below 1990 levels by 2010. This is the Federal government's first-ever goal tied to greenhouse gas reductions.

***New Energy Efficiency Goal for Facilities.*** The Executive Order requires each Federal agency to improve energy efficiency in its buildings by 35 percent relative to 1985 levels by 2010.

***New Energy Efficiency Goal for Industrial and Laboratory Facilities.*** The order requires each Federal agency to improve its energy efficiency in industrial and laboratory facilities by 25 percent relative to 1990 by 2010.

***Expanded Use of Renewable Energy.*** Building on the President's commitment to install 20,000 Federal solar energy systems by 2010, the order calls for Federal agencies to expand their investments in renewable energy through applications of solar, wind, geothermal, and biomass technologies at Federal facilities and through the purchase of electricity from renewable energy sources.

***Water Conservation.*** The order calls for Federal agencies to improve their efficiency in the use of water in order to reduce water consumption and associated energy use. The order requires the U. S. Department of Energy (DOE) to work with other Federal agencies to develop water consumption baselines and then set appropriate goals for water conservation.

***Fewer Exempt Facilities.*** Prior to the President's new Executive Order, a large number of facilities (accounting for 17 percent of energy use in buildings) were exempt from meeting Federal energy goals. Now all facilities are subject to those goals and requirements unless they meet new exemption criteria to be developed by DOE. In addition, each agency must report all exempt facilities in its annual report to the President and explain the rationale behind excluding them from Federal energy goals.

## Cutting-Edge Tools and Strategies

The Executive Order calls for agencies to use a wide range of energy management tools and strategies to fulfill the new energy efficiency, renewable energy, and greenhouse gas reduction goals.

***Alternative Financing.*** Financing options such as Energy Savings Performance Contracts (ESPCs) and utility energy efficiency service contracts offer Federal agencies powerful tools for leveraging private sector financing to fund cost-saving energy improvements at no net cost to taxpayers. Under ESPCs, private sector energy service companies finance the up-front cost of purchasing and installing new energy efficient equipment. The Federal government uses a portion of the savings it accrues through reduced energy bills to repay the energy service company over the life of the contract. Contractors then receive a predetermined share of the value of the energy savings generated by their efforts and may be paid only if actual savings result from the reduced energy use. All additional savings go to the Federal government. The government benefits from new equipment, reduced energy costs, improved energy efficiency, reduced greenhouse gas emissions, and conservation of nonrenewable fuels.

To date, DOE and the U.S. Department of Defense (DoD) have made more than $8 billion in ESPC contract authority available for all Federal agencies to fund energy improvements. In addition, many of these contracts are "Super ESPCs" that rely on the same principles as regular ESPCs but offer an umbrella contract to allow expedited service. The Executive Order calls for agencies to maximize their use of ESPCs and utility energy efficiency service contracts to realize energy and cost savings.

***Life-Cycle Cost Analysis.*** Federal agencies need to consider the full cost of their investments, including energy, operation, and maintenance costs, not simply the purchase cost of projects or products. By taking all costs into account, agencies can save money and reduce energy use. To that end, the order requires agencies to consider life-cycle costs—that is, investment, capital, installation, energy, operating, maintenance, and disposal costs—over the life of the project or product.

***ENERGY STAR® Labels and Other Energy Efficient Products.*** The order calls for agencies to purchase energy efficient products such as those with the

ENERGY STAR label. Purchasing compact fluorescent light bulbs, highly efficient boilers, and other energy efficient products can save Federal agencies hundreds of millions of dollars.

***ENERGY STAR Building℠ Label.*** Agencies shall strive to meet the ENERGY STAR Building criteria in their eligible facilities to the maximum extent practicable by the end of 2002. The label signifies that the building is in the top 25 percent of similar buildings with regard to energy efficiency.

***Electricity from Renewable Energy and Energy Efficient Sources.*** Given that more than 70 percent of the Federal government's costs for energy used in buildings comes from electricity, the Executive Order requires agencies to consider the source of their electricity and opt for cleaner, more efficient electricity generation. Specifically, agencies shall strive to minimize the greenhouse gas intensity of purchased electricity. In addition, agencies should adopt policies to increase the use of electricity from renewable energy sources.

***Highly Efficient Energy Systems.*** The Executive Order calls for agencies to make greater use of highly efficient energy systems, including combined heat and power systems that use "waste" heat from industrial processes to supply power to other needs. These systems can offer tremendous energy and cost savings, as well as significant environmental benefits.

***Off-Grid Electricity Generation.*** The Executive Order requires agencies to consider off-grid electricity opportunities that often provide energy and environmental benefits, while allowing agencies to avoid the costs of building new transmission lines or digging up existing lines. Off-grid options can be particularly effective in remote locations such as some U.S. national parks. Technologies range from solar outdoor lighting to small wind turbines and fuel cells.

***Sustainable Building Design.*** In July 1998, a number of Federal agencies committed to constructing sustainably designed buildings. The June 1999 Executive Order requires all Federal agencies to apply sustainable design principles to the siting, design, and construction of new facilities, thereby saving energy and taxpayer dollars, and reducing pollution.

## Strengthening Agency Accountability

The Executive Order provides a framework to hold agencies accountable for their progress in Federal energy management. The following new management strategies and reporting requirements will help ensure that all Federal agencies manage energy use wisely, reaping substantial fiscal and environmental benefits for years to come.

***Annual Reports to the President and Annual Score Cards.*** Under the Executive Order, each Federal agency must submit an annual report to the

President describing the agency's progress in meeting the goals. In addition, the Deputy Director for Management of the Office of Management Budget will evaluate each agency's performance and submit agency score cards to the President.

***President's Management Council.*** The President's Management Council, which generally consists of deputy secretaries from all agencies, will monitor agency progress on Federal energy management and provide a high-level forum for identifying ways to accelerate improvements.

***Agency Energy Teams.*** The Executive Order requires each agency to form a technical energy support team to ensure that energy management strategies are implemented across all facilities. The energy teams bring together legal, procurement, and other essential agency representatives to overcome barriers to realizing energy and cost savings.

***New Public-Private Advisory Committee.*** The order calls for DOE to organize an advisory committee to bring together private and public sector experts who can advise agencies on ways to improve their energy management practices.

## Concrete Steps, Concrete Savings

In conjunction with the signing of a new Executive Order to promote energy efficiency, President Clinton announced the Pentagon's intent to award **the Federal government's largest-ever Energy Saving Performance Contract (ESPC).** Under this award, Viron Energy Services and Pepco Energy Services will upgrade the energy performance of 837 Federal buildings at no up-front cost to taxpayers. The 18-year service contract, covering five military installations in the Washington, DC, area, will reduce annual energy consumption by 17 percent. The reductions will reduce annual greenhouse gas emissions by 24,000 metric tons of carbon equivalent (MTCE)—equivalent to taking more than 19,000 cars off the road—and will save DoD more than $219 million in energy and related costs.

Other examples of energy-saving actions that the Executive Order is designed to promote include:

***Energy Efficient Procurement.*** The Defense Logistics Agency (DLA), which supplies almost 20 percent of all light bulbs purchased by the Federal government, teamed up with DOE to offer half-price compact fluorescent light bulbs to any Federal purchaser.

Last year, the DLA supplied 1.5 million bulbs to Federal purchasers. If the bulbs had all been compact fluorescents, savings over the life of the bulbs would have totaled $7.5 million. Recently, DOE added compact fluorescents to the ENERGY STAR product-rating program, providing consumers with quality assurance when they purchase the bulbs. A compact fluorescent bulb can last up to five years, saving $67 over its lifetime.

## THE PRESIDENT'S NEW FEDERAL ENERGY EFFICIENCY EXECUTIVE ORDER

***Renewable Energy Projects.*** Some 18 Federal agencies—from the departments of Agriculture, Interior, and Transportation to the Smithsonian Institution and the U.S. Postal Service—recently received a combined $1.5 million in DOE funding for more than 100 cost-effective renewable energy projects at government sites. The technologies include more than 50 new or renovated solar water heating systems, large and small photovoltaic (PV) systems, PV-powered lights, wind power, and "solar walls" that preheat outside air for interior heating.

***Buying Renewable Power.*** EPA's Richmond, California, laboratory became the first major Federal facility to use 100 percent renewable energy. Initially, 60 percent of the power supplied will come from geo-thermal sources, and 40 percent will come from biomass. This green power purchase will produce environmental benefits equivalent to eliminating more than two million passenger car miles driven in California each year.

***ENERGY STAR Buildings.*** EPA retrofitted GSA's Foley Square Federal Office Building in New York City to qualify for the ENERGY STAR Buildings Label. The building, which opened in 1994, has 1.2 million square feet and houses offices of the Federal Bureau of Investigation, Internal Revenue Service, and EPA. By deploying equipment and products that qualify the building for the ENERGY STAR label, Foley Square saves taxpayers $1.3 million annually in energy costs.

### Prior Federal Energy Efficiency Efforts

The President's June 1999 Executive Order builds upon previous efforts to improve Federal energy efficiency. The Energy Policy Act of 1992 established the goal of improving energy efficiency in Federal office buildings by 20 percent on an energy-per-square-foot basis by the year 2000, compared with a baseline year of 1985. In March 1994, President Clinton issued Executive Order 12902, which extended the energy efficiency goal to 30 percent below 1985 levels by 2005. The latest order extends these goals still further, while also tightening provisions on exempted facilities and setting forth the first-ever Federal goal tied specifically to greenhouse gas reductions.

# WIND POWERING AMERICA INITIATIVE

Wind is an emissions-free energy technology with largely untapped potential to meet future U.S. energy needs while helping address the challenge of climate change. ***Wind Powering America*** is a new U.S. Department of Energy (DOE) initiative announced in June 1999 to supply 5 percent of U.S. electricity through wind technologies by 2020. Meeting this goal will avoid annual greenhouse gas emissions of over 30 million metric tons of carbon equivalent (MMTCE) in 2020. Mid-term program goals include:

- Doubling the number of states with more than 20 megawatts of wind capacity to 16 by 2005, and tripling that number to 24 by 2010.
- Increasing the contribution of wind turbines to Federal electricity use to 5 percent (1,000 megawatts) by 2010.

## Accelerated R&D

Wind Powering America will seek to meet its goals through a robust program to accelerate the research, development, and deployment of wind technologies. The initiative will build partnerships with states and localities, educate the U.S. public on the benefits of wind power, and encourage Federal agencies and organizations to lead by example in the employment of wind technologies.

## Wind Power Is Here and Now

***A New "Crop" for Farmers.*** Since 1998 more than 400 megawatts of new wind generating capacity has been installed on farmlands in the Great Plains region of the United States, providing a substantial economic boost directly to farmers, landowners, and local communities while satisfying the growing demand for clean electricity. Wind farming creates construction and service jobs in rural regions, as well substantial tax revenues for local municipalities.

***Remote Community Power.*** Kotzebue, Alaska, located north of the Arctic circle, is putting wind energy to work in reducing its dependence on diesel fuel for electric power. Shipment of diesel fuel to Kotzebue as well as many other Alaskan communities is expensive, seasonally limited, and environmentally risky. Kotzebue recently began operating a wind farm comprised of 10 rugged 66-kilowatt turbines that are reliably providing up to 10 percent of the community's power needs with an energy cost savings of about 40 percent.

***Federal Opportunity.*** Three 225-kilowatt wind turbines are saving the U.S. Navy more than $100,000 each year in diesel fuel costs for powering its station on San Clemente Island, 70 miles off the coast of Southern California. In addition, the turbines are helping the Navy respond to stringent local air pollution control mandates. With a near-perfect reliability record, the project is serving as a model for the way that wind energy can bring benefits to Federal facilities.

# BRIGHTFIELDS INITIATIVE

Brightfields is a new initiative launched by the U.S. Department of Energy (DOE) in August 1999, aimed at using former industrial sites contaminated with toxic waste for producing pollution-free solar energy. This novel concept addresses three of the nation's greatest challenges: climate change, urban revitalization, and toxic waste cleanup.

## From "Brownfields" to "Brightfields"

Many former industrial sites in U.S. urban areas are hard to redevelop because of a legacy of toxic waste contamination. This initiative will turn these "brownfields" into "brightfields" by placing clean energy systems, such as photovoltaic arrays, and high-tech solar manufacturing facilities on these sites.

Solar energy technologies, and photovoltaic systems in particular, are well-suited to brownfield sites. They require little maintenance and can stand directly on the ground without penetrating the surface or disturbing any existing contamination. The systems can be installed to function on or off the local power grid, depending on the needs of the site and existing infrastructure. They are especially attractive in urban areas with air quality concerns. With zero emissions, solar energy systems can offset emissions from other energy sources, particularly during peak hours when utilities often rely on older systems that pollute more heavily.

Brightfields also provide an opportunity for blighted urban neighborhoods to attract high-tech jobs and environmentally conscious businesses that are interested in supporting green investments or locating in environmentally friendly industrial parks.

## Chicago First City to Use Brightfields Approach

The City of Chicago, working with DOE and Commonwealth Edison, developed an extensive plan that uses the brightfields approach to advance its economic development, climate change, air quality, and electricity reliability goals.

As a first step, municipal officials persuaded the Spire Corporation to manufacture solar panels at one of the city's brownfields, creating more than 100 new jobs. A solar energy system also will be installed, both to supply some of the company's electricity needs and to serve as a demonstration and educational site. In addition, the city and Commonwealth Edison committed $8 million over the next five years to purchase and install solar energy systems at other brownfield sites, schools, office buildings, and municipal and commercial properties, and along transportation routes.

DOE has begun work with cities in California, Connecticut, Minnesota, New York, and Virginia to explore ways that brightfields can help communities address concerns about land use, economic development, energy, air quality, and climate change.

# PART II: STATES AND LOCALITIES TAKING ACTION

Many U.S. states and communities are helping lead the fight against global warming. State and local governments, as regulators of many direct and indirect sources of greenhouse gas emissions and as managers of facilities that consume significant amounts of energy, are in a unique position to make a difference. Many are doing just that by stepping forward—both in partnership with the Federal government and on their own initiative—with innovative programs to reduce emissions. Their efforts are creating jobs and strengthening local economies, saving energy and money, and improving local air and environmental quality.

## State and Local Success Stories

The following are just a few examples of the wide array of actions that states and localities are taking to address climate change:

The ***State of New Jersey*** committed to reduce its greenhouse gas emissions by 3.5 percent below 1990 levels by 2005. This amounts to a reduction equal to 5.7 million metric tons of carbon equivalent (MMTCE) from the state's business-as-usual projections. Strategies include improving commercial and industrial energy efficiency, using innovative technologies, preventing pollution, recycling, reducing solid waste, and sequestering carbon. One project, the Affordable Housing Initiative, offers grants to developers to design low-income housing that meets energy efficiency

### U.S. Mayors Issue Statement on Global Warming

In September 1999, a group of more than 530 local officials in the United States issued a "Statement on Global Warming," expressing concern about the impacts of climate change on their communities and urging accelerated Federal efforts to assist them in reducing global warming pollution. Signatories included the mayors of Atlanta, Baltimore, Chicago, Cincinnati, Denver, Honolulu, Las Vegas, Madison, Milwaukee, Minneapolis, Newark, New Orleans, Portland, Salt Lake City, San Francisco, Seattle, St. Louis, and Tampa. The International Council for Local Environmental Initiatives (ICLEI) coordinated issuance of the statement.

Sixty-six U.S. cities have joined ICLEI's ***U.S. Cities for Climate Protection Campaign***. Participating cities agree to a set of milestones that includes preparing a baseline survey of emissions, setting a reduction target, preparing a local action plan, and implementing the plan. In 1998, the campaign avoided greenhouse gas emissions of approximately 1.3 million metric tons of carbon equivalent (MMTCE).

standards 30 percent better than current building codes. The state also established a Carbon Dioxide Bank working group and signed a letter of intent with the Netherlands that establishes a framework for developing joint initiatives to address global warming, including an emissions trading system.

In 1997, the ***State of Oregon*** enacted landmark legislation establishing a carbon dioxide standard for all new power plants of 25 megawatts or more. New natural gas-fired plants must emit 17 percent less carbon dioxide per kilowatt-hour than the most efficient gas-fired plants currently operating in the United States. The standard can be met by any combination of efficiency, co-generation, or offsets from off-site mitigation. The mitigation measures will offset 3.2 MMTCE over the next 100 years.

The ***State of Wisconsin*** is implementing energy efficient technologies and practices throughout state government, and encouraging consumers and businesses to do the same. The state's high-visibility public education campaign included retail store displays, newspaper and radio spots, brochures, and a toll-free call-in number. To date, Wisconsin has upgraded 53 million square feet in state government buildings, avoided annual greenhouse gas emissions of almost 30,000 metric tons of carbon equivalent (MTCE), and saved more than $7 million in annual energy costs.

As part of an overall restructuring of the ***State of California's*** utility industry, the state established a Renewable Resource Trust Fund to collect $540 million from investor-owned utilities to support existing and emerging renewable energy technologies. Municipal utilities and individual customers also may contribute to the fund. The fund is used to support production incentives, producer and consumer rebates, and an education program to help develop a consumer market for renewables. California also is collecting $218 million from the state's investor-owned utilities for energy efficiency projects.

In the ***State of North Carolina, Wake County Public Schools*** embarked on an ambitious effort to upgrade the energy efficiency of the county's 120 school and administration buildings. By using a shared savings program in which individual schools receive a 10 percent share of their total annual energy savings, the school system involved the entire community in energy efficiency efforts. Measures already in place are avoiding more than 2,400 MTCE annually.

The city and county of ***Denver, Colorado***, invested in lighting upgrades in 4.5 million square feet of office space, as well as multiple energy efficiency measures in nearly 2,000 additional facilities. The city's downtown district now has the highest number of buildings with the ENERGY STAR® label of any U.S. municipality. ENERGY STAR Buildings℠ is a U.S. Environmental Protection Agency

(EPA) program recognizing buildings that are in the top 25 percent of their class with regard to energy efficiency. The city also replaced incandescent light bulbs with high-efficiency red light emitting diodes in traffic signals at more than 1,200 intersections. All told, Denver's efforts avoid emissions of more than 1,900 MTCE each year.

In ***San Diego, California***, the city government, San Diego County, and the San Diego Unified School District are focused on a concentrated effort to improve building energy efficiency. The city's Environmental Services Building, for example, became the first facility in the United States to receive EPA's ENERGY STAR Buildings label. The county recently installed energy efficient lighting in some 5 million square feet of office space in less than 18 months. Together, these efforts are reducing annual greenhouse gas emissions by more than 1,200 MTCE and saving $5.6 million in annual energy costs.

The ***New York State Energy Research and Development Authority (NYSERDA)*** now offers to pay 50 percent of an applicant's consulting services for feasibility audits for energy upgrades in five of the state's electric distribution systems. NYSERDA will pay for an additional 25 percent of the audit costs of any applicant who has joined EPA's ENERGY STAR Buildings partnership.

***Minneapolis*** and ***St. Paul, Minnesota***, continued efforts toward fulfilling their pledge (made in 1993) to reduce their combined carbon dioxide emissions by 20 percent below 1988 levels by the year 2005. So far, the Twin Cities' efforts have focused largely on improving energy efficiency in municipal properties, which has saved more than $877,000 in annual energy costs.

### Low Income Weatherization and State Energy Grants

Two U.S. Department of Energy (DOE) programs specifically target energy efficiency investments at the state and local levels. The ***Weatherization Assistance Program*** delivers home energy efficiency services, such as insulation, to low-income U.S. households, reducing energy costs, improving health and safety, and reducing carbon emissions. In Fiscal Year 2000, this program will weatherize the homes of 66,000 low-income families, avoiding emissions of more than 760,000 metric tons of carbon equivalent (MTCE) and saving $248 million. The ***State Energy Program*** has provided grant funds to carry out more than 8,700 projects since 1976. The program promotes the adoption of high-potential energy technologies developed under DOE energy efficiency and renewable energy research programs, flexibly addressing unique state needs and opportunities.

Soon, more than a dozen school districts in the ***State of Iowa*** will have installed nonpolluting wind turbines to produce electricity for classrooms. Forest City Community Schools, for example, began operating a 600-kilowatt wind turbine in January 1999 that is expected to provide 80 to 90 percent of the school's electrical needs.

***Prince Georges County, Maryland***, installed a methane recovery system at a landfill and uses the methane to provide heat, hot water, and electricity to a nearby correctional facility. Annual methane emissions were reduced by more than 250,000 MTCE, and energy revenues total nearly $1.3 million.

The ***University of Virginia*** is making energy efficiency upgrades to more than 7 million square feet of facilities through lighting retrofits, building system improvements, heating pipe insulation, occupancy sensors, and other measures. The university invested $4.3 million in energy efficiency steps, avoiding annual greenhouse gas emissions of more than 1,700 MTCE.

In 1999, ***Santa Monica, California***, became the first major municipal government in the world to purchase renewable energy to provide all of its power needs (approximately 5 megawatts).

In 1994, the ***State of Utah*** established a partnership with the National Park Service to demonstrate the use of renewable energy and energy efficient technologies in the parks and monuments of Utah. Renewable and energy efficiency projects have been initiated at four sites in the state, reducing annual greenhouse gas emissions by 185 MTCE, and saving $140,500 per year in energy costs and fuel savings.

## Working In Partnership with Federal Government

In addition to the Weatherization Assistance Program and the State Energy Program, the Federal government has numerous programs that provide support to state and local climate change efforts, including many of those discussed here. Among these programs are ENERGY STAR Buildings, WasteWi$e, and a number of others set forth in the final section of this report.

One program, EPA's ***State and Local Climate Change Program***, is a capacity-building initiative that provides states and communities with guidance and technical information in establishing greenhouse gas baseline emissions inventories and identifying options to reduce emissions. To date, 34 of 50 states have completed greenhouse gas emission inventories, and 25 states are producing action plans to identify options that reduce emissions. For example, Vermont's State Action Plan identified ways to reduce cumulative emissions by 21 percent, or almost 13 MMTCE by 2020. Vermont's policies also would reduce acid rain precursors by 24 percent, ground level ozone by 30 percent, and energy use by 16 percent.

# PART III: U.S. COMPANIES MOVING FORWARD

Many U.S. businesses are stepping forward to assume leadership roles in addressing the challenge of climate change.

## Growing Commitment to Greenhouse Gas Reductions

An increasing number of U.S. companies are committed to taking real actions to cut their greenhouse gas emissions. In the past six months:

***DuPont*** announced three goals for 2010 related to climate change. The first is to reduce greenhouse gas emissions by 65 percent from a 1990 baseline; the second is to hold energy use flat at 1990 levels; and the third, to generate 10 percent of DuPont's energy from renewables. These goals build upon previous objectives announced for 2000.

***Motorola*** led efforts in the semiconductor industry to reduce greenhouse gas emissions by pledging to reduce the company's perfluorocarbon (PFC) emissions by 50 percent relative to a 1995 baseline by 2010. The mitigation is made possible by reducing the use of PFCs or replacing them during the cleaning and etching stages of the manufacturing process. Motorola's target exceeds the goal for PFC reduction set by most of the other members of the semiconductor industry. (See "World Class Leadership.")

DuPont and Motorola are just the latest additions to the roster of U.S. corporations that understand the threat of global warming is real. In 1998, ***United Technologies***—producers of Otis elevators, Carrier air conditioners, Pratt & Whitney engines, and Sikorsky helicopters—announced a plan to cut emissions by improving energy efficiency 25 percent per unit of production by 2010. In addition, ***IBM*** announced a corporate-wide annual goal of improving energy efficiency by 4 percent. IBM also set a reduction target for PFCs; and by 2002, IBM will reduce its emissions of perfluoroethane by 40 percent per unit of production. Also, British Petroleum extended its commitment to reduce greenhouse gas emissions 10 percent below 1990 levels by 2010 to include its newly acquired U.S. subsidiaries, ***Amoco*** and ***Arco***.

### World Class Leadership

In April 1999, thanks to the leadership of Motorola and others, the global semiconductor industry agreed to reduce perfluorocarbon (PFC) emissions by 10 percent by 2010 relative to a 1990 baseline. Manufacturers in Europe, Japan, Korea, the United States, and Taiwan committed to aggressive action to reduce the use of PFCs in existing equipment and agreed to invest in major design changes for future low- or no-emitting manufacturing processes. Companies that accepted the World Semiconductor Council's reduction target for PFC emissions produce more than 90 percent of the world's semiconductors.

## Real Actions, Real Reductions

In recent years, dozens of firms in a variety of industries have been moving forward with real actions to reduce their emissions of greenhouse gases and improve their energy efficiency. Examples include:

***Alcan Ingot*** committed to reducing its PFC emissions by about 50 percent, relative to 1990 levels, by the year 2000 through the U.S. Environmental Protection Agency's (EPA) Voluntary Aluminum Industrial Partnership program. At Alcan's Sebree Aluminum Plant, the company reduced its PFC emissions by 63 percent over the past five years through the installation of computer-based systems that improve the flow of raw materials into aluminum smelting pots.

***Applied Materials*** is addressing climate change aggressively by developing a technology that cleans semiconductor chemical vapor deposition chambers with minimal emissions of PFCs. The technology simultaneously improves productivity by reducing chamber clean time by up to 60 percent. A high-density, microwave-driven plasma discharge dissociates PFC molecules with an efficiency greater than 99 percent and consequently reduces greenhouse gas emissions by two orders of magnitude.

***Panasonic*** is a leader in the manufacture and promotion of energy efficient ENERGY STAR® home electronic products. During Panasonic's first year of partnering with EPA, almost 97 percent of the company's unit sales qualified for the ENERGY STAR label, compared with the industry average of 40 percent. Panasonic also aggressively promotes public awareness of energy efficiency. Because of the firm's efforts, EPA's ENERGY STAR public service announcement recently ran hourly on the large astrovision screen in Times Square, New York City.

***Ricoh Corporation*** is a leader in the design and manufacture of energy efficient ENERGY STAR office equipment and in educating its own employees and the public about the environmental benefits of energy efficiency. Ricoh markets a wide range of ENERGY STAR digital printers, faxes, and copiers. The company also developed an exceptional web-based interactive educational tool on ENERGY STAR and the environment. The tool was intended initially for the Ricoh's sales staff and service technicians in the United States and Canada but is now used for public education as well. Ricoh expects to attract millions of web viewers by the end of 1999 and to expand the use of this educational tool to other countries.

***ST Microelectronics*** improved energy efficiency and reduced PFC emissions in semiconductor manufacturing. The company benchmarked its energy use at production facilities and is implementing energy efficiency projects using wind turbine, photovoltaic, thermal solar, fuel cell, and cogeneration technologies that will reduce greenhouse gas emissions by a factor of 10 by 2010.

***Texas Industries*** is pursuing a goal of zero waste in its cement and steel oper-

ations. To jumpstart the process of reaching this goal, the company developed a technology that uses a steel making by-product, slag, in the cement manufacturing process. The technology increases cement production by up to 15 percent, reduces greenhouse gas emissions by about 10 percent, and lowers conventional air pollutants by up to 40 percent.

***Trigen*** is a corporate leader in promoting combined heat and power across the country, and the company has been successfully installing high-performing projects. For example, Trigen's Grays Ferry combined-cycle gas turbine cogeneration unit in Philadelphia replaced several old oil-fired district heating boilers. The project is designed to operate at 70 percent fuel efficiency, producing 150 megawatts of power and 1.4 million pounds of steam per hour. The district energy system provides heat to 70 percent of the downtown area's buildings and institutional facilities. The project is estimated to reduce emissions by approximately 90,000 metric tons of carbon equivalent (MTCE) annually. The cogeneration project at the Loctite Corporation in Rocky Hill, Connecticut, operates at 88 percent efficiency and is capable of generating 9.5 million kilowatts per year of electric energy. Annual emissions reductions are estimated at 750 MTCE per year.

***TXU***, one of the largest energy providers in the United States, is committed to reducing emissions of sulfur hexafluoride ($SF_6$) gas voluntarily in partnership with EPA's Climate Challenge and Emission Reduction Partnership for Electric Power Systems program. TXU realized significant reductions in the use of $SF_6$ gas by introducing advanced leak detection equipment, initiating aggressive policies to identify equipment in need of repair, and implementing a strict inventory protocol that ensures all purchased $SF_6$ is fully and properly used.

## Industry Sectors Move Forward

In addition to the semiconductor industry (see "World Class Leadership" on page 20), a number of other industry sectors

### Corporations Speak Out for Action

In 1998, the new **Pew Center on Climate Change** launched a $5 million campaign to build support for taking action on climate change. ***Boeing, DuPont, Shell, Weyerhaeuser***, and some 17 other major corporations joined the center's *Business Environmental Leadership Council*, agreeing that "enough is known about the science and environmental impacts of climate change for us to take actions to address its consequences." In addition, the **Business Roundtable**, a group of CEOs from leading U.S. corporations, this year released a report advocating "the deployment of more energy-efficient and breakthrough technologies" and called on government and industry to work together to find answers to the challenges of climate change.

also are improving efficiency and reducing greenhouse gas emissions:

The ***electric utility*** sector entered into the *Climate Challenge* program in 1994 and agreed to reduce, avoid, or sequester greenhouse gas emissions voluntarily by 2000. Utility companies, together with the U.S. Department of Energy (DOE) and EPA, developed a workbook of reduction options that was widely circulated. Individual companies entered into agreements, and, as a result of their participation, utilities estimate emissions reductions of as much as 47 million metric tons of carbon equivalent (MMTCE) in 2000.

The ***steel industry*** is the fourth largest energy-consuming manufacturing subsector in the United States. The industry recently undertook a number of projects to increase energy efficiency and reduce waste. From 1994 to 1996 alone, the energy intensity of blast furnace iron making dropped by 4 percent. A comparable drop in carbon dioxide emissions accompanied the reduction in energy consumption. Nearly 80 percent of obsolete scrap from post-consumer products, such as discarded cars and appliances, is currently recycled; the steel industry is engaged in research to allow it to meet its goal of 100 percent recovery. Utilizing scrap steel greatly reduces the amount of energy required to make steel from virgin materials.

The ***chemical industry*** represents nearly 7 percent of total U.S. energy use. About half of this sector's energy is used for feedstocks, while the remainder provides fuel, power, and steam. The Chemical Manufacturers Association (CMA) adopted its own Climate Action Program to reduce or avoid greenhouse gas emissions. A large portion of the industry reported emissions every year from 1992 through 1997; energy efficiency performance for those companies improved nearly 22 percent per pound of production with a corresponding drop in carbon dioxide emissions of 24 percent. The CMA awards companies for outstanding energy efficiency projects, thereby providing a model that other companies can use to reduce emissions and improve efficiency. The projects range from waste elimination and equipment innovations to new catalysts and process redesign. CMA intends to continue to implement its Energy Efficiency Continuous Improvement and Climate Action Programs vigorously in order to strengthen the industry's performance.

The ***cement industry*** emits carbon dioxide from the use of fossil fuels as well as from the calcination process in which limestone is heated. Companies representing more than 70 percent of U.S. cement production have joined EPA's Climate Wise program to take advantage of the latest methods of improving energy efficiency and reducing emissions. A spreadsheet-based workbook incorporates issues specific to the cement industry and enables companies to prepare an action plan and report the results of their efforts. The companies estimate that in 2000, annual emissions will be reduced by 8

percent below the business-as-usual projection and that annual savings will total $2.3 million.

The ***aluminum industry*** is another energy-intensive sector with many opportunities to reduce its greenhouse gas emissions. The industry is investing in R&D, with a goal of a 15 percent reduction in energy use and concomitant decrease in carbon dioxide emissions, as well as zero carbon dioxide emissions released from the smelting process. In addition, 11 of 12 U.S. primary aluminum manufacturers reduced their annual greenhouse gas emissions by 1.8 MMTCE annually and are committed to reducing PFC emissions by 45 percent to 1990 levels by 2000 through EPA's Voluntary Aluminum Industry Partnership.

## Industry Consultations

An important component of the President's October 1997 plan to reduce U.S. greenhouse gas reductions is to build voluntary partnerships with energy-intensive industries to develop strategies to cut emissions. High-level Administration officials have met with top management of the aluminum, cement, forest products, gas pipelines, and steel industries, and publicly owned and investor-owned electric utilities. These consultations between the Administration and industry leaders are focusing on the development of a common methodology on emissions baselines, measuring, monitoring, and reporting, as well as the identification of opportunities for the development and diffusion of less carbon-intensive technologies and practices. As part of these consultations, the Administration and industry officials discuss ways to ensure credit for businesses that take early actions to reduce emissions.

# PART IV: ONGOING U.S. DOMESTIC PROGRAMS

In addition to efforts by U.S. states and localities, U.S. companies, and new Federal initiatives, there are literally dozens of win-win climate change programs and initiatives put into place by President Clinton since 1993. These new programs aim to develop and deploy energy efficient technologies and spur the development and broader use of renewable energy. These efforts have accelerated and expanded since the Kyoto climate change conference in 1997. Sustaining this commitment to reducing U.S. greenhouse gas emissions has been a focused effort by President Clinton to invest in the research, development, and deployment of energy efficiency technologies and renewable energy—an area whose budget in the U.S. Department of Energy (DOE) has exceeded $800 million each and every year of the Clinton Administration.

The following survey highlights the most important of these investments, as well as a number of programs aimed at reducing or avoiding U.S. greenhouse gas emissions administered by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), and other agencies. Together, the programs cover the four major greenhouse gas-emitting sectors of the U.S. economy (buildings, transportation, industry, and electricity), carbon sequestration, agriculture and forestry, and a robust scientific research program.

As the other components of the President's strategy are implemented by industry partners, citizens, and the U.S. Congress, the Administration expects accelerated and greater energy efficiency, environmental, security, and economic benefits.

## Buildings

The buildings sector is responsible for approximately 35 percent of U.S. greenhouse gas emissions. Most of the emissions result from the electricity needed to run appliances and equipment in buildings, such as heating, ventilation, and air conditioning equipment. Studies show that many homes and businesses could reduce their energy use by about 30 percent using proven, cost-effective products, and investing in simple profitable building upgrades. A variety of DOE and EPA programs focus on developing and promoting the broader use of cleaner and more efficient building and appliance technologies. The programs include:

### Partnership for Advancing Technology in Housing (PATH)

PATH is a partnership between the Federal government and the building industry to develop and deploy housing technologies to make new homes 50 percent more energy efficient and to make at least 15 million existing homes 30 percent more energy efficient within a decade. Meeting PATH's goals would reduce annual carbon emissions

in 2010 by an amount equal to nearly 24 million metric tons of carbon equivalent (MMTCE)—the amount produced by some 20 million cars—and would save consumers $11 billion a year in energy costs. PATH has established five pilot communities in Denver, Los Angeles, Pittsubrgh, and Tuscon that are incorporating new housing technologies and advanced building concepts.

### Energy Efficiency Standards for Equipment and Appliances

To save energy and reduce consumer utility bills, the U.S. government develops test procedures and national minimum energy efficiency standards for equipment and appliances, such as heating and cooling equipment, water heaters, lighting, refrigerators, clothes washers and dryers, and cooking equipment.

### Climate Change Technology Initiative

The centerpiece of President Clinton's domestic climate change program is the Climate Change Technology Initiative (CCTI)—a package of targeted tax incentives and investments aimed at increasing energy efficiency and spurring broader use of renewable energy. The package amounts to an additional $6.3 billion over five years ($3.6 billion in tax cuts and $2.7 billion in new investment), over and above what was already planned for climate change-related investments. The CCTI has been endorsed and supported by the President's Committee of Advisors on Science and Technology (PCAST). In 1997, PCAST produced a major analysis of energy R&D needs that provided the analytical underpinning for CCTI's package of investments. In Fiscal Year 1999, the President secured more than $1 billion for CCTI investments—a 25 percent increase over the prior year. As of this writing, the Administration was engaged in negotiations to preserve these gains in the face of efforts by the U.S. Congress to scale back on investments in energy efficiency and renewables.

Most of CCTI's specific investment initiatives and programs are discussed within this section. Highlights of CCTI's proposed tax package include:

- **Tax credits for energy efficient homes.** Consumers would receive $1,000-$2,000 credit toward the purchase of a new energy efficient home; a 10-20 percent tax credit for the purchase of selected energy efficient products for their homes and buildings; and a $1,000-$2,000 credit for installing a rooftop solar system.
- **Tax credits for fuel-efficient cars.** The package includes tax credits ranging from $1,000-$4,000 for the purchase of a qualifying electric, fuel cell, or hybrid vehicle.
- **Tax credits for renewable energy.** The package extends the 1.5 cents per kilowatt hour tax credit for the production of electricity from wind and biomass; expands the biomass credit to cover additional sources of biomass; and adds a 1.0 cent per kilowatt hour tax credit for co-firing coal and biomass in power plants.

Through 1997, residential appliance standards avoided cumulative emissions of 37 MMTCE and saved consumers a cumulative $13.3 billion. By 2010, the currently enacted standards will have avoided cumulative emissions of more than more than 225 MMTCE and saved consumers almost $50 billion.

In the upcoming year, the U.S. government expects to publish standards for clothes washers, water heaters, fluorescent lamp ballasts, and central air conditioners. These standards, and the recently enacted standards for refrigerators and room air conditioners, are expected to have avoided cumulative emissions of almost 12 MMTCE through 2010.

### ENERGY STAR® Partnerships

The ENERGY STAR partnership programs are designed to remove market barriers to the purchase of energy efficient products, services, and technologies in residential, commercial. and industrial buildings.

- The ***ENERGY STAR Products*** program allows manufactures of selected energy efficient products to promote their products with the ENERGY STAR label. This allows consumers to easily identify products that help the environment and save energy and money. More than 3,000 highly efficient ENERGY STAR product models, ranging from computers to refrigerators to central air-conditioning units, currently are available to consumers.
- The ***ENERGY STAR Buildings℠ Partnership*** encourages individual building owners, developers, and managers to install energy efficient lighting and undertake a five-stage strategy to capitalize on system interactions that maximize energy savings at minimum cost. To date, buildings representing more than 13 percent of U.S. commercial square footage have signed up for the program. Among them are the Empire State Building, World Trade Center, and Chicago's Sears Tower.

EPA estimates that by 2010 investments in ENERGY STAR technologies and services already in place today will reduce cumulative greenhouse gas emissions by 40 MMTCE and save consumers and businesses more than $13 billion in energy costs.

### Energy Efficiency in Schools

The energy to run the nation's 115,000 primary and secondary schools costs approximately $5 billion annually—more than the cost of textbooks and computers combined. DOE and EPA have two programs that are working in coordination to improve energy efficiency in U.S. primary and secondary schools. DOE's ***EnergySmart Schools*** works in partnership with major companies, unions, nonprofits, and Federal, state, and local agencies to cut energy bills in schools so that the savings can be reinvested in students and their education. EPA's ***ENERGY STAR Label for Schools*** provides tools

for schools to evaluate their own energy use, find ways to reduce it, and meet indoor air quality standards. DOE estimates that a 25 percent reduction in schools' energy use will cut annual U.S. greenhouse gas emissions by 3 to 4 MMTCE.

### New United States and European Community Agreement on ENERGY STAR Labeling

Later this year, the United States and the European Community are expected to sign an agreement making the ENERGY STAR label an international symbol for energy efficiency. The agreement is intended to unify voluntary energy efficiency labeling programs in two of the major global markets for office equipment. This coordinated effort will serve to increase global supply of energy efficient equipment and demand by establishing uniform criteria for energy efficiency in the United States and the European Union. In addition, the proposed agreement would lend greater authority to efforts by other countries to stimulate the market for energy efficient products and establish the ENERGY STAR program as the international symbol for energy efficiency. The agreement currently is awaiting EC approval.

## Transportation

The transportation sector accounts for approximately 30 percent of U.S. annual greenhouse gas emissions (and 65 percent of U.S. annual petroleum consumption). Reflecting the fact that more than three-fourths of total energy consumption in the transportation sector is used in cars and trucks, U.S. climate efforts in this area aim almost exclusively at reducing the consumption of oil (and oil by-products) in those vehicles.

### Partnership for a New Generation of Vehicles

Partnership for a New Generation of Vehicles (PNGV) is a Federal government-industry effort that aims to develop attractive, affordable, family-size cars that meet all applicable safety and environmental standards while achieving up to three times the fuel efficiency of today's cars. Since 1993, the program has made great strides in developing lower-cost, lightweight materials, operational fuel cells, and advanced internal combustion engines for use in hybrid vehicles. The PNGV program aims to develop concept cars in 2000 and produce a production prototype mid-sized family car capable of 80 miles per gallon (mpg) by 2004. In Fiscal Year 1999, appropriations for PNGV-related work totaled more than $240 million.

### Light and Heavy Trucks

Similar government and industry efforts are aimed at developing cleaner, more efficient diesel engines for both light and heavy trucks.

- By 2002, DOE aims to develop **advanced diesel cycle engine technologies** for pickup trucks, vans,

and sport utility vehicles that achieve at least a 35 percent fuel efficiency improvement relative to current gasoline-fueled trucks while meeting strict emission standards.

- By 2004, DOE, in coordination with EPA and the U.S. Department of Defense, aims to develop **engine and vehicle technologies for heavy trucks** that will increase the fuel economy to 12 mpg from the current average of 5.3 mpg.

### Breakthroughs on Concept Cars

A direct result of the Partnership for a New Generation of Vehicles (PNGV) is the development of "concept cars," including hybrid vehicles that combine a traditional power source with battery storage and electric motors. On October 5, 1999, Ford presented to DOE the company's P2000 concept car, which uses advanced materials to reduce the weight of a full-size vehicle by 40 percent. Combined with an advanced direct injection engine, the P2000 is projected to deliver 63 miles per gallon. In addition, General Motors and Daimler Chrysler displayed driveable vehicles powered by fuel cells. Concept cars that meet PNGV's 80 mpg goal are expected to be unveiled in 2000.

## Industry

Industry accounts for approximately one-third of U.S. annual carbon dioxide emissions (and 27 percent of U.S. energy consumption in 1997). A number of DOE and EPA programs focus on developing and promoting energy efficient technologies and practices in the nation's most energy-intensive industries.

### Industries of the Future

This DOE program works cooperatively with the nation's most energy-intensive industries—such as aluminum, glass, chemicals, forest products, mining, petroleum refining, and steel—on research to develop technologies that increase energy and resource efficiency. Together, participating industries use more than 80 percent of all energy consumed in U.S. manufacturing. Promising collaborative efforts include improvements in the process of making steel, pulp and paper, and other energy-intensive products that could dramatically increase efficiency and lower greenhouse gas emissions. DOE estimates that participating industries will prevent emissions of more than 25 MMTCE by 2010 and realize $4 billion in energy cost savings.

### Climate Wise

This EPA program gives technical assistance to more than 530 individual manufacturing companies that have entered into partnership agreements with the Federal government to reduce green-

house gas emissions, increase productivity, and save money. Companies submit comprehensive action plans that identify specific steps they will undertake between the time they enter into the compact and 2000. By 2010, Climate Wise partners are projected to have avoided cumulative greenhouse gas emissions of nearly 14 MMTCE and saved $2 billion through their participation in the program.

### Methane Reduction Programs

The U.S. government administers a variety of industry-government voluntary partnerships that significantly reduce U.S. methane emissions from a variety of sources: The Landfill Methane Outreach Program, the Coalbed Methane Outreach Program, Natural GasStar, AgSTAR, and the Ruminant Livestock Efficiency Program (RLEP). These programs encourage emissions reductions either through the profitable collection and use of methane, as opposed to its release to the atmosphere, or, in the case of RLEP, through more efficient production in the livestock and dairy sectors. In 1998, participants in the programs reduced methane emissions by almost 5 MMTCE. EPA estimates that investments already made to reduce methane emissions by partners in these programs will reduce cumulative emissions by almost 70 MMTCE and save more than $1 billion. By 2010, EPA expects that methane emissions will be stabilized at 1990 levels as a result of these voluntary partnerships.

### HFC, PFC and $SF_6$ Emission Reduction Programs

Of all greenhouse gases, perfluorocarbons (PFCs), sulfur hexafluoride ($SF_6$), and several hydrofluorocarbons (HFCs) are the most potent because of their extreme stability in the atmosphere and strong absorption of radiation. PFCs, for example, commonly have atmospheric lifetimes on the order of thousands of years. The U.S. government administers a variety of industry-government voluntary partnerships that are reducing emissions of those gases substantially. The ***Voluntary Aluminum Industrial Partnership (VAIP)*** works with 11 of the nation's 12 primary aluminum producers to reduce PFC emissions while increasing the efficiency of primary aluminum production. The Federal government also administers a regulatory program through the Clean Air Act to help direct industry toward safe, new alternatives as manufacturers consider substitutes for ozone-depleting chlorofluorocarbons (CFCs) and halon compounds.

Investments already made by partners in voluntary programs will reduce cumulative emissions by more than 49 MMTCE over the lifetime of the projects. In addition, an estimated 54 MMTCE will have been prevented by 2000 through regulation. HFC and PFC emissions in applications to replace ozone-depleting substances are expected to be significantly below business-as-usual scenarios due to voluntary and regulatory initiatives. HFC, PFC and $SF_6$ emissions from other industrial

sources are expected to be at or below 1990 levels by 2010.

### Industrial Combined Heat and Power Systems

DOE is developing new industrial combined heat and power (CHP) systems to capture thermal heat that otherwise would be wasted. CHP systems are expected to be 15 percent more energy efficient and 80 percent cleaner than conventional power systems and cut electricity costs by 10 percent. In addition, EPA and DOE are working to eliminate barriers to the rapid dissemination of combined heat and power technology.

### Motor Challenge

Motor Challenge, Steam Challenge, Combined Heat and Power Challenge, and Compressed Air Challenge are a group of voluntary initiatives aimed at improving energy efficiency in U.S. manufacturing plants by breaking down market barriers to the development and diffusion of energy efficient technologies and practices. These four Federal programs offer industry a variety of technical assistance, tools, and information. By 2015, these initiatives are expected to reduce emissions by approximately 20 MMTCE and generate $3 billion in annual cost savings.

### WasteWi$e

WasteWi$e works with U.S. businesses; Federal, state, local, and tribal government agencies; and other institutions to reduce municipal solid waste. Presently, more than 900 organizations are WasteWi$e partners. Waste reduction activities reduce greenhouse gas emissions in several ways, including energy savings, increased carbon sequestration, and avoided methane emissions. In 1998 alone, the combined waste reduction results of WasteWi$e partners prevented emissions of approximately 4.5 MMTCE—equal to the average annual emissions from electric power consumption from roughly 2.7 million households.

## Electricity

Greenhouse gas emissions from the generation, transmission, and distribution of electricity account for 30 percent of U.S. annual greenhouse gas emissions. U.S. climate efforts in this area include improving the efficiency of electricity generation through substituting lower carbon and carbon-free fuels, reducing the demand for electricity through greater end use efficiency, and restructuring the electric power industry. These efforts are being accomplished through a combination of DOE and EPA voluntary partnerships and R&D efforts.

### Electricity Restructuring

A core element of the President's climate change program involves restructuring the electricity industry in a manner that will reduce greenhouse gas emissions while cutting consumers' energy bills. The Administration's restructuring proposal includes a requirement that utilities open up their distribution and transmission wires to all qualified sellers; a renewable portfolio standard to increase the use of

electricity from renewable sources to at least 7.5 percent of sales by 2010; a $3 billion per year Public Benefits Fund to spur greater investment in energy efficiency and renewable energy technologies; and a green labeling requirement to inform consumers about clean energy options. This plan is projected to reduce carbon emissions by roughly 40 to 60 MMTCE in 2010 while saving consumers at least $20 billion per year on their electricity bills. The plan is now under consideration by the U.S. Congress.

### Photovoltaic Energy Systems R&D

Over the past 20 years, Federal research and development has resulted in a 90 percent cost reduction in solar photovoltaics (PV). As a result, industrial manufacturing of PV modules more than doubled between 1994 and 1998, growing from 26 megawatts in 1994 to more than 53 megawatts in 1998. DOE now is accelerating its R&D of the next generation of photovoltaic cells; increasing manufacturing R&D; increasing research in buildings-integrated applications; and developing new, unconventional technologies.

- ***Million Solar Roofs.*** This initiative, announced by the President in June 1997, seeks to place solar energy systems on one million roofs by 2010. To date, commitments for 900,000 have been made, indicating the potential for widespread market penetration of solar technologies. The President's Climate Change Technology Initiative includes $120 million in proposed tax credits to support this program. Meeting the initiative's goals will reduce carbon emissions equivalent to the annual emissions from 850,000 cars by 2010.

### Hydrogen Research Program

DOE currently is accelerating research on low-cost hydrogen production and storage—prerequisites to the widespread use of hydrogen as a fuel. Over the next five years, hydrogen is expected to make a significant penetration into several niche fuel markets, owing to the recent demonstration of low-cost, high-performance Proton Exchange Membrane (PEM) fuel cell systems by Daimler Chrysler, Ford, and other companies.

### High Temperature Superconductivity

DOE supports industry-led projects to capitalize on recent breakthroughs in superconducting wire technology, aimed at developing super-efficient power equipment, such as advanced motors, power cables, and transformers. These technologies would allow more electricity to reach the consumer without increasing the use of fossil fuels.

### Climate Challenge

This program is a joint voluntary effort between DOE and the electric utility industry to reduce, avoid, or sequester greenhouse gases. Utilities identify and implement cost-effective activities that are specified in agreements between the

Federal government and individual electric utilities. Under this program, the electric utility industry as a whole also has developed nine industry-wide initiatives to research, develop, and promote technologies and practices that lower greenhouse gas emissions. Currently, Climate Challenge's partner utilities number more than 600 and represent 71 percent of the 1990 U.S. carbon emissions from electricity generation. Utilities estimate that pledged Climate Challenge actions would reduce emissions by as much as 47 MMTCE in 2000.

### Cleaner Coal and Natural Gas

DOE supports an aggressive R&D effort to develop next-generation technologies for the combustion and use of coal and natural gas. For example, research and development of new coal combustion technologies, such as integrated gasification combined-cycle and pressurized fluidized bed combustion, could lead to ultra-high efficiency coal plants with dramatically lower greenhouse gas emissions—as much as 75 MMTCE by 2030.

### Nuclear Energy

Nuclear power plants provide approximately 20 percent of U.S. electricity and avoid greenhouse gas emissions of 150 MMTCE annually. Licenses for U.S. nuclear power plants will begin to expire in large numbers in 2010. To ensure that current nuclear plants can continue to deliver adequate and affordable energy supplies up to and beyond their initial 40-year license, DOE initiated the Nuclear Energy Plant Optimization (NEPO) program. NEPO supports collaborative R&D with industry, aimed at resolving open issues related to plant aging. It also supports the application of new technologies to improve plant economics, reliability, and availability.

## Sequestration and Agriculture

### R&D for Sequestration

DOE is pursuing research on sequestration technologies to separate and capture carbon dioxide from energy processes and combustion, disposal technologies for storing carbon dioxide in underground geological structures and in the deep ocean, and advanced concepts to transform carbon dioxide into either useful or environmentally benign products. In the post-2015 time period, this program has the potential to eliminate hundreds of millions of metric tons of greenhouse gases from the atmosphere.

### Carbon Sequestration in Agriculture and Forestry

Natural carbon sinks will play a critical role in helping the world meet the challenge of climate change. Recently, focus has intensified on agriculture and forestry practices that can affect the ability of farmland and forests to sequester carbon and help mitigate the impacts of climate change. As understanding of these practices has increased, the U.S. government has begun to analyze the net carbon effects of various USDA conservation and

environmental programs and to determine how they can be enhanced and expanded to foster greater sequestration. In general, the programs assist farmers, ranchers, and other landowners in conserving and improving soil, water, and other natural resources associated with rural land. The programs include:

- ***Conservation Technical Assistance (CTA)*** helps farmers develop and implement conservation plans on farms and ranches. Practices that sequester carbon include cover crops, residue management, crop rotation, and buffer establishment.

- ***Conservation Reserve Program (CRP)*** provides rental payments and cost-sharing on 36.4 million acres for grass, shrub, or tree planting in exchange for retiring highly erodible or other environmentally sensitive cropland.

- ***Forestry Incentives Program (FIP)*** provides financial and technical assistance to encourage production of sawtimber and pulpwood on nonindustrial private forestlands, and the Stewardship Incentives Program (SIP) provides financial and technical assistance to expand tree planting and implement stewardship plans on private properties.

## Scientific Research

The Administration is continuing its strong support ($1.7 billion in Fiscal Year 1999 funding) for the U.S. Global Change Research Program (USGCRP), which seeks to provide a sound scientific understanding of the human and natural forces that influence the Earth's climate system. National and international policymakers use the information produced by USGCRP scientists to make informed decisions on global change issues. Specific new research focuses include:

- ***Carbon Cycle Initiative***—a new multiagency initiative to improve understanding of the ways that carbon cycles between the atmosphere, oceans, and land.

- ***Soil Carbon Inventory***—expanded efforts to conduct a comprehensive scientific inventory of carbon stored in U.S. soils and develop methods to predict how various practices and policies would affect soil carbon levels.

- ***Consequences of Climate Change***—the first national assessment of the potential impacts of climate change on the United States.

# FACTS ON GLOBAL CLIMATE CHANGE

## CONTRIBUTIONS of GHGs to GLOBAL CLIMATE CHANGE

*GENERAL OVERVIEW OF DIRECT GHGS*

• **GHGs** (in order of importance): $CO_2$, $CH_4$, $N_2O$, halocarbons, $SF_6$.* [U.S. Global Change Research Info Office]

***Tropospheric Ozone** is "an efficient greenhouse gas in the upper troposphere"[D. Brunner et al., *Science 282*: 1305-1309 (1998)], but it's importance on GCC is not known, and it usually isn't included in lists of GHGs. It has a lifetime measured in hours and is a product of chemical processes in the presence of sunlight involving precursors of $CH_4$, CO, $NO_2$ (e.g., from vehicle exhaust and oxidation of NO from power plants), and volatile organic compounds (non-methane hydrocarbons) from refineries, gas stations, vehicles, and solvents like house paints and dry cleaning. [WRI 96/97, except where otherwise specified]

• **Climate forcing** by GHG increases since the Industrial Revolution:

| | |
|---|---|
| $CO_2$ | 65%* |
| $CH_4$ | 19% |
| Halocarbons | 10% (CFCs, HCFCs, HFCs, perfluorocarbons) |
| $N_2O$ | 6% |

[NOAA's Report to the Nation, Fall 1997--p. 17; *64% according to WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• Fossil fuel use accounts for 70% of the carbon accumulation in the past 150 years, and land use change the other 30%. [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• Between 1850 and 1995, a total of 368 gigatons of CO2 emissions were released globally. However, 208 gigatons were absorbed into the oceans, vegetation and soils, leaving 160 gigatons of carbon in the atmosphere. [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

FACTORS COUNTERACTING WARMING

- Anthropogenic aerosols, mostly from sulfate aerosols and smoke from burning vegetation, are believed to have offset about 20% of the GHG warming effect since the Industrial Revolution [NOAA's Report to the Nation, Fall 1997--p. 18].
- Because cloud droplets form around small particles or "nuclei", "**clouds** that form in polluted air...contain more droplets than those that form in relatively clean air." The result is that these clouds contain larger numbers of smaller droplets, which makes such clouds brighter, reflecting back more sunlight into space. Clouds in polluted air also promote cooling for another reason: rain forms when enough of the smaller droplets coalesce into a sufficiently large raindrop. In clouds with smaller droplets, this process takes longer, so the clouds persist longer.

**CONTRIBUTIONS OF $CO_2$ and $CH_4$ (1991)**

| Source | Million of metric tons[1] | % of total $CO_2$ or $CH_4$ |
|---|---|---|
| $CO_2$ (total ff + industry) | | |
| Petroleum combustion | 9,050 | 32.9% |
| Bunker fuel combustion[2] | 476 | 1.7 |
| Coal combustion | 8,590 | 31.2 |
| Gas combustion | 3,830 | 13.9 |
| Gas flaring | 249 | 0.9 |
| Cement production | 627 | 2.3 |
| Other industrial (direct)[3] | 600 | 2.2 |
| $CO_2$ from land use changes | 4,100 | 14.9 |
| | | 100% |
| Methane (total anthropogenic[4]) | | |
| Solid waste[5] | 43 | 16% |
| Coal mining | 36 | 13% |
| Oil & gas production | 44 | 16% |
| Wet rice agriculture[6] | 69 | 26% |
| Livestock(fermentation + manure)[7] | 81 | 30% |
| | | 100% |

[1] 1.1 tons per metric ton

[2] Counted separately because too difficult to track by country since it is used primarily for international transportation. Bunker fuel accounts for 2.2% of all $CO_2$ produced via fossil fuel combustion.

[3] This data mostly from WRI's World Resource 1996/97, but since they give only $CO_2$ from fossil fuel combustion and cement production so I had to estimate a value for direct process emissions from the production of aluminum, glass, soda ash, hydrogen, iron and steel as follows: EIA's 1995 report on "Emissions of GHGs in the U.S., 1994" estimated that 53% of the U.S. industrial direct $CO_2$ emissions were from cement. Since WRI estimates that direct emissions from cement production account for 2.3% of the world's $CO_2$ emissions, it follows that about 2% of the world's $CO_2$ emissions are due to direct industrial process emissions other than cement production. The global and U.S. ratios of cement versus other industrial emissions are likely to differ somewhat, but a 50/50 ratio should be fairly accurate.

[4] These WRI values (*World Resources 1996/97*) do not include $CH_4$ from industrial sources (the production of iron, steel, and organic chemicals). Biomass burning is also not included here, presumably since too uncertain.

[5] The IPCC says that methane from solid waste and organic-loaded wastewater lagoons is 8% of total anthropogenic methane, yet their estimates of tonnes emitted is in the same range as WRI's: 20-70 million.

[6] The IPPC 1991 estimate for wet rice agriculture was 20%.

[7] The IPPC (1993) estimated that about 25% of total methane comes from livestock, with a breakdown of about 70/30 for enteric fermentation/manure.

*DEPENDENCE OF $CO_2$ AND $CH_4$ ON NON-GREENHOUSE GASES*

**• Air Pollutants that are not GHGs**

- *Not GHGs:* CO, $SO_2$, $NO_2$, NO, toxic metals (such as lead, cadmium, mercury), particulates, hazardous organics (such as benzene, formaldehyde and vinyl chloride), asbestos, and volatile organic carbons (VOCs). However, both CO and VOCs are converted to $CO_2$—see below.

- *Power Plant Emissions* are $SO_2$ and $NO_x$ (but 95% of the $NO_x$ is NO, which is then readily converted to $NO_2$ once emitted), ... [Source on $NO_x$: the web, Jeffrey Kahn of LBL] So power plants do not emit GHGs directly, though running the plants uses fossil fuels.

**• Dependence of $CO_2$ and $CH_4$ on Non-GHGs – The Role of Hydroxyl**

- "The main removal mechanism for...$CH_4$, CO, non-methane hydrocarbons [i.e., VOCs],...and $SO_2$, from the atmosphere is through photochemical oxidation. ...The main oxidant in this context is the hydroxyl radical (OH), the primary source of which is the photolysis of ozone in the presence of water vapor. Ozone in turn is produced in the troposphere by the photochemical oxidation of CO and hydrocarbons in the presence of $NO_x$. ...Because high UV flux and high ambient humidity enhance the formation of OH, most of the global oxidation of the long-lived, radiatively [i.e., important to GCC] and chemically important trace gases actually takes place in the tropics. **Perturbations to the budgets of $O_3$, $NO_x$, CO, $CH_4$ and nonmethane hydrocarbons could therefore cause significant changes in the oxidising power of the global atmosphere** and consequently change the budgets of the long-lived trace gases as well." [www.mpch-mainz.mpg.de/~eustach/intro/oxpower.htm]

**• Carbon Monoxide:**

- "**$CO_2$ production through the reaction of CO and OH** is currently about 1.1 Pg C/yr, which **is about 20% of estimated total current $CO_2$ emissions** [IPCC, 1996]. It is well known that CO and methane emissions are not negligible factors even in today's carbon dioxide budget." The lifetime of CO in the atmosphere is presently two months. {NOTE: In the second sentence, "even" refers to the fact that this paper is addressing the change in concentration, lifetime, and impact on $CO_2$ through the next century. The reference to IPPC is only for the fact that 1.1 Pg C/yr is 20% of the total $CO_2$.} [Source: Chien Wang and Ronald G. Prinn, MIT Joint Program on the Science and Policy of Global Change, Report #35: "Impact of Emissions, Chemistry, and Climate on Atmospheric Carbon Monoxide: 100-year Predictions from a Global Chemistry-Climate Model".]

- Various other sources on the oxidation of CO to $CO_2$: (1) "The Chemistry of Atmospheric Pollutants", www.aeat.co.uk/netcen/ airqual/kinetics/ (saying CO lasts 1 month; (2) an EIA web site, www.eia.doe.gov/oiaf/1605/95report/chap6.html, (saying it lasts 2 to 3 months); (3) and www.eng.rpi.edu/dept/chem-eng/Biotech-Environ/AirPoln/pollutes.htm (saying CO lasts 2 to 4 months).

- **CO indirectly increases methane**, because CO is the primary component of the atmosphere that removes hydroxl radicals, and hydroxyl radicals destroy methane (forming $CO_2$). So increased CO decreases $OH^{\bullet}$ and thereby allows methane to increase. [The EIA site] "The main sink for methane is the hydroxyl radical whose concentration in the atmosphere decreases as that of CO increases. There is growing evidence that atmospheric CO has increased significantly over the last decades and modeling studies indicate that much of the observed methane ($CH_4$) increase can be explained by a concurrent CO increase." [International Energy Agency web site: www.ies.org/pubs/studies/files/danish/13-dan1.htm] The **complex reactions of $CH_4$ and $OH^{\bullet}$ to**

$CO_2$ are shown in an American Chemical Society website:
http://163.13.134.120/cas/hydroxy.html.
- *Sources of CO:* 90% of CO in Delhi was attributable to motor vehicles in 1987, and 100% in Colombo (Sri Lanka) in 1992. (*World Resources 1996-1997*, p. 860)

• **Volatile Organic Compounds**

- **VOCs are oxidized to $CO_2$** and $H_2O$ in the presence of sunlight and $NO_x$ (sunlight photodissociates ozone to form free radicals which catalyze the oxidation of the HCs). ["The Chemistry of Atmospheric Pollutants", www.aeat.co.uk/netcen/ airqual/kinetics/.]

- VOCs are defined as "any organic compound which, once released into the atmosphere, can remain there for a sufficiently long time to participate in photochemical reactions."
"...Compounds that evaporate rapidly at ambient temperatures account for the main share of VOC" (vapor pressure >0.1 mm at 20 C and 1 atm). Uncombusted hydrocarbons contain for a large proportion of methane, but since it's inert it isn't classified as a VOC. "In addition to higher hydrocarbons (ethane, propane,...), oxygenate compounds (aldehydes, ketones, phenols, alcohols, nitromethane and esters), which have a higher reactivity, are also considered" VOCs.
["Emissions – How are They Formed?", DOE's Hybrid Electric Vehicle Program web site: www.hev.doe.gov/general/emiss2.html]
- *Sources of VOCs:* In Delhi, 85% of VOCs were attributable to motor vehicles in 1987, and in Colombo (Stri Lanka), 100% of VOCs were due to motor vehicles in 1990. (*World Resources 1996-1997*, p. 860)
- VOCs contribute to the formation of particulate matter (see below...)

• **Particulate Matter**

- In a spark ignition engine (i.e., gasoline), the three main causes of PMs are lead*, sulfur and "rich mixture". But in a well tuned engine using unleaded, low sulfur fuel, PMs are negligible. [Unclear to me how lead increases PM.] In compression ignition engines (i.e., diesel), soot (the solid, carbon-rich material resulting from incomplete combustion) is the primary particulate. ["Emissions – How are They Formed?", DOE's Hybrid Electric Vehicle Program web site: www.hev.doe.gov/general/emiss2.html]
- *VOCs contribute to PM*: "On a smoggy day in Los Angeles, up to 20% of the mass of particulate matter of less than 2.5 micrometers in diameter can come from hydrocarbons in evaporated and burned gasoline", paint solvents, etc. They condense onto "bits of dust". [*Science 276*, 4 April 1997, p. 33]
- ***Aromatics in gasoline increase PM***: There is a direct correlation between the quantity of aromatics in gasoline and PM emissions (and ozone). [*Science 276*, 4 April 1997, p. 33]

[*lead in gasoline increases octane (preventing knock and giving more power) and lubricates metal in the engine (prolonging engine life). The tetraethyl-lead comes out as lead oxide.]

## CONTRIBUTIONS BY SECTOR

• **Relative Contributions of Different Sectors to the Different GHGs**

| Sector | $CO_2$ | $CH_4$ | $N_2O$ | CFC |
|---|---|---|---|---|
| Energy Production | 70% | 25 | 67 | 0 |
| Forestry Destruction | 20% | 25 | 0 | 0 |
| Agriculture | 6% | 50 | 0 | 0 |
| Industry (direct emissions) | 4% | 0 | 33 | 100 |

[The German Federal Environment Agency, Climate Change web site (last updated 5/11/98)]

• **Iron and steel** production are estimated to contribute 7-8% of global carbon emissions, **aluminum** is estimated to contribute 3%, and "high density building materials (such as concrete, glass, brick and tile represent about 2.6%. [Cited in Doug Fox's paper for USAEP: "GCC: Potential Opportunities for the USAEP", June 1998.]

• In the U.S., the sources of [GHG or $CO_2$?] emissions are:

- Electric Power 30%
- Transportation 30%
- Industry 17%
- Buildings 11% {------> 88% for these 4 sectors} (56/44 residential/commercial)
- Waste 5%
- Industrial Processes 4%
- Agriculture 3%

[Tamara Nameroff's 11/98 presentation, citing EPA 1995]

• PLANES: "Fully loaded **jet aircraft** can use about as much fuel per passenger as each passenger driving a typical car the same distance". (See www.benjhm.free-online.co.uk/flying/) [*Green Energy News*, 17 July 1999, Vol 4, No 15.]

## CONTRIBUTIONS BY COUNTRY/REGION

• The top ten emitters of carbon dioxide from fossil fuel combustion and cement production in 1995 were:

| | | |
|---|---|---|
| 1 - U.S. | 5 - Germany | 8 - Canada |
| **2 - China** | **6 - India** | 9 - Italy |
| 3 - Russia | 7 - United Kingdom | 10 - South Korea |
| 4 - Japan | | |

[WRI]

• "Developed countries have contributed 65% to the overall atmospheric buildup of CO2 that has occurred over the past century and a half." [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• "Developed nations have contributed roughly 80% of the CO2 from industrial sources that has accumulated between 1850 and 1995." [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• CUMULATIVE EMISSIONS: "Even assuming that annual industrial emissions from developing countries reach those of developed nations as early as 2016, the stock contribution [i.e., total to the atmosphere] from industrial sources in developing countries will not equal those from developed nations until after 2055." Including land use change, parity will be reached about 2038. Parity in **annual** carbon emissions is expected in 2015. (All the above based on a BAU scenario.) [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• **Relative Contributions of GHGs in 1995 for selected countries**
(estimated carbon equivalents, expressed as percent of a country's total GHG emissions)

| Country | $CO_2$ | $CH_4$ | $N_2O$ | Halo-carbons | Perfluoro-carbons | $SF_6$ |
|---|---|---|---|---|---|---|
| **U.S.** | 84.8 | 10.6 | 2.4 | 1.2 | 0.5 | 0.5 |
| **Norway** | 70 | 18 | 8 | 0.4 | 3 | 1 |
| **Philippines** | 83.2 | 16.3 | 0.06 | - | - | - |
| **Thailand** | 39.4 | 60.3 | 0.3 | - | - | - |
| **China** | 74.2 | 25.8 | 0 | - | - | - |

Points to note:

1) The Asian values are preliminary data from the U.S. Country Studies Program. The halogenated compounds (CFCs, HCFCs, HFCs, perfluorocarbons and $SF_6$) were not estimated, but are presumably very low. China's zero value for $N_2O$ (nitrous oxide) seems unlikely.

2) U.S. data from www.epa.gov/...inventory/trends.html (EPA Inventory of GHGs); Norway from the Norwegian National Technology Programme web site.

• $CO_2$ emissions due to energy are predicted to increase by about 120% in the 60 years from 1990 to 2050 {from 6 Gt C to 13.1 Gt}. The breakdown by then is predicted to be 50/25/25 industry/buildings/transportation {though it is frightening to ponder the assumptions that would have to go into such a prediction}. [IPCC; D. Fox's paper: "GCC: Potential Opportunities for the USAEP", 6/98]

• The "industrial" $CO_2$ emissions from non-Annex I countries (developing and transition economies) are projected to increase five-fold from 1990 to 2040 {??-can't tell the exact dates, because Doug Fox phrased it as "in the next 50 years" without giving a start or end date; I suspect, however, that the start date is 1990 and the end 2050. Also don't know what he means by "industrial".} [IPCC; cited in Doug Fox's paper for USAEP: "GCC: Potential Opportunities for the USAEP", June 1998]

• **Since 1950**, industrial countries and the former Soviet Union accounted for 74% of carbon emissions. On an annual basis today they account for 60% of carbon emissions, but only 20% of the world's population. [Seth Dunn, "Can the North and South Get in Step?", *World Watch*, Vol. 11, No. 6 (1998), p. 22]

• "The 260 million people in this country release as much carbon dioxide to the atmosphere as the 3.2 billion people in the 135 least-polluting countries." "Michigan alone emits as much $CO_2$ as about 80 developing countries, according to the National Environmental Trust", a Washington think tank. [*Detroit Free Press*, 11/20/98]

**ASIA REGIONAL**

• In 1995, Asia produced 30% of the world's carbon dioxide emissions from fossil fuel combustion. (This does *not* count the Central Asian countries from the former Soviet Union.) For comparison to other developing regions of the world: all of Central America, South America and the Caribbean produced only 4% of the world's $CO_2$ emissions from fossil fuel combustion; Africa produced only 3%; and the Middle East 4%.
[calculated from data from WRI's *World Resources 1998/1999*]

• Asia's share of the world's $CO_2$ emissions (not counting land use change) is steadily and rapidly increasing: it was 19% in 1989, 27% in 1992, and 30% in 1995.
[WRI's *World Resources 1998/1998*]

• Carbon Emissions (in million metric tons) for Developing Asia:

| | **1990** | **1995** | **2000** | **2005** | **2010** | **2015** | **Average Annual % Change, 1995-2015** |
|---|---|---|---|---|---|---|---|
| **Developing Asia** | 1,092 | 1,475 | 1,865 | 2,295 | 2,735 | 3,232 | 4.0 |
| **China** | 625 | 821 | 1031 | 1,257 | 1,523 | 1,838 | 4.1 |
| **India** | 159 | 221 | 276 | 350 | 421 | 490 | 4.0 |
| **Other Asia** | 307 | 432 | 557 | 688 | 792 | 904 | 3.8 |

[U.S. Energy Information Administration; see files for data on other countries/regions.]

• The average *annual* percent increase in carbon emissions from 1995 to 2015 by region:

| | |
|---|---|
| (China) | 4.1% |
| Developing Asia | 4.0 |
| (India) | 4.0 |
| Central/So. America | 3.7 |
| TOTAL DEVELOPING | 3.5 |
| TOTAL WORLD | 2.2 |
| Africa | 1.8 |
| Total EE/FSU | 1.7 |
| Industrialized Asia | 1.4 |
| US/Canada/Mexico | 1.3 |
| TOTAL DEVELOPED | 1.3 |
| Western Europe | 1.2 |
| U.S. | 1.2 |

• Even under a business-as-usual scenario (for example, no steps taken to implement Kyoto):
~ The developing countries of Asia will produce more carbon dioxide emissions from fossil fuel combustion than North America (U.S., Canada, Mexico) before 2000.

[U.S. Energy Information Administration]

~ The developing world will produce more carbon dioxide emissions from fossil fuel combustion than all developed countries combined before 2012 (not counting Eastern Europe and the former Soviet Union).
[U.S. Energy Information Administration]

• If the Kyoto Protocol is successfully implemented, $CO_2$ emissions from Asia are predicted to about equal those from the developed world by 2010.
[U.S. Energy Information Administration]

• Of the carbon dioxide and methane emissions from developing countries in Asia--normalized to carbon dioxide's potency for absorbing heat in the atmosphere-- half of the climate forcing is due to methane. Broken down by source, 57% of the "warming potential" comes from fossil fuels (combustion, extraction and production), 27% from wet rice agriculture and livestock, 14% from land use change, and less than 2% from solid waste.

• Although methane accounts for only about 2% of developing Asia's greenhouse gas emissions, it is responsible for 30% of climate forcing, because methane traps 21 times as much heat as carbon dioxide. Therefore the capture of methane from organic waste, such as municipal solid waste and organic waste streams, is an important component of any effort to curb greenhouse gas emissions from cities and certain industrial processes.
[Data for 1991, calculated from WRI's *World Resources 1996/1997* and *1995/1994*]

• Percent of Asian population with **access to electricity**:

| | Urban | Rural |
|---|---|---|
| South Asia | 53% | 25% |
| E. Asia/Pac. | 82% | 45% |

[Gordon Weynand, Jul 99 presentation]

**INDIA**

• India is the world's sixth largest emitter of carbon dioxide from fossil fuel combustion, with its output of emissions increasingly rapidly: India's $CO_2$ emissions increased by 39% from 1990 to 1995. (In the U.S., by comparison, emissions grew by 6.5% over the same five year period.)
[U.S. Energy Information Administration]

**CHINA**

• China's is the world's second largest emitter of carbon dioxide from fossil fuel combustion, and it's emissions are increasing rapidly: China's $CO_2$ emissions grew by 35% from 1990 to 1995. (In the U.S., by comparison, emissions grew by 6.5% over the same five year period.) [U.S. Energy Information Administration]

• "*Assuming aggressive nuclear and hydro development and substantial declines in industrial energy intensity* (energy per unit GDP) [emphasis added], [China's] $CO_2$ emissions from energy use are projected to increase from 0.7 billion tons today to 2.1 billion tons by 2015 and to 3.2 billion tons carbon by 2025. This compares to current global $CO_2$ emissions of 6.15 billion tons carbon."
[T.E. Drennen and J.D. Erikson, *Science 279*, 1484 (1998)]

• The China Energy Research Group estimates that China could be using 5-10% of the world's energy output by 2025 and as much as 50% by 2050. [Green Energy News 10/30/99, vol 4, #30]

**COMPARISONS of ASIA with the U.S.**

• Although in 1995 China and India ranked very high worldwide in carbon dioxide emissions (#2 and #6, respectively), they ranked much lower on a per capita basis: #18 and #20. Per capita in 1995, the U.S. emitted 23 times as much $CO_2$ from industrial sources as India, 8 times as much as China, and over twice as much as Japan. [WRI]

• The U.S., with less than 5% of the world's population, is responsible for over 23% of the world's carbon dioxide emissions. U.S. emissions are almost twice that of the world's second largest emitter, China. [Data from 1995, WRI]

• Attitudes of citizens towards GCC: "The first commercially available survey of global environmental attitudes in 5 years was conducted by Environics International, a Canadian environmental group. Of the 24 countries surveyed, the U.S. appears to be the least concerned". 27,000 people surveyed between Jan and April 1997. Percent saying they thought "we should assume the worst and take major action now to reduce human impacts on climate, even if there are major costs": U.S. (46%), Canada and Chile (61%), New Zealand (64%), Australia (67%), Japan and Korea (69%), Switzerland (70%), Italy (71%), France (74%).
[*Environmental Protection*, March 1998, p 10; a monthly environmental industry trade mag.]

**Global Warming Potentials and Lifetimes:**[8]

| Compound (Common) | Compound (Formula) | Est'd Atm Lifeti (yrs) | 20 yr GWP | 100 yr GWP | 500 yr GWP | ODP[9] |
|---|---|---|---|---|---|---|
| $CO_2$ | | 50-200 | 1 | **1** | 1 | 0 |
| Methane | $CH_4$ | 12.2 +/- 3 | 62.0 | **21** | 7.5 | 0 |
| Nitrous oxide | $N_20$ | 120 | 290 | **310** | 180 | 0 |
| HCFC-123[10] | $CHCl_2CF_3$ | 1.4 | 300 | **93** | 29 | 0.014[5] |
| HCFC-124[11] | $CHClFCF_3$ | 6.1[7] | 1500 | **480** | 150 | 0.03[6] |

[8]Global warming potentials are based on *mass*, not moles. Most GWPs from the EIA 1997 Report "Emissions of GHGs in the U.S. 1996" (available at www.eia.doe.gov/oiaf/1605/ gg97rpt/fromt.html), which got them from the 1995 IPCC Report "Climate Change 1995: The Science of Climate Change", Cambridge U. Press, 1996. 1997 GWP values can also be found in reference #3 in Hammitt et al., *Nature 381*, 301-303 (1996), which says that GWP values are typically +/-35%. Some GWPs were directly from the IPCC 1995.

[9]Ozone Depletion Potential, on a scale from 0 to 1. Source: www.afeas.org/atm_cl.htm (Alternative Fluorocarbons Environmental Acceptability Study)

[10]Replacement for CFC-11 for large chillers for A/C and process refrigeration and fire suppression, though it has not replaced it for foam-blowing and aerosol applications. Source: *Science 278*: 1090-1091 (1997).

| | | | | | | |
|---|---|---|---|---|---|---|
| HFC-23[12] | $CHF_3$ | 264 | | **11,700** | | |
| HFC-32 | $CH_2F_2$ | 5.6 | 2100 | **650** | 200 | 0 |
| HFC-41 | $CH_3F$ | | | **150** | | |
| HFC-125 | $CHF_2CF_3$ | 32.6 | 4600 | **2800** | 920 | 0 |
| HFC-134 | $CHF_2CHF_2$ | | | **1000** | | |
| HFC-134a[13] | $CH_2FCF_3$ | 14.6 | 3400 | **1300** | 420 | 0 |
| HFC-143 | $CHF_2CH_2F$ | | | **300** | | |
| HFC-143a | $CF_3CH_3$ | | | **3800** | | |
| HFC-152a | $CH_3CHF_2$ | 1.5 | 460 | **140** | 42 | 0 |
| CFC-11 | $CFCl_3$ | 50 +/- 5 | 5000 | **1320** | 1400 | 1.0 |
| CFC-12 | $CF_2Cl_2$ | 102 | 7900 | **6650** | 4200 | 1.0 |
| Perfluoromethane | $CF_4$ | 50,000 | | **6900** | | 0 |
| Perfluoroethane | $C_2F_6$ | 10,000 | | **9200** | | 0 |
| Perfluoropropane | $C_3F_8$ | | | **7000** | | 0 |
| Perfluorobutane | $C_4F_{10}$ | | | **7000** | | 0 |
| sulfur hexafluoride | $SF_6$ | 3200 | | **23,900** | | 0 |

***Evidence of Global Climate Change & Future Projections***

**TEMPERATURE**

• "The average global temperature in 1998 exceeded by the previous record set in 1995 by ).25 degrees C. Some of the warming . . . can be explained by the El Niño phenomenon, but not most of it, says James E. Hansen, director of NASA's Goddard Institute for Space Studies." "The average global temperature in 1995 was already about 0.75 degrees C above temperatures during the late 1800s." ["Case Grows for Climate Change", *Chemical & Engineering News*, 9 Aug 1999]

• **Models**: When aerosols and solar irradiance are included in GHG models, the curve very closely matches actual global temperature measurements, especially from about 1940 on. [My description of a graph showing both curves, shown in "Case Grows for Climate Change", *Chemical & Engineering News*, 9 Aug 1999, citing Tom Wigley, "The Science of Cliamte Change", Pew Center on Global Climate Change.]

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[11]Used as a blend component for transition refrigerants and medical sterilant gases.

[12]HFC-23 is a by-product of the production of HCFC-22. Source: GCC EPA web site.

[13]Replacement for CFC-12, used largely for motor vehicle air conditioners.

• 1998 Global Surface Temperatures Highest in since 1860. [World Meteorological Organization (WMO), Geneva (December 17, 1998) XINHUA]. Also...

- The earth's global temperature in 1998 will be the highest, according to the.
- The global mean surface temperature is estimated to be 0.58 degrees centigrade above the recent long-term average based on the period 1961-1990, said the WMO in its "Annual Statement on the Global Climate" made public here Thursday.
- "It will be the 20th consecutive year with an above normal global surface temperature," it said. "The previous warmest year, 1997, was 0.43 degrees above average."
- It noted that the 10 warmest years have all occurred since 1983, with seven of them since 1990.
- The regional temperature patterns (January through November) show all of the continents with above average temperatures, except the northern sections of Eurasia.
- Meanwhile, higher in the atmosphere, where regular measures are made by instruments on weather balloons and satellites, record high temperatures also occurred.
- From the surface to seven kilometers altitude, record temperatures in 1998 were 0.47 degrees higher than the average of the last 20 years, making 1998 by far the warmest year, said the WMO. In the lower stratosphere, 1998 was colder than usual, though not quite as cold as in the 1995-1997 period.

• *A different source, and a couple months earlier:* The annual report of the World Meteorological Organization (WMO)* announced that 1998 was the warmest year on record, surpassing the previous record set in 1997. "Seven of the hottest years on record have occurred in this decade", according to WMO. "Identical findings were announced by NASA Goddard Institute for Space Studies" (GISS). Year-to year variations in temperature are usually measured in hundredths of a degree, making this year's rise of 0.27 F "impressive", according to GISS director James E. Hansen. The 30-year norm was surpassed by a full degree. (*The WMO is made up of 180 meteorological organizations from around the world. [Cited in the *Washington Post*, 18 Dec. 1998]

• "There is no period that we can recognize in the last 1,200 years that was as warm on a global basis", said Jonathan Overpeck, head of the paleoclimatology program for NOAA. "Not only has the 20th century produced the hottest years on record, he said, but the magnitude of the change appears to be without parallel since at least 800 A.D."
[*Washington Post*, 12/8/98]

• "The period January through October 1998 was the warmest such period on record at 58.65 degrees. This is 1.25 degrees F above the 1880-1997 mean of 57.4 degrees F, and exceeds the previous records for this period set in 1997 by 0.36 degrees F." "At 58.18 F, the mean global surface temperature for October 1998 was 1.08 F above the 1880-1997 mean global surface temperature of 57.1 F. October 1997 had been the warmest October on record at 58.15 F." [USA Today, 11/24/98, citing NOAA.]

• "All 14 of the warmest years since 1860 have occurred in the past two decades." "The average temperature for January-August 1998 was a full four tenths of a degree warmer than the average for 1997, the previous record-setting year." "Six of the first eight months of 1998 set an all-time temperature record for" their respective months--"exceeding the monthly figures recorded in the

139 years that global average temperatures have been tracked." [Christopher Flavin, "Last Tango in Buenos Aires", *World Watch*, Vol. 11, No. 6 (1998), p. 11-12]

•. Nine of the past 11 years have been the warmest on record (based on land and ocean surface temperature data. 1997 was the warmest year of this century (averaging 0.75 degree F above normal, where normal is defined as the mean temperature over the 30 year period from 1961 to 1990, 61.7 F). [NOAA Report, Vol. 7, Number 1 (January 1998)]

• At the height of the last ice age (20,000 years ago), the average global temp was approximately 10 deg F cooler than now. At that time, the atmosphere contained 40% less $CO_2$ than just prior to the Industrial Revolution, and it is estimated that the reduced $CO_2$ may account for nearly half of the global cooling. [NOAA's Report to Nation, Fall 1997--p. 11]

• Antarctica is warmer than it has been during the last 4,000 years, according to ice core samples. [Worldwatch, Jan/Feb 1999]

• "In England, four of the five warmest years in the 340-year record occurred in the last decade." [Indicators of Climate Change in the UK", Institute of Terrestrial Ecology and the Climatic Research Unit at the University of East Anglia, 1999; www.nbu.ac.uk/iccuk]

**Answers to Skeptics re Temperatures**

• It used to be believed that there was a global warming period, called the 'Medieval Warm Period', from the beginning of the 9$^{th}$ century until nearly the 14$^{th}$ century. GCC skeptics frequently cited this as proof of natural climate variations. However, "new research suggests that the Medieval Warm Period never really happened, Overpeack said. Based on evidence from ancient tree rings, glaciers and other 'proxy' measurements of past climate, the thaw appears to have been limited to northern latitudes in Europe and North America, while other parts of the globe saw little change in temperature. The apparent cause of Europe's warming was a change in ocean currents, he said." [*Washington Post*, 12/8/98] (Jonathan Overpeck is head of NOAAs paleoclimatology program.)

•. People who did not believe in global warming used to point to satellite data, which gave cooler temperatures than those measured with thermometers at ground level. However, two scientists demonstrated that the satellite data was flawed because it failed to take into account atmospheric drag causing satellite orbits to decay. [*Nature 394*, 661 (1998); cited in *C&EN*, 17 August 1998]

**ATMOSPHERIC GHG CONCENTRATIONS**

• The atmosphere's carbon content has increased 30% since 1800, increasing from 278 ppm to 360. (Data prior to 1957 was measured from ice cores.)
[NOAA's Report to the Nation, Fall 1997--p. 13 and C&EN, 11/27/95]

•. GHG concentrations rise about 1% per year [Post 11/12/97]

•. $CO_2$ levels calculated from ancient air trapped in Antarctic and Greenland ice, going back to ~160,000 years ago, shows the concentration of GHGs to be higher now (at 360 ppm) than at any other time within this time frame. [NOAA's Report to the Nation, Fall 1997--p. 12]

• "The atmospheric concentration of CO2 was stable at 280 +/-5 ppm for 1000 years before the year 1800, according to ice core records. As a result of human-made emissions, it has now increased by about 30% above this baseline." [*Science 270*: 1454 (1995), P.E. Kauppi (1 Dec 95 issue); citing U. Stegenthaler and J.L. Sarmiento, *Nature 356*: 119 (1993); U. Stegenthaler and H. Oeschger, *Tellus 39*: 140 (1987).]

• Because of the Greenhouse Effect, the average surface temperature of the Earth is 15 C (59 F) rather than -18 C (0 F).

• IPPC's estimate is a rise in average global temp {at Earth's surface} by between 1 and 3.5 degrees Celsius, corresponding to a rise in sea level of 6 inches to 3 feet (37"). [IPCC, cited in a UNEP brochure]

• NOAA says that warming over next century will be between 2 and 8 degrees F [NOAA's Report to Nation, Fall 1997--p. 21]. UNEP says that the IPCC says that the increase will be between 2 and 6 F.

• Over the past century, global mean surface temperature has already increased by about 1 F, and sea level is 4" to 10" higher. [NOAA's Report to Nation, Fall 1997--p. 19] A UNEP brochure puts the temperature rise at between 0.5 and 1 F.

**FUTURE PROJECTIONS of Temperature and [GHG]s**

• In order to stabilize the atmospheric concentration of $CO_2$ at two times pre-Industrial, emissions will have to be reduced 60 to 80% below 1990 levels over the next century. [IPCC, cited by Christopher Flavin, "Last Tango in Buenos Aires", *World Watch*, Vol. 11, No. 6 (1998), p. 14, but he doesn't specify over what time period the reductions must take place. I think it's one century, based on what Tim Wirth and others have said.]

• "When emissions of developing countries are added to those of the industrialized countries covered by the [Kyoto] Protocol, the global total is projected to increase by some 30% *above* the 1990 level by 2010." [Christopher Flavin, "Last Tango in Buenos Aires", *World Watch*, Vol. 11, No. 6 (1998), p. 14]

• "In order to stabilize atmospheric carbon dioxide at twice pre-industrial level, by the year 2050 there needs to be a ten-fold increase in carbon emission-free power generation over the next 50 years, according to university researchers." (Current C emission-free generation is at 1.5 terawatts.) The research team found that "non-fossil fuel generation must account for at least 50%" of the world's total power production of 30 terawatts. According the team leader, New York physicist Matin I. Hoffert, "Stabilizing CO2 at twice pre-industrial levels without untenable economic disruptions implies a massive shift to carbon-free power, particularly in developing nations." [ENN (www.enn.com/news/enn-stories/...), 11/19/98]

• In the U.S., GHGs emissions will be >30% above 1990 levels by 2010, and >45% greater by 2020. [Tamara Nameroff presentation; I believe from EIA]

## IMPACTS of the Greenhouse Effect and Global Climate Change

### NON-LINEAR CLIMATE RESPONSES

• "Scientists have known for a long time that the climate is a 'non-linear system' that may respond marginally or not at all to initial changes--but then leap suddenly to a new equilibrium if pushed a little further." [Christopher Flavin, "Last Tango in Buenos Aires", *World Watch*, Vol. 11, No. 6 (1998), p.12]

• "This year [1998] has been so unusual scientists are beginning to wonder if we are witnessing a flip to a new climatic regime. It's a scenario climatologists have discussed for some time but considered unlikely. In the **climate-flip scenario**, the climate does not change in a smooth trend but jumps to a new state abruptly."

• "10 trillion tonnes of methane is trapped under pressure in crystal structures on the edges of **continental shelves**", according to Gerald Dickens, a geologist at James Cook University in Townsville, Australia. The methane could become destabilized as ocean waters warm, creating a catastrophic runaway global warming. "Some **55 million years ago**, after a long, slow period of global warming, water in the deep ocean suddenly warmed by about another four degrees and released several trillion tonnes of methane into the atmosphere. This set in train an even more catastrophic global warming at the surface, during which millions of species died. It was a mass extinction comparable with the disappearance of the dinosaurs 10 million years before. Nobody is quite sure why this happened, says geologist Gerald Dickens. Perhaps a flip in ocean currents warmed the ocean and released methane from the ocean bed. But 'something snapped—everything happened at once', he says." [*The Guardian*, 11/25/98]

• "The **Gulf Stream**...could be on the verge of breaking down. The world's oceans seem to have two 'modes'. One maintains the Gulf Stream; the other does not. And geological evidence suggests that it switches between the two modes without warming, and virtually overnight. 'We are close to the cusp of a change', says Stefan Rahmstorf of the Potsdam Institute for Climate Impacts Research in Germany. 'If the system shuts down, winter temperatures in the North Atlantic region would fall by 10 C within years', says Wallace Broecker, a geochemist at Columbia Univ. in NY. ...The Gulf Stream...depends on the saltiness of the North Atlantic. This salty water is dense, and as a result, sinks to the ocean floor off the shores of Iceland and Greenland. ...This in turn sucks in the Gulf Stream from the tropics. But computer models of climate predict that global warming will start to melt the nearby Greenland ice cap, making the ocean less salty. ...'The flip could persist for thousands of years', and flips in ocean circulation systems often appear like 'El Ninos lasting a thousand years'." [*The Guardian*, 11/25/98]

### CHANGES IN POLAR REGIONS

***Arctic (and North Atlantic ice)***

• "Various groups had found that the area covered by the [arctic] ice in the summer has been decreasing by about 3% per decade during recent decades. ...But polar researcher Ola Johannessen of the Nansen Environmental and Remote Sensing Center in Bergen, Norway, and his colleagues report on page 1937 that the arctic ice is undergoing much more rapid change." From microwave emissions data "made from 1978 to 1998, Johannessen and his colleagues found that the area of multiyear ice had declined by 7% per decade during the 20-year period—twice the rate at which

the total ice pack has been [believed to be?] shrinking." A University of Washington team found that the ice over the deep-Arctic thinned [by] about 15% per decade. That's five times faster than the ice had been shrinking. What's more, the ice thinned at every one of the 26 sites for which the researchers compiled data. Overall, says Rothrock, **the arctic has lost 40% of its volume in less than 3 decades.**" Polar researcher John Walsh of the University of Illinois, Urbana-Champaign says that "if thinning continues at this rate,.. 'there really are only a few decades before ice thickness reaches zero'. That would convert the Arctic Ocean from a brilliantly white reflector sending 80% of solar energy back into space into a heat collector absorbing 80% of incident sunlight, with effects on ocean and atmospheric circulation extending into mid-latitudes. These could include shifts in storm tracks, says Walsh, with changes in precipitation." Opinions vary on whether this is an extreme state of the Atlantic Oscillation which will likely go back to normal, or whether greenhouse gas emissions are the cause. A climate researcher from the University of MD compared the ice loss with that in two climate models of the greenhouse effect and concluded that the chances of this being an extreme swing of a natural cycle are less than 0.1%. [Richard Kerr, *Science, Vol 286*, p. 1828]

• Arctic ice is now thinner by a third than is was 20 years ago. British researchers, who have been measuring Arctic sea ice since 1976, found that it is now up to two meters thinner on average than it was in the 1970s, when it averaged six meters thick. Also, Norway scientists say that satellite data show a 5% decrease it in the total area of Arctic ice over the past 18 years, a reduction equivalent to the area of France. [*Times of London*, 11/23/98]

• "The Nansen Environmental and Remote Sensing Center in Norway found a 4.6% decline in ice extent and a 5.8% decline in actual ice area between 1978 and 1994." Greenpeace says that the **Arctic** is warming at least twice as fast as the rest of the globe, and that the resulting loss in sea ice is endangering **polar bears**, which "feed nearly exclusively on ringed seals which they hunt from the ice edge or through the pack ice itself". The reduction in ice is reducing the bears' accessibility to the seals. "The food chain in the Arctic is short. The algae that grows on the bottom of the ice is eaten by ringed seals, which are eaten by the polar bears." [CNN Interactive (http://cnn.com/, 11/4/98]

• Caleb Pungowiyi, a Yupik Eskimo elder form Nome, Alaska, says the changes in Arctic areas his people have witnessed include: earlier ice bridge thaws, a reduction in Bering Sea ice cover, more precipitation, thawing and subsiding permafrost, increased coastal erosion, later river freezings, and earlier thaws. [*Deseret News*, 11/27/98]

• Russ Page, an Anchorage-based ice forecaster for the National Weather Service, says that sea ice has been a month late this winter in the Chukchi and Beaufort seas, and this summer had record breaking minimum icepack in the eastern Chukchi and western Beaufort, according to records going back three decades. Gunter Weller, professor of geophysics at the University of Alaska Fairbanks, says that Soviet ice pack data going back to 1955 suggests that there is a warming trend on top of regular oscillations (for example, due to El Nino). "Sea ice is a pretty sensitive indicator", said Weller. "It doesn't take much (temperature change) to make a change in ice." [*Anchorage Daily News*, 11/28/98]

• For the first time since the International Ice Patrol (IIP) was established in 1914, it has not reported a single **iceberg in the North Atlantic** (south of 48 degrees N, where the IIP tracks bergs). [*Science, Vol. 285*, 2 July 1999, p. 37]

*Antarctic*

• "Even slow climate change can unleash sudden catastrophic events, says Schneider. For instance, global warming could be on the verge of triggering the destruction of the **West Antarctic ice sheet**. Its 3 million cubic kilometers of ice, enough to raise sea levels worldwide by five meters if it came adrift, do not rest on solid rock but are perched on an archipelago of submerged islands,...with ocean water flowing underneath the ice." It will probably take a few hundred years to completely break up, but "once started, the break-up would be irreversible". [*The Guardian*, 11/25/98] "The West Antarctic ice sheet is not melting rapidly, is reasonably stable and has been so for more than a century, according to an international team of scientists. The ice sheet is the largest grounded repository of ice on the planet." "The majority of the West Antarctic ice sheet sits atop dry land while the east Antarctic ice sheet is grounded below sea level. Changes in the east Antarctic sheet would have little effect on sea level since the ice displaces sea water." {See also section below on Sea Level.} [ENN, 12/1/98 (www.enn.com/)

• An iceberg with an area of 1,073 $km^2$ [CHECK!!—I'm wondering if way too small] calved off the Antarctic ice shelf on October 15, 1998. [*World Watch* Jan/Feb 1999, p. 9]

*Tundra*

• Due to warming, "the **tundra**, which for millenia has stored large amounts of carbon in the form of peat, now seems to have become a net source of carbon dioxide emissions across vast areas of the Arctic". ["Case Grows for Climate Change", *Chemical & Engineering News*, 9 Aug 1999]

• According to Stephen Schneider, climatologist at UCSD, warming is happening faster than almost anywhere else on the planet in Siberia, where billion of tonnes of methane trapped close to the surface of the permafrost will be released if the **permafrost** melts. [*The Guardian*, 11/25/98]

## CHANGES IN SEA LEVEL

• Three sources of sea level rise:

1) **thermal expansion** due to warming of water, which in the last century is estimated to amount to 1 to 2.5 mm/year, or a total of ~half a foot (4 to 10", or 10-25 cm). Thermal expansion leads to uneven rises in sea level across the globe due to the fact that cold water expands about 3 times less than tropical water. It is estimated that a 1° C increase in the top 100 m of *tropical* ocean will result in an increase of 3 cm.
2) **Glaciers and ice caps outside polar regions.** The retreat of glaciers has added an estimated 1" to 2" (2-5 cm) to sea level in the past century. Uncertain what their fate will be, but in the hypothetical case that they all melted the resulting increase in sea level could be as much as 20" (50 cm). Note that in the ice ages, glaciers advanced as far south as southern England and south of the Great Lakes, at which time sea level was lower by as much as 100 m (330 feet). In the warm period between the last two ice ages, sea level was 5 m (16') higher than now.
3) **Ice sheets over Greenland and Antarctic.** Considered separately from other ice because they are in such cold areas they are less vulnerable to melting,. However, since most of the freshwater on the planet is held by these two ice sheets, any melting would have a dramatic effect. Their fate is highly uncertain. The **East Antarctic sheet**, where more than 3/5 of the world's freshwater is stored, seems to be stable. Less certain is the West Antarctic sheet, which if melted could add between 4 and 7 m (13'-23') to sea

level. Most of the sheet rests on the ocean bottom, but there is a large section floating that is under tremendous pressure from rising and falling tides. Pieces of this section routinely fall off, float away and melt, but records don't go back far enough to know trends. Greenland is a concern because it isn't as cold as the Antarctic, and loses water both from melting and from iceberg calving. It is uncertain what the state of play is with Greenland, although it is assumed that the trend is towards melting.

In summary, even if the West Antarctic sheet remains largely intact, the current estimates for sea level rise are 15 cm **(6") by 2030**, and 50 cm **(20") over the next century**. (Note that Antarctic and Arctic **sea ice** has no effect on sea level, since it is already displacing sea water. However, that Arctic sea ice is melting rapidly, by 2.8% from 1978 to 1987 and by 4.5% between 1987 and 1994.)

[Paul Brown, "Global Warming: Can Civilization Survive?", chapter 8, Blandford Press, 1996.]

• If the West Antarctic ice shelf collapsed and melted, sea level could rise by as much as 5 meters. [*World Watch* Jan/Feb 1999, p. 9]

**WEATHER**

• Storm-related weather damage in 1998 "climbed to a new high of $89 billion. This not only exceeded the previous record set in 1996 by an astonishing 48%, but it exceeded the weather-related damage for the entire decade of the 1980s." [Lester Brown, *Worldwatch 12*(2): 15 (1999); Mar/Apr]

• "Preliminary estimates by the Worldwatch Institute and Munich Re of Frankfurt, Germany, the world's largest reinsurance firm, put total losses from **weather-related disasters** for the first 11 months of the year 48% higher than the previous one-year record of more than $94.8 billion, in 1996." "This year's damage was also ahead of the $86.9 billion in losses for the *entire decade* of the 1980s. Even when adjusted for inflation, the 1980s losses, at $130.6 billion, still fall short of the first 11 months of this year." [The Age-Australia, 11/30/98]

• "Bangladesh suffered its most extensive flood of the century in the summer of 1998, when two-thirds of the country remained inundated for months. The 1998 floods reached near record levels and did not recede for months. More than 30 million people were left temporarily homeless, 10,000 miles of roads were heavily damaged, and the annual rice harvest was reduced 2 million tons." [*World Watch*, Jul/Aug 99]

•. In 1998, "China was swept by its worst floods in three decades last summer,...two-thirds of Bangladesh was underwater for most of the summer,... At least 54 other countries were hit by severe floods in 1998, and at least 45 were stricken by droughts, many of which led to runaway wildfires. Tropical forests normally do not burn but unusually harsh droughts contributed to a series of unprecedented fires in southeast Asia starting in late 1997 and in the Amazon through most of 1998. Last spring, much of southern and central Mexico was aflame,...scores of fires were sweeping the sub-tropical forests of Florida." [Christopher Flavin, "Last Tango in Buenos Aires", *World Watch*, Vol. 11, No. 6 (1998), p. 12]

• "One computer model predicts a loss in soil moisture of more than 20% in the Great Plains and SE U.S. if $CO_2$ levels double. Under quadruple $CO_2$, soil moisture losses climb to 50% and even higher". [Post 11/12/97]

• **Hurricanes**: The thermal energy of seawater is what fuels typhoons and hurricanes. MIT atmospheric scientists Kerry Emanuel says that wind speeds increase 5 mph for every additional degree Fahrenheit of water temperature, which means that sustained winds of hurricanes in a globally warmed climate could top 200 m.p.h. (Hurricane Floyd in Sep 1999 was so strong because the North Atlantic was unusually warm that fall.) Warmer world hurricanes might also pick up a lot more rain, increasing the flooding associated with hurricanes, and storm surges would be more damaging with higher sea levels. However, it is difficult to predict just how strong these hurricanes might be because as hurricanes increase in strength, they stir up deeper, usually colder, water, and cold water causes hurricanes to weaken and eventually die. [*Time* magazine, 27 Sep 99]

• "Storms, floods, droughts and fires in 1998 caused a staggering 32,000 deaths worldwide. In that year another 300 million people—more than the population of the U.S.—were displaced from the homes or forced to resettle because of extreme weather events. According to figures copiled by Worldwatch and the Munich Reinsurance Company, the costs of weather-related disasters in 1998 reached a record high of more than $92 billion—a 50% increase over the prrevios record of $61 billion in 1996. Disaster losses in 1998 alone far exceed the $78 billion in losses for the entire decade of the 1980a. Munich Re estimated in its 1998 year-end report that the number of natural catastrophes has tripled since the 1960s, increasing the overall cost to the world's economies nine-fold." [*World Watch*, Jul/Aug 1999]

**Changes to ECOSYSTEMS**

• A State Dept. report released 5 March 1999, "the most complete documentation of the problem", found that record high sea temperatures "triggered the largest mass die-off of tropical corals in modern times last year". The report made "the most forceful pronouncement by federal officials linking the phenomenon to climate change". "More than 70% of corals died off across a wide region of the Indian Ocean." "The mortality rate topped 75% near the Seychelles and more than 80% in the Mafia Marine Park off Tanzania." "The phenomenon was observed in at least 60 countries and island nation... Only the central Pacific region appears to have been spared." Coral reefs provide "food and shelter for at least 1 million species of animals, plants and microbes. Reefs yield a host of benefits for humans, including food, medicines and tourism income". [*Washington Post*, 5 March 1999]

• **Coral reefs** are "canaries in the coal mine", according to Australian marine scientist Terry Done. Bleaching is caused when increases in sea temperature "cause coral polyps to expel their symbiotic microscopic algae from their cells". NOAA data suggests that reefs in the Northern Hemisphere would be more severely affected by warming. "NOAA's soon-to-be-published data suggests rises of up to 5 C over the next 100 years in tropical waters." Participants at the international coral reef symposium in Townsville that "tropical sea surface temperatures in 1997-1998 have been higher than 'at any other time in the modern record'." The draft of the IPCC's 2001 report says: "corals live near the upper edge of their temperature tolerance, with high temperatures directly damaging aspects of their physiology". Thus an increase by about 2 C as predicted by the IPCC for the next 50 years is of concern." [*Sydney Morning Herald*, 11/26/98; see also http://cnn.com/WORLD/asiapcf/9811/25/BC-AUSTRALIA-REEFS.reut/index.html]

## PROCESSES PRODUCING *GHGs*

| GHG | GWP (100 yr) | Atmosp. Life(yrs) | SOURCES or USES |
|---|---|---|---|
| **$CO_2$ (carbon dioxide)** | 1.0 | 50-200 | *Combustion* of gas, oil and coal<br>Land use changes (loss of sinks)<br>Biomass burning<br>Gas flaring<br>Direct release from industrial processes (cement, aluminum, $CO_2$, glass, soda ash, iron, & steel production) |
| **$CH_4$ (methane)** | 24.5 | 12 | *Extraction* of fossil fuels<br>Animal waste decomposition<br>Enteric fermentation in ruminants<br>Wet rice agriculture (large contributor)<br>Solid waste decomposition<br>Direct release from industrial processes (production of aluminum, organic chemicals, iron, steel) |
| **$N_2O$ (nitrous oxide)** | 320 | 120 | Agriculture soil management and fertilizers<br>Animal waste decomposition<br>Fossil fuel combustion & catalytic converters<br>Nylon production (via adipic acid)<br>Nitric Acid production (for synthetic fertilizers, explosives, and adipic acid)<br>Biomass burning |
| **CFCs**, for ex:<br>CFC-11<br>CFC-12 | <br>1320<br>6650 | <br>50<br>102 | <br>CFC-11: refrigeration; blowing agent for foams<br>CFC-12: A/C, refrigeration, blowing agent |
| **HCFCs**, for ex:<br>HCFC-123<br>HCFC-124<br>HCFC-141b | <br>93<br>480<br>270 | <br>1.4<br>6.1<br>9.4 | Replacements for CFCs<br>HCFC-123: refrigeration and A/C<br>HCFC-124: refrigerants and medical gases<br>HCFC-141b: to blow polyurethane for rigid insulation boards and refrigerator lining |
| **HFCs**, for ex:<br>HFC-23<br>HFC-134a<br>HFC-152a | <br>11,700<br>1300<br>140 | <br>264<br>14.6<br>1.5 | Replacements for CFCs and HCFCs<br>HFC-23: by-product of HCFC-22 production<br>HFC-134a: auto A/Cs and refrigerators<br>HFC-152a: aerosol propellant |
| **perfluorocarbons**<br>$CF_4$<br>$C_2F_6$<br>$C_3F_8$ | <br>6,900<br>9,200<br>thousands | <br>50,000<br>10,000<br>>2000 | Plasma etching, cleaning of wafers to make silicon chips in semiconductor industry. Aluminum smelting. Perfluoropropane ($C_3F_8$) also used in high voltage insulation & as refrigerant in combination with HCFCs. |
| **Sulfur hexa-fluoride** ($SF_6$) | 23,900 | 3,200 | Insulation in high voltage equipment (about 80% of world use); casting molten magnesium (20%) |

**ANTHROPOGENIC ACTIVITIES DIRECTLY EMITTING GREENHOUSE GASES (GHGs)**

| **FOSSIL FUELS** | **GHGs Emitted** |
|---|---|
| Combustion of Fossil Fuels (mobile and stationary) and Wood | $CO_2$, methane, nitrous oxide ($N_2O$); additional $N_2O$ from catalytic converters |
| Extraction of Fossil Fuels (coal mining, and oil and gas production and distribution) | methane |
| **AGROFORESTRY/MUNICIPAL** | |
| Solid Waste Decomposition (including landfills) | methane, $CO_2$ |
| Biomass Burning | $CO_2$, methane, $N_2O$ |
| Enteric Fermentation in Ruminants | methane |
| Animal Waste | methane, $N_2O$ |
| Wet Rice Agriculture | methane |
| Fertilizer Use (especially overuse); Tilling | $N_2O$ |
| **INDUSTRY** (non-agricultural) | |
| Cement Production | $CO_2$ |
| Flue Gas Desulfurization | $CO_2$ |
| Soda Ash Production from Trona Ore (instead of from brine carbonation) | $CO_2$ |
| Aluminum Manufacture from Ore | $CO_2$, perfluorocarbons ($CF_4$, + some $C_2F_6$) |
| $CO_2$ Manufacture | $CO_2$ |
| Glass Manufacture | $CO_2$ |
| Hydrogen & Ammonia Prod. (from Natural Gas) | $CO_2$ |
| Iron and Steel Production | $CO_2$, methane |
| Production of Ammonia and Some Organic Chemicals | $CO_2$, methane |
| Nylon and Adipic Acid Production | $N_2O$ |
| Nitric Acid Production | $N_2O$ |
| Refrigeration, Air Conditioning, Foams, Blown Insulation, and Medical Gases | chlorofluororocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), $C_3F_8$ |
| Semiconductor Industry | perfluorocarbons ($CF_4$, $C_2F_6$, $C_3F_8$) |
| High voltage Electrical Equipment | $SF_6$ (used as dielectric and insulating gas in) |
| Casting Molten Magnesium | $SF_6$ (used as cover gas to protect Mg from $O_2$) |

## *Sources of CARBON DIOXIDE*

FOSSIL FUEL COMBUSTION

• **Fossil fuel combustion** produces 80 to 85% of $CO_2$ emissions. [USGCRP, web]

• **Coal burning**

- Produces $CO_2$, CO, $SO_2$, $N_2O$, $NO_x$, particulates, radionuclides, and metals. (Coal contains only trace amounts of metals, but since it is burned in such large quantities, metal emissions are significant.) Coal produces more $CO_2$ than petroleum or natural gas because it has a higher carbon content. {M.K. Hill; but it was only the EIA report on $N_2O$ on the web that said coal burning produces $N_2O$.}

• **Carbon emissions per kWh:**

- 0.57 lb. per kWh average existing coal-fired plants (based on heat rate of 10,360 btu/kWh)
- 0.38 lb. per kWh from coal (best achievable)
- 0.32 lb. per kWh for all gas-fired plants
  (steam, peaking, and combined cycle, based on average heat rate of 11,380 btu/kWh)
- 0.24 – 0.26 lb. per kWh for state-of-the-art natural gas combined cycle
  (earlier in the document said 0.19 was the "best achievable" for natural gas)

[From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

• **Power Plants:** Exempt from the standards in the Clean Air Act, "Emissions from New England's 14 oldest power plants have increased for the third consecutive year". [*The Daily Gist*, 28 Oct 99.]

•. **Motor vehicles (including diesel)/Transportation**

~ Motor vehicles give off CO, $CO_2$, hydrocarbons, $NO_x$ (mostly $NO_2$), $N_2O$, $SO_x$ ($SO_2$), phosphorous, particulates, lead and other metals. [One source: www.advancedmechanics.com/exh.htm]

~ Motor vehicles are responsible for 20% of U.S. $CO_2$ emissions per year [M.K. Hill].

~ In 1990, transportation accounted for about 25% of global energy use and 21% of global $CO_2$ emissions. [Doug Fox in: "GCC: Potential Opportunities for the USAEP", June 1998.]

~ "Air travel is one of the dirtiest forms of travel." [BBC News (http://news.bbc.co.uk/), 11/21/98]

~ California's Air Resources Board recently concluded that 2% of the vehicles on that state's roads, heavy duty diesel trucks, generate one-third of the smog-causing nitrogen oxide emissions. The EPA found that diesel trucks emit more than half of the fine particulates emitted by vehicles. Last year the California board listed diesel exhaust as a toxic air contaminant. [*Wash Post*, 19 Sept 99]

•. **Shipping (Bunker Fuels):** $NO_x$, $SO_x$, $CO_2$,...?

- Almost all ships use diesel engines fueled with bunker fuels, which are cheaper "residual fuels" left behind after secondary refining to remove the higher quality distillates. Since secondary refinery technologies were improved after the 1973 fuel crisis, residuals have increased concentrations of sulfur, ash, asphaltenes, and metals. Some ship fuels mix higher quality fuels with residuals, but 70 - 80% use only residual fuels.
- $NO_x$ emissions depend on the type of combustion system (because of variations in peak temperature), and to a lesser extent on the nitrogen content of the fuel.

- $SO_2$ emissions depend solely on the fuel's sulfur content.
- $CO_2$ from ships are only 2% of the total carbon emitted from fossil fuel combustion. (Table 14.1 of WRI 96/97 agrees with this--2.1%--including gas flaring and cement production.)
- "Ship emissions account for 14% of nitrogen emissions from fossil fuels and 16% of all sulfur from petroleum uses."
[Source: J.J. Corbett and P. Fishbeck, *Science 278*: 823-824 (1997).]

**INDUSTRIAL PROCESSES** (including DIRECT EMISSIONS of $CO_2$)
• The principal source of direct industrial $CO_2$ emissions is from limestone. Table for the U.S. only:

| **Source** (U.S.) | **mmt C (93)** | **%** |
|---|---|---|
| Clinker[14] Production | 9.09 | 53 |
| Masonry Cement | 0.02 | 0.1 |
| TOTAL CEMENT MANUFACTURE | **9.11** | **53** |
| Lime Manufacture | 3.63 | 21 |
| Flue Gas Desulfurization | 0.51 | 3 |
| Iron Smelting | 0.31 | 2 |
| Steel making | 0.13 | 0.8 |
| Glass Manufacture | 0.05 | 0.3 |
| TOTAL LIMESTONE CONSUMPTION | **4.63** | **27** |
| Dolomite Consumption | **0.07** | 0.4 |
| Soda Ash Manufacture | **0.91** | 5 |
| Glass Manufacture | 0.35 | 2 |
| Flue Gas Desulfurization | 0.02 | 0.1 |
| Sodium Silicate | 0.06 | 0.3 |
| Sodium Tripolyphosphate | 0.03 | 0.2 |
| TOTAL SODA ASH CONSUMPTION | **0.46** | 2.7 |
| $CO_2$ Manufacture | **0.26** | 1.5 |
| Aluminum Production | **1.86** | 11 |
| **TOTAL** | **17.31** | 100 |

----> therefore, in the U.S., 90% of industrial $CO_2$ emissions are from 5 sources:
Cement production 53%
Lime production 21%

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[14]Clinker is powdered cement produced by heating a properly proportioned mixture of firmly ground $CaCO_3$, silica, alumina, and iron oxide at around 2700 F.

Aluminum Prod. 11%
Steel & Iron Prod. 3%
Glass Production 2%
[EIA's 1995 report on "Emissions of GHGs in the U.S., 1994";
available at www.eia.doe.gov/oiaf/95report/chap2.html]

•. **Cement production**
- Produces about 2% of the world's $CO_2$ emissions. [IUCC, WWW]
- The production of lime (CaO) for cement is produced by heating $CaCO_3$ in kilns:

$$CaCO_3 + \text{heat} \text{ ---> } CaO + CO_2$$

Portland cement contains 60 to 67% lime by weight. [IUCC, WWW]
- About 1.25 tons of $CO_2$ are released per ton of concrete produced, 60% of it due to the energy to produce the concrete, and 40% in direct release from the calcination process. [Cited in Doug Fox's paper for USAEP: "GCC: Potential Opportunities for the USAEP", June 1998.]
•. "The production of one metric ton of cement releases 0.136 metric tones of carbon as $CO_2$ [due to energy consumption, presumably]. This figure does not include the production of $CO_2$ during combustion when calcining limestone."
["A Strategic Approach to Environmental Protection", January 1994, USAID/India]

*LIMESTONE AND DOLOMITE PRODUCTION*
• **Lime Manufacture** (from limestone and dolomite consumption). The most important industrial process source of $CO_2$ after cement production. [Energy Information Administration web site[15]]
• **Flue Gas Desulfurization** - limestone is used to remove $SO_2(g)$ by creating solid $CaSO_4$:

$$CaCO_3 + SO_2 \text{ ---> } CaCO_3 + CO_2 \; [ + 1/2\ O_2 \text{ ---> } CaSO_4(s)]$$

Note that trucking in the limestone also expends a great deal of energy. [Ref 5]
• **Glass Manufacture** - uses soda ash
• **Iron Smelting** - limestone and/or dolomite are used as an impurity-removing flux in iron smelting. [Ref 5]
• **Steel making**- $CO_2$ is released from the coking ovens. (Coke is the solid carbonaceous residue obtained from bituminous coal after removal of volatile material by destructive distillation--Amer. Her. Dict.)

• **Soda Ash Manufacture** - Most is made by calcination of trona ore (naturally occurring sodium sesquicarbonate). For every mole of soda ash produced, one mole of $CO_2$ is released to the atmosphere. (The other process to produce soda ash is to carbonate brines, and all $CO_2$ produces is captured and reused.) Soda ash is used in the production of glass, chemicals, pulp and paper, and soap and detergent; and for water treatment and flue gas desulfurization. Sodium silicate and sodium tripolyphosphate (listed in table above) are components of detergent. Soda ash is crude anhydrous $CaCO_3$. [Ref 5]

•. **Aluminum Production** - $Al_2O_3$ is exposed to an anode of carbon, forming aluminum metal and $CO_2$. [Ref 5] The aluminum industry is working on an inert (non-consumable) anode to replace the carbon one , eliminating $CO_2$ emissions from the process; however the technology is probably about 10 years away. [Aluminum Industry Technology Roadmap, May 1997:

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[15]1995 report on U.S. GHG emissions from 1987-1994. On the EIA web site:
www.eia.doe.gov/oiaf/1605/95report/chap2.html

www.oit.doe.gov/IOF/aluminum/aluminum_roadmap.html; Inert Anode Roadmap, Feb 1998: syssrv9v1.nrel.gov/aluminum/inertmap.htm]

•. **$CO_2$ Manufacture** - $CO_2$ has many uses, "including food processing, beverage manufacturing, chemical processing, crude oil products, and a host of industrial and miscellaneous applications. For the most part, the $CO_2$ used in these applications will eventually be released into the atmosphere."
[EPA inventory of U.S. GHGs: www.epa.gov/.../inventory/co2.html]

•. **Chemical Manufacturing** -
~ Ammonia: Ammonia production from natural gas results in emissions of $CO_2$, $NO_x$, $SO_2$ and CO. "Depending on the $CO_2$ requirements of other production facilities on the site", some high purity CO2 byproduct can be used, while air-$CO_2$ mixtures are vented. ["Production of Ammonia", a March 1995 booklet produced by the European Fertilizer Manufacturers Association; www.efma.org/publications/bat01/section06.asp]

• The chemical industry is highly energy intensive. In 1994 in the U.S., all industries combined accounted for 37% of energy use, while chemicals accounted for 7% (or almost 19% of all industries combined). Organic chemicals are 90% of the chemical industry's output. "Transforming these inputs [organic chemicals] into chemical products often requires repeated heating and cooling cycles that use large quantities of energy." Half of the energy goes for feedstocks, that is, the energy required to transform the feedstock into chemical products. The other half of the energy goes into operating the chemical plants: 92% of the energy goes into production processes such as firing boilers, heating reactors, driving electrolysis, powering motors, and generating steam; the remaining 8% is used for non-production overhead such as lighting and ventilation.

## LAND USE CHANGE/SINKS

• **Deforestation** is defined as the conversion of land from forest to other uses, and carbon released in this process will not be replaced. **Land Use Change** is typically the conversion of forest land to cropland or pasture. [WRI, 96/97; WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• Fossil fuel use accounts for 70% of the carbon accumulation in the past 150 years, and land use change the other 30%. "Roughly one-third of all carbon emissions from land use change over the past 150 years have come from the soil." [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• "**Developing countries** have contributed roughly 77% of the atmospheric buildup of $CO_2$ attributable to carbon emissions from changes in land use over the period from 1850 to 1990", and "each unit of deforestation in developing countries tends to make a greater contribution to the atmospheric buildup of $CO_2$ because tropical forest vegetation stores more carbon". "For many developing countries, halting their current deforestation and restoring degraded forest and soil resources constitute the biggest steps they can take." [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• A NOAA study concluded that forests and soils of **North America**, especially those below the 51st parallel, are absorbing as much or more carbon than the U.S. was emitting from burning fossil fuel. North American forests and soils are sucking up 1.7 billion metric tons of carbon dioxide (measured as carbon) annually—the entire so-called missing sink—while the rest of the world is taking up very little carbon dioxide. However, groups in France and Australia, from research unpublished as of Aug 1999, say that U.S. vegetation is taking up much less $CO_2$ than the NOAA study found. ["Case Grows for Climate Change", *Chemical & Engineering News*, 9 Aug 1999; citing *Science 282*, 442 (1998), a paper by NOAA's Geophysical Fluid Dynamics Lab.]

• "**Forest soils and vegetation store 20 to 50 times more carbon per unit area than land use for agricultural purposes.** Nearly all of the carbon stored in forest vegetation and 20%-50% of the carbon stored in forest soils is eventually released to the atmosphere after forest land is converted to other uses." "Carbon in soils is released gradually, with the amount released depending on the type of soil and how intensively it is used." [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• "It's entirely possible every bit of carbon that goes into these systems [forests, plantations, and soils] now will come right out" as temperatures rise. So to use sinks, "you have to account for sink carbon forever, so if it comes out of forests or soils, countries [should be] penalized for that". ["Case Grows for Climate Change", *Chemical & Engineering News*, 9 Aug 1999; quoting Kevin R. Gurney, an atmospheric scientist at Colorado State U. who served as an expert at Kyoto.]

• "**China** has had low or even declining carbon emissions from land use change in recent years as a result of intensive afforestation and forest management programs." Land use on China has therefore "only contributed about 5 gigatons of carbon to the carbon added to the atmosphere between 1850 and 1990". [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• "Between 1850 and 1990, Latin America and tropical Asia each contributed roughly 14 Gtons to the atmospheric buildup of $CO_2$, or together approximately 60% of the total stock contribution from land use change during that period." [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• "In the central scenario offered by the IPPC, 73% of all tropical forests are cleared by 2100, and much of the forested area in Africa and SE Asia is converted to other uses by 2050." [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• Restoration of soils in degraded agricultural land in developing countries would increase agricultural productivity while building soil carbon stocks. [WRI Climate Note Oct 98: "Contributions to CC: are conventional metrics misleading the debate?"]

• "Forestation of 100,000 hectare would absorb an estimated 500,000 to 600,000 tons of carbon dioxide per year, equivalent to 6-% of the total release of Japan's paper industry in fiscal 1997." [*Nihon Keizai Shimbun*, 11/25/98

• **Biomass Burning**
- Gives off $CO_2$, CO, $CH_4$, HC's, NO and $NO_2$ (---> $O_3$). [Sources: *New Scientist*, 18 May 1996, p. 4; good, referenced source on web]

- The burning of biomass, per se, does not necessarily contribute to the $CO_2$ flux. Grasses or trees that grow back after a fire merely recycle the carbon and do not contribute $CO_2$ to long-term GHG heating. [WRI, 96/97]

## *METHANE*

•. **Sources of anthropogenic methane emissions** in 1991 [WRI 96/97, Table 14.2]:
- 30% due to extraction of fossil fuels (coal mining and oil and gas production),
- 30% due to livestock
- 25.6% due to wet rice agriculture* (~90% from Asia; ~50% from China + India)
- 16% due to solid waste

- {#'s add up to more than 100%, but these are values calculated from Table 14.2. In the footnotes (p. 335) they add that biomass burning, especially in the tropics, is a "major anthropogenic source of methane, unaccounted for here".
- *Estimates of global methane production from rice paddies is highly uncertain: IUCC said that wetland rice farming accounts for 17% globally [year not known], and the IPCC (1991) gave an estimate of 20%, or "between 25 and 170 tonnes".}
- Another part of the same source [WRI 96/97, p. 231] says that about *70%* of anthropogenic methane is from agriculture. Perhaps they were including livestock in that figure.

•. **Natural Gas Production, Distribution and Transmission**[2]
- Losses during oil and gas production occur due to drilling, venting, and transmission. Methane emissions from production were estimated at 0.5% of production. Leaks from pipelines accounts for about 2 to 5% of all anthropogenic methane emissions [WRI, 96/97], although newer, well-sealed pipeline systems can have leakage rates of <0.1% [IUCC, web data 5/1/93]. Losses through leakage during distribution are no more than 1% in the U.S. (WRI, 96/97, p. 334), but according to a 11/19/96 cable of FBIS translated text: "According to several Russian and foreign sources, gas escapes from extraction to consumption are estimated at between 10 and 30% [in Russia]." Venting accounts for about one-quarter of the amount flared.
- Natural gas is 85-95% $CH_4$ [IUCC, last updated 5/1/93].

•. **Coal Mining:** Some coalbeds contain significant quantities of $CH_4$. It can be collected before, during or after mining and used on-site or locally, or sold to a pipeline.[2]

+ contains methane, both in pockets ( in seams and tiny pockets) and adsorbed to the coal on a molecular level through pressure and chemical attraction. Crushing releases the methane in the tiny pockets, while it can take days or even months for the adsorbed methane to escape from mined coal.

+ In general, lower quality coals such as "brown coal or lignite have lower methane contents than higher quality coals such as bituminous and anthracite coal.

+ Surface-mined coal releases on average just 10% as much as methane per unit mined as does coal removed from underground mines, since coal under pressure contains more methane.

+ China, the former Soviet Union and the U.S. produce 2/3 of the world's methane emissions from coal.

•. **Livestock Manure:** Anaerobic decomposition of animal manure accounted for 10% of U.S. anthropogenic methane emissions in 1990. Livestock producers and energy utilities can work together to cover animal waste lagoons and collect the methane for electricity generation or on-

farm fuel (using for example a conventional methane digester system). "Animal wastes from anaerobic waste management systems are likely to yield on the order of 15 million tonnes globally." [IPCC, 1991: "Climate Change: The IPCC Response Strategies", 77-84, Washington, D.C., Island Press]

•. **Enteric Fermentation in Ruminant Livestock:** Methane is produced in the rumen by methanogenic bacteria. How much methane is emitted depends on the type of carbohydrates in the diet, level of feed intake, digestion passage rate, presence of ionophores or lipids in the diet, and ambient temperature. [A Gov't of Alberta web site.] "Total methane emissions from domestic ruminant animals have been estimated to be between 65 and 100 million tonnes per year." [IPCC, 1991: "Climate Change: The IPCC Response Strategies", 77-84, Washington, D.C., Island Press]

•. **Municipal Solid Waste:**
- Since methane released from a landfill is due to anaerobic decomposition of organic matter in the landfill, the amount of methane released is proportional to the amount of degradable organic carbon content of the waste.
- "Total global methane emissions from waste disposals and from wastewater lagoons are estimated to be 20-70 million tonnes per year, or an average of 8% of total anthropogenic methane emissions." ("Anaerobic conditions exist. . . in most lagoons used for treating organic-loaded wastewater.") [IPCC, 1991: "Climate Change: The IPCC Response Strategies", 77-84, Washington, D.C., Island Press]
- In the U.S. landfills are the largest anthropogenic source of methane, accounting for 36% of the total anthropogenic methane emissions.[16]

•. **Microbial Decay of Plant Matter** $+ H_2O \text{ ---> } CO_2 + CH_4$ + (other products)
Although $CO_2$ is also released by anaerobically decaying plant matter, the carbon came from plant matter "sustainable produced" and therefore does count toward net $CO_2$ emissions. [IUCC (Information Unit on Climate Change), UNEP]

[16]Web site of DOE's Energy Efficiency and Renewable Energy Office, EREN (http://www/eren.doe.gov/partnering/epse/cc_option3.html ), "Climate Change Option Workbook"

## NITROUS OXIDE ($N_2O$)

•. $N_2O$ accounts for about 6% of the greenhouse effect; it has about 320 times greater ability to absorb IR than $CO_2$; and it has at atmospheric life of at least 120 years. Another source: $N_2O$ contributes ~8% of what $CO_2$ contributes to the greenhouse effect. *Environmental Protection* June 1998: "An EPA report last year estimates about 7.2% of GHGs contributing to global warming is nitrous oxide. Half of that is created by vehicle emissions." [Doesn't say if these figures are for the U.S. or global.]

•. **Fertilizers**: tilling of soil to which nitrogen-containing fertilizers had been added releases $N_2O$ due to microbial oxidation of nitrate. Compounded by over-use of fertilizers. Accounts for about 90% of anthropogenic $N_2O$ world-wide [ M.K. Hill, p. 131; WRI 96/97, p. 232]. In the U.S. (1995), agriculture accounted for 46% of $N_2O$ (although that was higher than usual due to high fertilization rates following the 1993 floods) [EPA web site]. Natural sources of nitrous oxide are $N_2O$-producing bacteria in the ocean and soils.

•. **Internal Combustion Engines**:
- $N_2O$ is produced in cars and other sources from the reaction of $N_2$ and $O_2$ at the high temperatures of combustion (>2500 F). This problem can be mitigated with an Exhaust Gas Recirculation (EGR) valve which recirculates some of the exhaust gas back through the intake manifold to the cylinder, lowering the combustion temperature. The configuration of an exhaust system is: exhaust manifold/catalytic converter/muffler/tailpipe.
[Source: www.advancedmechanics.com/exh.htm]
- In the U.S. in 1995, total fossil fuel combustion accounted for 31.4% of all $N_2O$ emissions, with mobile sources accounting for 75% of that (or 23% of total $N_2O$ emissions). [EPA web site]

•. **Automobile Catalytic Converters** convert nitrogen oxide emissions into nitrous oxide [EPA web site]. However, there is apparently another type of catalytic converter that *removes* $N_2O$: a 3-way dualbed catalytic converter consisting of a stainless steel container lined with aluminum oxide, Pt, Pd, rhodium and other chemicals which react with CO, HCs and nitrous oxide to create water and $CO_2$ [and what from the $N_2O$?). [Source: www.advancedmechanics .com/exh.htm] {Note that I have never seen any other reference to a catalytic converter that avoids N2O.}

•. **Nylon production** - through its precursor adipic acid. Adipic acid production accounted for 13% of all U.S. $N_2O$ emissions in 1995, but supposedly by 1996 $N_2O$ controls were to have been installed in all adipic acid plants, reducing $N_2O$ emissions by 98%.

•. **Nitric Acid production**: mostly to make synthetic commercial fertilizer; also for adipic acid and explosives. From oxidation of ammonia to form nitric acid, giving off $N_2O$ [EPA site on $N_2O$].

•. NOTE: WRI (96/97) also cites biomass burning (fuelwood and cleared forests), but other good sources, including M.K. Hill and Levine (off the web) do not include $N_2O$ as a byproduct of biomass burning. I think WRI is confusing $N_2O$ with $NO_x$, which are released by biomass burning.]

•. NOTE: **$NO_x$** ($NO$ and $NO_2$) are **not** GHG's, although they can affect the chemistry.
•. Coal burning [check also other ff's; EIA web site on N2O]

## HALOCARBONS and $SF_6$

***See also chapter 5 of "Emissions of GHGs in the United States 1996", October 1997, EIA (at www.eia.doe.gov/oiaf/1605/gg97rpt/chapt5.html; and in my "Sources of GHGs" file)***

• EPA web site: www.epa.gov/globalwarming/inventory/xfcs-sf6.html
• May account for as much as 20% of the greenhouse effect, although a 1992 study concluded that their warming effect may be cancelled out by the cooling they cause as they destroy stratospheric ozone. [M.K. Hill, pp. 125 and 131]

• **Hydroflurocarbons**
- Substitutes for CFCs and HCFCs, and are also formed as by-products of other processes.
- In the U.S. since 1993, HFC emissions are mostly the result of HFC-134a in mobile air conditioners.
- An Arthur D. Little, Inc. study, done for the Alliance for Responsible Atmospheric Policy, "analyzed the advantages and disadvantages of using HFCs—which are greenhouse gases—as coolants in refrigerators and air conditioners and as foam blowing agents, compared with simple hydrocarbons". (U.S. firms exclusively use HFCs, while some European and Asian firms have switched to HCs.) "The report concludes that using HFCs rather than alternatives would save the world economy $35 billion annually in the period 2020 to 2030. . . . HFCs will have a negligible impact on the environment because they are projected to account for less than 2% of greenhouse gas emissions in 2030." {But...is this because the HCs get converted into CO2? When they say less than 2% of emissions, do they mean in terms of tons or molecules, or in terms of climate forcing? Need to check credentials of the Alliance.} [*C&EN*, 4 Oct 99]
- See table below for more info on HFCs.
[EPA web site: www.epa.gov/globalwarming/inventory/xfcs-sf6.html].

• **Pefluorocarbons**
- have extremely long lifetimes due to their low reactivities, and are strong absorbers of IR radiation.
- They have 2 main uses, in the semiconductor industry for plasma etching ("dry etching") on silicon chips, and in aluminum production. In plasma processing, PFCs such as tetrafluoromethane ($CF_4$) and hexafluoroethane ($C_2F_6$) are activated (in the form of gases) in a plasma to produce fluorine radicals that react to volatize silicon by forming $SiF_4$.
- PFCs are also produced in small quantities by primary aluminum production during the reduction process.
[Sources: www.api.org/...ge3bizvoluntary.htm; inert anode roadmap (Al production) and www.cchem.berkeley.edu/~amsgrp/index.html (plasma processing)]

•. **Sulfur Hexafluoride ($SF_6$)**
-The strongest GHG identified by the IPCC, with a global warming potential 24,000 times greater than $CO_2$.
- Lifetime = 3200 years.
- World-wide, ~80% is used as an insulating material for high-voltage equipment such as circuit breakers for electrical transmissions and distribution. It is also used as a protective atmosphere when casting molten magnesium to keep the Mg from oxidizing in air.
[http://cgi.pathfind.... on Japan electronics; www.epa.gov/globalwarming/inventory/xfcs-sf6.html]

## *ENERGY*

### ENERGY STATISTICS AND GENERAL INFORMATION

• In 1996, the total world production of electricity amounted to 13,720 TWh (4,942 TWh of it in non-OECD countries). [GEF proposal, project #502486, author unknown; received for review April 1999.]

• *The Seven Most Energy- and Waste-Intensive Industries are:*
- Primary Aluminum Production
- Chemical Production
- Pulp and Paper
- Glass Production
- Metal casting
- Steel Production
- Petroleum Refining

• **Globally**, energy consumption accounted for the following amounts of $CO_2$ emissions in 1990. [IPPC, 1995: www.unfccc.de/fccc/science/sumwg2.htm]:

| | |
|---|---|
| Industry: | 45% |
| Residential/Commercial: | 29% |
| Transportation: | 21% |

• In the U.S. from 1949 to 1998, energy use by the average American *grew 62%*, while the amount of energy required to produce a dollar's worth of goods and services *fell by 42%* in the same period. [Annual Energy Review by the Energy Information Administration: http://www.eia.doe.gov/emeu/aer/eh1998/eh1998.html]

• 36% of U.S. energy is consumed by the generation of electricity. By 2010, that will rise to 41%. [unknown web source]

• In the area served by Virginia Power, it takes an average of one megawatt to power 250 homes. [*Wash. Post*, 10 Oct 1999]

• In **industry** *globally*, 36% of the energy used goes for generating electricity, while in *developing* countries about 43% of industry's energy usage goes for generating electricity. (This presumably reflects less efficient energy generation in developing countries. Note however, that the developing country figure is good only to one significant figure.) [IPCC 1995; cited in Doug Fox's paper for USAEP: "GCC: Potential Opportunities for the USAEP", June 1998]

• In the U.S. energy use in residential buildings is broken down as:

| | |
|---|---|
| Space heating | 36.1% |
| Water Heating | 13.9% |
| Other Uses | 13.0% |
| Refrigerators and Freezers | 9.5% |
| Space Cooling | 8.5% |
| Lighting | 5.7% |

| | |
|---|---|
| Washers and Dryers | 3.9% |
| Color TVs | 3.4% |
| Cooking | 3.2% |
| Furnace Fans | 2.0% |
| Dishwashers | 0.8% |

[Tamara Nameroff's 11/98 presentation, citing EIA 1997]

• In the U.S., land use planning and urban design affect about 56% of the nation's total energy use! [Tamara Nameroff's 11/98 presentation, citing Anderson et al, 1993]

•. Energy in developing countries is often heavily subsidized, costing consumers an average of 4 cents per kW-h for electricity, compared with a cost of 10 cents/kW-h to produce it. [*The Economist*, "A Survey of Development and the Environment", March 21, 1998, p. 8]

•. Global energy consumption will grow by about 50% in the next 20 years. [A conclusion from the 17th Congress of the World Energy Council, 1998]

•. 72% of all energy generated is used by end users, with the remaining 28% consumed by energy conversion and distribution. Among end users, three sectors account for 95% of all energy use: industry 45%, buildings 29%, and transportation 21%. [IPPC; cited in Doug Fox's paper for USAEP: "GCC: Potential Opportunities for the USAEP", June 1998.]

• "Nuclear power provides about 34% of Europe's energy requirements." In the U.K., "all existing British nuclear stations except the newest...will have retired by 2020." Nuclear power "would then be contributing less than 3% of the UK power total." [Reuters, 11/19/98]

• "The International Energy Agency (IEA) said world oil production from conventional sources could peak during the period 2010 to 2020, but said there would be no shortage of liquid fuels since reserves of unconventional oil are large. 'The oil-importing countries' dependence on supplies from the Middle East will increase until liquid fuels from unconventional sources—shale oil, tar sands, conversions from coal, biomass, gas—begin to play an important role as 2020 approaches,' IEA said." [Reuters, 12/4/98]

**ENERGY STATISTICS: ASIA**

• "If the Chinese were to consume oil at the American rate, the country would need 80 million barrels of oil per day—more than the entire world's production of 67 million barrels a day". [Lester Brown, *WorldWatch 12*(2): 14 (1999); Mar/Apr]

• In the absence of new policies, the carbon output from developing countries is projected to exceed that of developed countries as early as 2020, "with China eclipsing the U.S. as the world's leading emitter by 2015". [US DOE, cited by Seth Dunn, "Can the North and South Get in Step", *World Watch* Vol. 11, No. 6 (1998), p. 23]

•. COMPARISON with the US: In terms of energy consumption, the U.S. consumes 33 times as much energy per person as India, 13 times as much as China, and 2 1/2 times as much as Japan. [DOE; year for the data not given, but it was taken from a 2/98 web site]

• Among **ASEAN** countries, industry and transportation each account for about one-third of energy consumption. [cited in Doug Fox's "GCC: Potential Opportunities for USAEP", 6/98]

• "Prior to the current crisis, energy demand in Asia was doubling every 12 years and demand for electricity was growing two or three times faster than GDP." [Paper by D.P. Angel, T. Ferudhanusetyawan, and M. Rock]

## ENERGY EFFICIENCY

• "Powerful Partnerships: A Synthesis of a Report by the President's Committee of Advisors on Science and Technology" says that: "In the next two decades, over half of global energy growth will be in the developing and transition economies as those nations improve their standard of living. . .Vigorous deployment of energy efficiency technologies would mean the difference between doubling and quadrupling world energy supply by 2100—a quantity of energy equal to the current oil output of nearly 50 Saudi Arabias."
[http://www.whitehouse.gov/WH/EOP/OSTP/html/p2epage.html]

## RENEWABLE ENERGY

**NOTE:** Only *waste* biomass is considered a renewable energy source here. See Power Generation below for other discussion of biomass derived from non-waste agricultural or forest sources.

***General***

• According to Daphne Wysham, lead author of the Sustainable Energy and Economy Network (SEEN) report on "the World Bank's compromised role in mitigation of the climate change treaty": "The World Bank's own reports conclude that renewable energy projects are the most effective means of meeting the needs of those without power." "The World Bank...is the largest multilateral financier of climate-changing fossil fuels in developing countries". "The Bank currently lends 25 times as much money for fossil-fuel energy projects as it does for renewables." The report was produced by SEEN (U.S.) and the International Trade Information Service (U.S.), and is available at http://www.seen.org/wbstill/index.html. [ENN, 12/2/98]

**RENEWABLE ENERGY IN THE U.S.**

[www.eia.doe.gov/cneaf/solar.renewables/renewable.energy.annual/rea97/contents.html]

• Renewable energy contributed 7.9% to U.S. energy consumption in 1996, but if conventional hydropower is not included, the amount is only 3.7% (geothermal, biomass, solar and wind).

• Biomass is by far the greatest of the non-hydropower renewables, accounting for 87%. (Biomass includes wood, wood waste, wood sludge, peat, municipal solid waste, agricultural waste, straw, tires, landfill gases and fish oils.)

• Renewable energy consumption by sector:

- 52.5% of renewables were used by electric utilities (mostly geothermal; almost none from solar or wind);
- 36.9% by industry (mostly biomass);
- 9.6% by residential/commercial (mostly biomass, using wood for space heating);
- 1.0% by transportation (all in the form of ethanol mixed with gasoline).

•. In terms of **electricity production**:

- Industry production from solar and wind increased 10% from 1995 to 1996.
- Electricity generated from renewables by **industry** breaks down as: 66% from biomass, 18% from hydroelectric, 12% from geothermal, and 3.7% each from solar & wind.
- 98% of renewable electricity generated by the **utility sector** is from hydropower

• California, due to a combination of favorable policies and abundant resources, leads the nation in the use of renewables. In 1995 California accounted for 16% of the nation's utility energy from renewables, and 25% of the nation's non-utility renewable electricity.

• 75% of New Zealand's electricity is "renewable", coming from hydro and geothermal. [Evening Standard (New Zealand), 3 Feb 1998]

**RENEWABLE ENERGY IN DEVELOPING ASIA**

• Recent renewable energy installations in **China** include 20 wind farms, 7000 small hydro stations and a dozen tidal energy power plants. [Green Energy News 10/30/99, vol 4, #30]

• With a wind power capacity of 1025 MW, **India** now ranks fourth in the world. Its PV installations consist of 600,000 systems with a total capacity of 39 MW. [July 1999 REPSO newsletter.] *Compared with:* "Within the Indian PV program, more than 50,000 systems have been installed across the country, with a total capacity of 35 MW, with a further 4MW in exports. More than 80 Indian companies are engaged in the PV industry, and production of cells was 8.2 MW and modules 11 MW during 1997-8." [*Renewable Energy World*, March 1999]

• Solar: The U.S., Japan, and **India** are the world's first, second and third largest producers of solar cells and modules in the world. [*Renewable Energy World*, March 1999]

• The Municipal Solar Infrastructure Project in the **Philippines**, using PV technology from BP Solar, aims to design, supply, and install 1,003 solar-powered electricity generators in more than 400 villages in Mindanao and the Visayas in the southern Philippines. Public funding covers the local installment and initial administrative costs of implementation, while the technology is kept up to date by the investor. [Tim Forsyth, *Environment* Vol 40, #9, Nov 1998]

**SOLAR**

• ***Solar PV:*** can be up to mutli-MW facilities

~ *Advantages:* The technical advantages of solar PV devices include no-cost fuel; no emissions; applicability to a wide range of applications; low maintenance requirements; and portability to other sites. In terms of developing countries, it offers the opportunity for local input in assembling the solar modules and support structures, and employment in operations and maintenace.

~ *Disadvantages* are cost (depending on the situation), the diurnal and, in some locations, intermittent nature of solar power, and the need for devices to store electricity for times when the sun is not shining.

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov

1996: www.nautilus.org/esena/papers/dvhtech.html]

• "In terms of **lifetime average costs**, delivered per kWh costs from conventional courses amount to between 5 and 14 cents, while those from PV range between 30 to 38 cents in high insolation areas (2000 to 2500 kWh/$m^2$/year). In addition, solar energy is available only during (sunny) daylight periods, and in variable amounts. If short-term storage has to be added to the PV system to meet system peak load demand, the cost for PV increases to between 42 to 55 cents per $kWh^2$." However, "recent projections indicate that PV systems may fall within the next few years to around $3,000/kW or less. This would reduce per kWh costs in high insolation areas to between 15 to 18 cents, excluding supplemental storage. This would bring PV within striking distance of the 14 to 25 cent costs for delivered, flat to spiky peak power supplies" which "a significant number of countries and regions" in the developing world pay for peak load power. (Note that it is difficult to estimate average costs per kWh for PV "because of the long life expectancy of PV plants and their very low operating and maintenance costs". [GEF proposal, project #502486, author unknown; received for review April 1999.]

• The "average factory price for solar panel (photovoltaic) modules" was $70/W in 1975 and $4/W in 1997. [*Worldwatch 12*: 23 (1999), citing *Vital Signs 199*8, 1998.]

• The global market for solar power under a business as usual growth of 20% per year is expected to be worth about $10 billion by 2010.

**WIND**

• "Global wind generating capacity now stands at 9,600 MW—a 26% increase from a year earlier. "...it now provides less than 1% of the world's electricity."

- "Some 70% of the global wind power market in recent years has been centered in just three countries, Germany, Spain, and Denmark."
- U.S.: 230 MW were added in 1998
- Denmark's total wind capacity is 1350 MW. "Wind now generates over 8% of the country's power."
- Spain's total wind capacity is 850 MW
- India, which has a larger wind power industry than any other developing country, has over 900 MW installed.

[Christopher Flavin, *Worldwatch 12*(2): 24-27 (1999); Mar/Apr]

Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html:

• **Size:** Wind turbines range in size from fractions of a kW to hundreds of kWs.
• **Advantages:** no cost energy source, relatively low maintenance requirements, potential for using the land for other purposes (such as agriculture or grazing), very low environmental impact.
• **Disadvantages:** mostly the intermittent nature of wind the need for either energy storage or a back-up power supply; also, wind resources can be difficult to assess.

• "A typical wind turbine today produces 700 kW of electricity, costs $700,000 (including installation), and provides enough power annually for 200 homes. State-of-the-art wind turbines are highly automated and reliable; their downtime for maintenance, of less than 5%, is less than for fossil fuel plants, and maintenance costs are minimal." In terms of land use, "farmers can either

install their own wind turbines or lease the land to wind companies. The bulk of the land can still be used for grazing animals or raising crops. [Christopher Flavin, *Worldwatch 12*(2): 24-27 (1999); Mar/Apr]

• A 850-watt wind generating system costs about $2,000, and a 10-kW system is $16,000 and up. [ABC News, 1998]

• "Global average price for wind power" was $2,600 per kW in 1981, and $800 per kW in 1998. [*Worldwatch 12*: 23 (1999), citing *Vital Signs 199*8, 1998.] "In many areas, wind power is already less expensive than electricity from coal-fired power plants." [Christopher Flavin, *Worldwatch 12*(2): 24-27 (1999); Mar/Apr]

• "Wind power could provide 10% of western Europe's energy needs over the next decade as technology develops and costs fall," according to Christophe Bourillon, head of the European Wind Energy Association. "Installed capacity in the EU is now already 6,000 MW and is expected to reach 8,000 MW by the turn of the century." "Denmark is now generating 8% of its electricity from wind, and was aiming to raise this to 50% by 2030." "Bourillon said deregulation of the electricity industry in Europe provided wind energy with a 'great opportunity, provided we are all at the starting blocks at the same time'."

• Danish CO2 emissions have been reduced by 2.8% [since last year?], mostly due to newly installed wind power. 9% of Denmark" electricity was supplied by wind in 1998, displacing some coal-generated electricity. [*Green Energy News* 10/2/99, Vol. 4, #26]

**HYDROPOWER**

• "The **disadvantages** of hydropower plants include relatively high capital costs, long lead times for design and construction, potential disruption of water resources, potential fluctuations in output from year to year and season to season due to variations in river flow, and potentially large use of land." The **advantages** include a "free" resource [unless land is consumed by a dam], low operating costs, lack of emissions, the long life of hyrdo installations, and the extensive use of local materials in the construction of hydro impoundments (dams).
Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html.

• "**Microhydro**" is described [in this paper] as on the order of kilowatts, while "**minihydro**" is on the order of hundreds of kilowatts. Hydropower plants can be many gigawatts.
[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html.]

**BIOMASS from Waste**

• Biomass integrated gasifier/gas turbine combined cycle systems "can have efficiencies of 33% to over 40%". They "have relatively low capital costs, and provide baseload capacity in unit sizes less than 100 MW". [Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html.]

## TECHNOLOGIES Which REDUCE GHG EMISSIONS
(other than Renewables—see above)

### INDUSTRIAL SECTOR

• ***The Seven Most Energy- and Waste-Intensive Industries are:***
- Primary Aluminum Production
- Chemical Production
- Pulp and Paper
- Glass Production
- Metal casting
- Steel Production
- Petroleum Refining

[DOE's Office of Industrial Technology web site]

• "The most significant technological opportunities to reduce emissions from the direct use of fossil fuels in the industrial sector are in the area of **cogeneration** and local or **district heating**. The challenge here is more one of coordinated planning among adjacent industrial plants and municipalities, large shopping areas, and other public facilities. The district heating approach, i.e. utilizing exhaust steam from a turbine drive for heating purposes, can increase the energy utilization efficiency of that system by 50%." [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

• "**More than 80% of the energy savings available to U.S. industry comes from electric motor systems improvements**. Lighting and process improvements contribute slightly less than 10%. More than 33% of the energy savings available from motor systems improvements comes from the application of adjustable speed drives, with another 25% coming from drive train, electricity supply, and maintenance practices. Another 17% of electricity savings available from motors is estimated to come from installing more efficient motors. ...**Electric motors...consume 70% of all energy in a typical manufacturing facility**. These costs could be cut nearly in half with efficient motor systems." [The Energy Foundation web site, 1996: www.ef.org/reports/I/intro.html]

• **GENERAL** energy efficiency options:
- Heat recovery, waste minimization, material reuse/recycling
- High efficiency motors and variable speed drives; efficient lighting (bulbs, reflectors, ballasts)
- High efficiency air conditioning equipment and compressors
- Improved boilers (see section on Boilers below) and expanded use of cogen
- Modification to reduce friction in piping, valves and conveyance systems
- Harder, longer-lasting materials in cutting and grinding applications
- Computerized process optimization, control, energy management, and environmental management systems (that is, pollution emissions sensing and control).

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• **Cement** industry efficiency options:
- using waste heat to dry materials;
- differential grinding of limestone and clay;

- fluidized-bed drying with low-grade fuels;
- kiln combustion system improvements and modifications to reduce heat loss;
- the use of waste heat from product coolers;
- the use of fluidized bed kilns and all-electric or hybrid kilns;
- blending cement to reduce the energy required for production; and
- modified produce grinding equipment, including better control of particle size.

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

- The use of fly ash and furnace slags in cement manufacturing reduces CO2 emissions from lime.

[From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

• **Iron and Steel** energy saving measures include:

- The use of basic oxygen furnaces instead of open-hearth furnaces can save 1 to 3 GJ per tonne of steel, a savings of about 5% to 15% using current OECD practices;
- increased use of scrap steel;
- the use of power recovery turbines on blast furnaces;
- the use of continuous casting of steel products (as opposed to ingot casting, in which steel ingots must be re-melted to produce products in their final form)[17]; and
- rolling steel before it has cooled.

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• **Chemicals** manufacturing industries can reduce energy consumption by:

- using improved catalysts;
- improving distillation equipment;
- improving gas turbine efficiency;
- expanding process integration to conserve heat generated during reactions;
- insulating product pipelines to reduce heat losses; and
- using membrane technologies to separate reactants.

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• In the **refining** industry, energy efficiency option include:

- pre-heating of crude oil feedstocks;
- using reflux-overhead vapor compression; use of mechanical vacuum pumps; integrating heat use between distillation units; and
- improved catalysts.

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• **Pulp and Paper** efficiency option:

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[17] Continuous casting "dramatically improves the value of the product" as well as saving energy.

- continuous pulp digesters;
- alternative chemical and chemi-mechanical pulping processes;
- alcohol-based solvent pulping;
- oxygen or ozone bleaching and delignification;
- chemical recovery, including freeze concentration or gasification of black liquor;
- wet-pressing of paper products; and
- high-consistency forming, impulse drying, and microwave drying.

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• **Semiconductor** manufacturing: see excellent paper "Design for Energy Efficiency Adds Value to Semiconductor Company Shareholders", in Semiconductor Fabtech, 10th Edition: New Technological Developments in Semiconductor Manufacturing, IGC Publishing. (Date unknown, probably 1998)

## WASTE TO ENERGY, WASTE TO PRODUCTS AND REUSE/RECYCLING

**Incineration[18] of Industrial Waste** to destroy hazardous waste. Incineration produces $CO_2$, but overall, incineration should save energy for two reasons: 1) most incinerators are set up to recover energy to generate steam and electricity, and 2) the greatly reduced weight and volume of the waste saves in energy for transporting and/or treating the waste. The savings in energy for transportation are particularly good if the incinerator is on site.

**Using incineration of wastes to fuel cement production:** Formation of clinker requires flame temperatures of 3500 to 4000 °F, and kiln temperatures of more than 2000 °F for more than five seconds. Thermal destruction of organic compounds requires exposure to temperatures in excess of 2000 °F for two seconds, so hazardous organics are thoroughly destroyed. "Stack samples taken from the [Texas Industries' Midlothian cement] plant during the burning of recycled fuel showed destruction removal efficiency of organic material of 99.9999%--100 times greater than the EPA requirement. The system's removal efficiency of inorganic material is greater than 99% for most metals." [*Environmental Protection*, March 1999, p. 22]

**Waste Heat Recovery**

Illustrative example:

•. A heat-recovery system to capture exhaust steam from the mixing of hot asphalt, reducing energy costs and speeding up the production process.

**Waste-to-Energy Technology or Plant Design**

Illustrative examples:

•. Generation of energy from waste incinerators.

•. Using cement kilns to recover energy from wastes such as used motor oil, dry cleaning solvents, and agricultural wastes.

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[18]Assuming state-of-the-art technology that produces provides proper oxygen and temperature conditions and emission control apparatus. Includes cement kilns.

•. Forming fuel pellets from municipal waste and mixing them with coal
•. Capture of methane from landfills and conversion to electricity, steam or heat

**Technologies that Convert Waste to Products**
Illustrative examples:
•. Producing "plastic" bags from potato processing waste.
•. Compression Molding Systems to convert fibrous wastes (such as wood, paper, straw, rice husks) into furniture and building materials.

**Waste & Material Recycling/Recovery/Re-Use**
• **$SF_6$:** Toshiba is selling a system to recover SF6, an insulating gas in electrical systems which escapes easily from appliances while they are being checked. An oil-free vacuum pump recovers highly pure SF6 for reuse. [Comline Daily News, 6 Feb 1998]

• **Aluminum:** recycling uses 5% of the energy of primary production.

• **Copper:** recycling copper uses only 10% that required to produce it from ore.

• **Steel/Iron:** recycled steel requires almost half the energy of primary production. "In the U.S.,...56& of the steel produced now comes from scrap". Steel mills using scrap use electric arc steel furnaces that "produce steel with much less energy and far less pollution than that produced in the old steel mills from virgin iron ore". [quotes from: Lester Brown, *Worldwatch 12*(2): 17(1999); Mar/Apr]

• **Glass:** there is little energy savings in recycling glass (only 8% over primary production), but recycling glass reduces $CO_2$ emissions relative to primary production since the glass manufacturing process releases $CO_2$ as a byproduct.

• **Plastics:** Recycling plastics takes a mere 3% of the energy of primary plastic production.

• **Rubber/Tires:** Note that it is most advantageous to recycle old tires into clean rubber granules (which can be used to make a variety of products), rather than incinerating tires for energy. Rubber is energy intensive to produce, requiring 55,000 btu/lb, while the granulation of used tires requires only 1,000 btu/lb. Converting one pound of rubber to energy yields only 13,000 btu, so recycling the rubber to other uses is more energy effective on balance than burning it for energy.

• **Paper:** The main GCC argument for recycling paper is that it reduces logging. Beyond that, in terms of greenhouse gas emissions, the case for recycling paper rather than incinerating it is weak.[19]

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[19] A straight comparison of the energy to recycle versus primary production is 77% for newspaper--not a large advantage--and the recycling process itself uses large amounts of energy (especially the de-inking process). Also, transport to recycling mills is typically longer than to incinerators (which are usually located close to the site of waste generation, e.g., near cities), and incinerators are often equipped to generate energy from their operation. Finally, the recycling process produces a toxic sludge that must be either landfilled or taken to an incinerator.

• **Carpeting:** Interface, a leading world carpet manufacturer, has a carpet service where "when the carpet wears out, Interface simply takes it back to one of its plants and recycles it in its entirety into new carpeting. The Interface approach requires no virgin raw material to make carpets, and it leaves nothing for the landfill." [Lester Brown, *Worldwatch 12*(2): 19 (1999); Mar/Apr]

## ENGINES and BOILERS

**Boilers:** "Increasing efficiency and reducing the stack temperature by only a few percent on a 180 million Btu/hour boiler can mean fuel savings of more than $200,000 per year." [*Environmental Protection*, May 1999, p.30]

• "**Boilers** fired with natural gas instead of coal reduce $CO_2$ emissions by ~50% per unit of energy output. Further, using natural gas in a boiler that will ultimately generate electricity reduces $CO_2$ emissions by 65% per unit of electricity produced."
["A Strategic Approach to Environmental Protection", January 1994, USAID/India]

• **Boiler and furnace** improvements to increase efficiency include: improved fuel pre-treatment, better refractory materials that have better insulating properties and last longer (such as ceramic furnace linings), computerized boiler controls, natural gas pulse-combination boilers, upgraded or replaced burners, and operator training to increase the efficiency of operations and maintenance. [Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• Improvements that can be made to increase the efficiency of **gas and steam turbines**: combined cycle of gas and steam turbines, intercooled and recuperated cycles, advanced materials development, combustion technology, component efficiency improvements, advanced cooling and sealing techniques, and advanced coatings. [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

• **Cogeneration**

- "Defined as the simultaneous production of usable heat and electric power from a single fuel source." "The typical cogeneration system is basically a natural gas fueled electric power generation plant (engine or gas turbine) with the addition of heat recovery systems".
[Goss Engineering, Inc. web site: www.gossengineering.com/cogeneration_details.htm]

- Uses a common system to supply both heat and electricity. [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

- A large percentage of the energy available from the natural gas is converted to heat rather than useful energy. A cogeneration facility recovers and uses a portion of this exhaust heat, along with the heat in engine cooling water and other sources.

- In order for a facility to qualify as a **certified** Federal Energy Regulatory Commission Cogeneration Qualifying Facility (QF), there must be a use for the heat. "This can be a fatal flaw for many cogeneration systems." Also, the exhaust heat recovery unit cannot be used for mechanical energy, such as to drive a steam turbine connected to a pump or other equipment.
[Goss Engineering, Inc. web site: www.gossengineering.com/cogeneration_details.htm]

- Engines in cogen systems are either spark ignition or compression ignition (diesel) internal combustion types. Gas turbines typically provide slightly higher efficiency (in larger sizes) and require less maintenance than engines, but also require a high pressure gas supply or compressors to provide the necessary gas pressure. However, turbine efficiency is generally low in sizes less than 3 MW. Gas turbines are better suited for applications where high temperature, high pressure steam is required, while engines are better for applications with lower grade or quality fuels and that have less specialized maintenance, training and auxillary equipment requirements. [Goss Engineering, Inc. web site: www.gossengineering.com/cogeneration_details.htm]

- A type of cogeneration is a **combined cycle** system, which uses steam as a source of both mechanical and thermal energy: high pressure steam produced by exhaust heat first passes through a non-condensing type steam turbine connected to a generator. The now low pressure steam coming out of the steam turbine is used to meet a thermal requirement. Systems of this type are able to produce high efficiencies and are best suited for cases where the thermal use is a low temperature or low pressure requirement.
[Goss Engineering, Inc. web site: www.gossengineering.com/cogeneration_details.htm]

- **Fuel cells** are potential candidates for cogeneration because the water byproduct is 160 to 180 degrees F.

• More than 40% of Denmark's power comes from **cogen**, while Finland and the Netherlands get 30% of their power form cogen. In the EU, less than 10% of production comes from cogen, though the EC has targeted a level of 18% by 2010, and the European parliament favors a level of 25%. [Reuters, 11/26/98]

• Gas-fired power plants can operate in two ways: 1) combusting natural gas in a boiler to produce steam that drives a steam turbine which is connected to an electric generator; and 2) combusting gas in an engine or gas turbine which is connected to an electric generator. [Goss Engineering, Inc. web site: www.gossengineering.com/cogeneration_details.htm]

## POWER GENERATION, TRANSMISSION AND DISTRIBUTION

***Clean coal technologies***

• There are three **advanced coal technologies** (not counting low-$NO_x$ burner designs):

**1) Atmospheric Fluidized Bed Combustion** (AFBC):

Widely used. Pulverized coal is burned in a bed of circulating (or "bubbling", in a simpler alternative design) solid material that includes fuel, ash, and limestone. $SO_x$ formed during coal combustion reacts with the limestone and is removed as solid $CaSO_4$ with the coal ash. AFBC produces somewhat more solid wastes than a conventional pulverized coal boilers, but the volume of waste is comparable when the waste from scrubbers is counted. Also, the wastes are generally less hazardous than scrubber sludges and are considered suitable for some types of reuse (road construction, aggregate, cement production) in some countries.

*Emissions:* reduce $SO_x$ by 70-90% relative to conventional boilers, and because their operating temperature is lower than other boiler types, also produce significantly less $NO_x$.

*Cost:* somewhat lower (5-15%) than similar-sized conventional coal plants fitted with scrubbers.

*Fuel:* Can be low quality coal such as lignite and wastes from coal cleaning.

**2) Pressurized Fluid Bed Combustion** (PFBC):

As of Nov 1996, in the demonstration phase. A variant of AFBC where the boiler is

operated at higher than atmospheric pressures, and where the exhaust gas is cleaned after exiting the boiler, then expanded in a gas turbine. *More efficient electricity generation than AFBC, and easier to retrofit* existing power plants (due to lower space requirements).

*Emissions:* >90% $SO_x$ removal and low $NO_x$ emissions.

*Cost:* less than pulverized coal plants with wet scrubbers.

**3) Coal Gasification** (including **integrated gasification combined cycle,** IGCC):

The coal is heated to convert it into a gas, which is used as fuel for furnaces, kilns, boilers, or other power generation equipment. In an IGCC unit, the coal is gasified in the presence of oxygen and steam, which cleans it of ash and sulfur compounds. The clean gas is then burned in a combustion turbine, with the hot exhaust gases routed to a boiler to raise steam, which turns a steam turbine. (The use of exhaust gases makes it a combined cycle rather than an open system.) Very high conversion efficiencies of up to 45%.

*Emissions:* up to 99% $SO_x$ removal, low $NO_x$ emissions.

*Cost:* As of Nov 1996, in the demonstration phase, they were expected to have capitol costs ~20% higher than typical pulverized coal plants with scrubbers ($1300-$1600/kW).

*Fuel:* Adaptable to a variety of different grades of coal, including high ash coals.

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• "If all coal-fired power plants in the U.S. were converted to the most efficient coal-based technology currently available, future carbon emissions would be reduced by 30%." However, "with more than 1,200 coal-fueled electric generating units in the U.S., it would take considerably longer than 10 years [the approximate time until the Kyoto deadline] to replace these units or to convert them to lower-carbon technologies".

[David W. South, VP for Technology and Markets Group, Energy Resources International, Inc., *Washington Post*, 2 Nov 1998]

• Steam or chemical **cleaning of coal** reduces $CO_2$ emissions by improving combustion and decreasing transportation weight (if cleaning is done at the mine, due to decreased bulk of the coal). The use of cleaned coal lowers costs by increasing burning efficiency, decreasing boiler maintenance, enhancing the efficiency of particulate emissions control devices, and lower coal transport costs. Coal is cleaned by pulverizing it to detach the mineral component from the organic. The components can be separated by various means, including cyclone separator (air classification), froth flotation devices that separate the 2 components by their different densities in water, and organic solvents. "The removal of ash through cleaning can be up to 60%, with retention of 85% to 98% of the heating value of the coal." Sulfur removal is 10% to 40%, depending on the coal type and process used. The cost of coal cleaning is usually $1 to $5 per tonne. Note, however, that coal grinding is energy-intensive. [Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• Cleaned and **briquetted** coal is a way to decrease $CO_2$ and $SO_x$ emissions from coal used for heating and cooking in developing countries such as Mongolia and China.

[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• **Fly Ash:** "generally contains the following components: unburned carbon, cenosphere (hollow sphere), iron-rich spheres, iron-silicate spheres, silicate spheres, and irregular-shaped silicates—all in various concentrations , and each with characteristic physical and chemical properties". [Michigan Technological University web site on Wet Process for Fly Ash Beneficiation, downloaded 5/11/99]

• **Wet Process for Fly Ash Beneficiation** to maximize the use of fly ash – 3 Separation phases:
1) gravitational separation to collect the low density fraction, the cenospheres;
2) magnetic separation to concentrate the iron-rich materials; and
3) flotation to collect unburned carbon.

The carbon can be sold as activated carbon ($400/ton), and the remaining fly ash is more valuable because unburned carbon makes the ash unusable in cement and concrete.

*Natural Gas Technologies*

• **Natural Gas:** "Switching from coal to natural gas can reduce emissions by up to 40-50%." [UNEP Fact Sheet #25, updated March 1999.] "Converting existing combustion equipment from coal to natural gas is generally relatively inexpensive, and new gas boilers are less expensive and typicall smaller in size than new coal boilers of the same capacity." [Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html.]

• "**Combined cycle gas** plants are commercially available, have relatively low capital costs, and are significantly more efficiency than standard coal-fired power plants." "The main concern with natural gas technologies in **Northeast Asia**, however, is not the cost or availability of the generation technologies that use gas, but the cost of procuring the gas itself."
[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

• **Liquid Natural Gas**: "The importation of gas to NE Asia as a liquified natural gas is already common practice, but expansion of LNG imports is also not inexpensive. New LNG terminals are difficult to site, and cost on the order of one-half to one billion US dollars. LNG tankers cost on the order of a quarter-billion dollars each. The expansion of gas imports by pipeline or tankers will also require the expansion of natural gas distribution networks in the countries of the region."
[Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

*Other Energy Generation Technologies*

• **Crops grown for Biomass Fuel**: "It is estimated that a 2600 MW plant operating at a 65% capacity factor would require one half of the State of Ohio's available farmland and forests." The "latest estimates by USDA" on "the maximum available farmland in the U.S." "translates into a maximum generation of 210 billion kWh per year from biomass, or 3% of the total electric energy demand projected for 2010." [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

• **Fuel Cells:** A 3 kW proton exchange membrane fuel cell generator by Northwest Power Systems is 85% efficient with waste heat used for space and water heating. The price is expected to be $10,000 if mass produced. [*Green Energy News* Vol 4, No 8 (5/29/99)] Fuel cells operate at an **efficiency of 80% or better**. [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

[See the file "fuelcell.doc" for more info on fuel cell applications.]

***Transmission and Distribution***

• **Transformers:** AlliedSingal's amorphous metal core utility and industrial transformers (Amorphous Metal Transformers, or AMT) "are more energy efficient than those using silicon steel cores and can reduce no-load losses up to 80%. No-load losses which occur when voltage is applied to a transformer represent a major portion of energy lost during power distribution". [Green Energy News, 4/18/99] (See AlliedSignal at www.alliedsignal.com/)

• Electricity **T&D losses** can be decreased through "better system control facilities, improved transformers, the addition of capacitance to the system, and other measures to improve power factors and reduce voltage fluctuations". [Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html]

## BUILDINGS/RESIDENTIAL

• "A **building** that uses the electricity and hot water from a **fuel cell** fueled by natural gas would have about half the greenhouse gas emissions of the average building today."[20] An extensive list of locations of natural gas fuel cells operating in the U.S. is given in: "Natural Gas Fuel Cells", Federal Energy Management Program, Federal Technology Alert, March 1997.

• The initial target market of Plug Power, in partnership with General Electric, is distributed power generation in the form of small, stationary units. To be called "GE Fuel Cell Systems", the systems will be under 35 kW with **residential units** initially going for between $7,500 to $10,000. GE hopes to bring the price down to $3,500, in which case the cost of electricity generated by these units would be between 7 and 10 cents per kW-hour, and the payback period could be around 3 to 5 years. The systems have an electrical efficiency of 40% as stand alone generators, but if the excess heat is tapped for hot water or space heating, the overall energy efficiency could reach 70%-85%. The cells can run on a variety of different fuels. The intended market is residences and small businesses who want an alternative to grid supplied power and those inconvenienced by power outages. More information on Plug Power is available at www.plugpower.com.22

• "No regrets" measures for homes (i.e., ones for which the capitol cost of introducing them willl be paid back in a relatively short period of time) include: insulation, double glazing, draught proofing, the use of condensing boilers, low-energy lights, and switching to electrical appliances

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[20] Unknown USG source, possibly the White House.

[21] *Green Energy News 3 (45)*, 13 February 1999; and *3(43)*, 12 September 1998.

[22] *Green Energy News 3 (45)*, 13 February 1999; and *3(43)*, 12 September 1998.

and gas cookers. [A book: "Global Warming: Can Civilization Survive?", Paul Brown, Sterling Publishing Co., NY, 1996]

• "Energy use from building lighting, currently responsible for almost 20% of all electricity use, could be reduced by over 50% by 2020." [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

## TRANSPORTATION

### *General*

• David Cole, director of University of Michigan's Transportation Research Institute, said that "the **electric drive train** may be cost-effective with the power train in the traditional internal combustion engine within three or four years". "The secret will be making solid state switches more efficiently." [*Detroit Free Press*, 11/20/98]

• **Light-weight steel versus aluminum in motor vehicles:** A new study from MIT comparing a light-weight steel body to one made of aluminum "challenges the claim that a one ton increase in the use of aluminum in automotive applications can reduce carbon dioxide emissions by 20 tons over the average life of the automobile. The study notes that producing one ton of virgin aluminum generates 10 times more CO2 than producing one tone of steel. Efficiency savings from the use of the lighter metal would take decades to offset that difference." [*Green Energy News* Vol 4, No 8 (5/29/99)]

• "Last month, CA drastically tightened emission controls on full-sized pickups, vans and **sport utility vehicles**. Under the new rules, emissions levels from SUVs must begin coming down in 2004 and be as low as passenger cars by 2007. Other states are expected to follow suit, with the federal EPA not far behind." [Detroit News, 12/5/98]

• "Fuels such as compressed natural gas and propane can reduce carbon emissions by 10-20%, on a full fuel-cycle basis, over conventional gasoline or diesel fuel." [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

• **Aircraft:** Improvements in fuel efficiency of 1.3% annually through 2010 are expected from improvements being made by NASA and aircraft and engine manufacturers: hybrid turbofan propoulsion systems, blended wing body design, improved thermodynamic efficiency of turbine engines, and greater use of lightweight materials. [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

### *Diesel*

• "The latest **diesel engines** use as much as 33% less fuel per mile as their gasoline counterparts, according to auto industry engineers. And while even the cleanest diesels still produce slightly more soot and smog-causing gases than gasoline engines, diesels emit up to 20% less carbon dioxide". "Since the early 1980s, enormous progress has been made in building better diesels. The latest diesels coming out of the laboratories emit no visible smoke, produce up to 90% less soot and generate up to 75% less noise than the vehicles of the early 1980s." "In Europe,...diesels are

expected to reach 30% of the European market, once the factories catch up." "But making diesel engines as clean as gasoline engines is particularly difficult because current regulations, particularly in California, allow **diesel fuel** to be much dirtier than gasoline. California regulations require oil companies to remove almost all of the **sulfur from gasoline**, because sulfur clogs catalytic converters and allows a vehicle's emissions to soar. But California's rules allow diesel fuel to have nearly 17 times the sulfur of gasoline." [NYT, 11/27/98]

• "Heavy trucks and locomotives are universally powered by highly efficient (40-45%) **diesel** power plants", with emissions of NOx and particulates remaining "the greatest barriers to ultra-high efficiency diesels". "The efficiency of diesel engines could be further improved to 55% by the use of such technologies as advanced thermal barrier coatings, high-pressure fuel injection, turbocharging, and reduced friction and lightweight, high strength materials." [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

***Electric Vehicles (and Hybrids)***

• Budget Rent A Car at LAX just started offering rent by the day **electric vehicles**, which get about 70 to 90 miles between charges. It is hoped that drivers see the opportunity to try out an EV without paying much money. [Los Angeles Times, 12/9/98]

• **Hybrid vehicles** leak little or no **HFC coolant** because they have hermetically sealed air conditioners, while auto air conditioners in conventional cars currently "have flexible hoses that gradually leak HFC coolant to the atmosphere". [*C&EN*, 4 Oct 99]

***Fuel Cell Vehicles***

• **Daimler Benz** (or DaimlerChrysler, the world's fifth largest automaker), in partnership with **Ballard** Power Systems (the industry leader in the development of proton exchange membrane fuel cell stacks for transportation), unveiled its **NECAR 3** prototype on 10 September 1997. NECAR 3 is the first fuel cell vehicle to use on-line methanol as fuel rather than bulky, heavy cylinders of $H_2$ gas. A reformer at the rear of the vehicle converts methanol to $H_2$ through water vapor reformation[23] and feeds it directly into Ballard fuel cells. The reformation unit is 18" high. The direct injection into the cells means that 90% of the car's power is available in 2 seconds, putting fuel cell vehicles on par with conventional gas or diesel-powered cars. The range of the NECAR 3 is 250 miles on an 11 gallon tank, similar to conventional vehicles. No nitrogen oxides are emitted, and $CO_2$ emissions are substantially below those of conventional cars.[24]

On 17 March 1999, DaimlerChrysler unveiled the **NECAR 4** prototype, which has a more compact methanol reformation unit (helping lower a critical barrier to compact "packaging" of the car) and can travel **280 miles** before refueling.[25]

• The choice of fuel determines the reductions in carbon emissions from fuel cell vehicles (50% or more). [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]
[See the file "fuelcell.doc" for more on fuel cell mobile applications]

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[23] Methanol and water vaporize to yield $H_2$, $CO_2$, and CO, and the CO is catalytically oxidized to $CO_2$.

[24] http://news.hydrocarbononline.com/feature-articles/hcolfea93097.html

[25] *Washington Post*, 17 March 1999.

## POWER SECTOR REFORM/RESTRUCTURING

• **Energy Sector Development** requires:

1) Proper economic, policy, legal and regulatory climate for private investment
2) Elimination of subsidies
3) Enough trained personnel in government institutions and utilities.
4) Reliable, high quality energy

[Gordon Weynand, Jul 99]

More specifically:

- D unbundled from T & G
- Strong institutional management, including collections and billing
- Good customer service
- Transparency (lack of corruption)
- Environmental performance; safety
- Secure, reliable supply of energy
- Cost efficient
- Independent (autonomous) regulatory bodies that: are transparent and subject to removal if misconduct or a conflict of interest; protect the interests of regulated energy companies, the public, and investors; have predictable, revocable licenses and fees with standards and reporting requirements.

[Bob Ichord, Jul 99]

## TECHNOLOGIES TO REDUCE NON-GHG POLLUTANTS FROM THE ENERGY SECTOR

All information in this section is from the following source unless otherwise stated: Paper by David Von Hippel on the Nautilus Institute web site: "Technological Alternatives to Reduce Acid Gas and Related Emissions from Energy-Sector Activities in Northeast Asia", Nov 1996: www.nautilus.org/esena/papers/dvhtech.html.

• "Energy efficiency options provide the most effective means of reduce acid gas emissions", with many options "having low or negative costs of emissions reductions per unit acid gas. This is particularly true if" savings are counted from additional generation capacity avoided as well as energy (fuel) savings.

• ***Sulfur oxides:*** The three main technologies for controlling $SO_x$ emissions inject a sulfur-absorbing substance into the exhaust (flue) gases.

**1) Duct Injection**

Flue gases are cooled, typically with water, to an appropriate temperature and then routed to an absorber unit that sprays a solution of calcium hydroxide ($Ca(OH)_2$) into the flue gases, forming $CaSO_4$ and $CaCl_2$ upon reaction with the $SO_x$. These products, along with unreacted sorbent and fly ash, are removed from the flue gases by settling and a fabric filter. The unreacted sorbent can be reused. Putting the duct injector *before* the electrostatic precipitator (which removes particulates) removes 30-70% of flue gas $SO_x$, while doing the injection after the ESP achieves 80-90% removal. Relatively low-cost and can be retrofitted to existing plants. Relatively new, in the early commercialization phase in 1996.

**2) Wet Scrubber** or **Flue Gas Desulfurization** (FGD)

Flue gases enter a large reaction vessel where they are sprayed with a water slurry containing about 10% line (calcium oxide, CaO) or limestone. The calcium compounds react with the $SO_x$ in the flue gases, forming calcium sulfate ($CaSO_4$) and sulfite ($CaSO_3$) which are collected, thickened (by removing water and filtration), mixed with fly ash, stabilized with additional lime, and disposed in landfills. Variants on this process exist, notably the "limestone with forced oxidation" process which uses air to oxidize more of the $CaSO_3$ to $CaSO_4$ for easier removal. Removes 80-90% of $SO_x$ in flue gases. Widely used in developed countries.

**3) Dry Scrubbers or Spray Dryers**

A slurry of quicklime[26] is mixed with water (forming $Ca(OH)_2$), atomized, and then sprayed into a spray dryer tower, where it mixes with hot exhaust gases to form $CaSO_4/CaSO_3$. The $CaSO_4/CaSO_3$ falls to the bottom of the dryer and in equipment used to collect particulate matter (ESP or baghouse). They remove 7- 0 90% of the $SO_x$. As of Nov 1996 when this paper was published, the technology was not demonstrated for high-sulfur coals. It costs slightly less than wet scrubbers and is somewhat simpler to operate.

• ***Nitrogen Oxides:***

**1) Selective Noncatalytic Reduction**

A nitrogen-based chemical reagent—most commonly urea ($CH_2CONH_2$) or ammonia ($NH_3$)—is injected just after the exhaust gases exit the boiler (so the gases are still very hot), forming mostly $N_2$. The technology can reduce $NO_x$ emissions by 35-60%, can be used in new and retrofit installations, and has relatively low capital costs. Concerns with it include possible ammonia contamination of fly ash (ammonia can cause odor problems), releaase of unreacted ammonia into the environment with treated flue gases, and **production of nitrous oxide ($N_2O$)** from the reaction of $NO_x$ with injected reagent.

**2) Selective Catalytic Reduction**

Like the noncatalytic reduction except it uses a catalyst (typically oxides of vanadium and titanium) that allows the reactions to occur at lower flue gas temperatures. As of Nov 1996, it was significantly more expensive then the non-catalytic method, its use with medium- and high-sulfur coals was still in the demonstration phase, and there were concerns about the impact of alkalis and arsenic (common coal contaminants) on catalyst life, emissions of unreacted ammonia, and the impact of $SO_3$ on $NO_x$ removal (the catalysts convert $SO_4$ to $SO_3$).

**3) Low-$NO_x$ burners**

Used in virtually all new boilers in industrialized countries, and can be applied at "minimal incremental costs" in developing countries if the technology is made available. Retrofit applications have costs 2- or 3-times higher. Used for utility or industrial boilers, furnaces and cement kilns. Their effectiveness depends on the type of technology applied, ranging from 30% to 70% for an investment of $1 to $50/kW (as of Nov 1996)

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[26] Quicklime is the first solid product of calcining limestone (heating it to high enough temperatures that volatiles are driven off and a powder is formed, but not high enough to fuse it).

## CORPORATE BEHAVIOR and ACTIONS (See also "business-gcc.doc")

RENEWABLE ENERGY

• **Royal Dutch/Shell** "has invested $500 million (U.S.) to establish Shell International Renewables to develop alternatives to fossil fuels". [*Toronto Star*, 11/15/98]

• **BP Amoco**, the world's second largest oil company, is spending $45 million to "win control of Solarex", making BP Amoco the world's largest solar-energy company. They began a program to "bring power to 200 petrol stations using solar panels". They have also "launched an internal market for emissions-trading among its divisions around the world". [*The Economist* 17 April 1999, p. 74]

• A 1995 meeting of the **World Energy Council** in 1995 had in its concluding report a call for investment decisions to be made now to boost renewable energy. "Depending on the decisions taken in the next 20 years, renewables could be a mere 16% of primary energy production or as much as 39%. The Council is advocating the removal as quickly as possible of the subsidies for fossil fuels and the addition of carbon taxes to reflect their true environmental cost." [A book: "Global Warming: Can Civilization Survive?", Paul Brown, Sterling Publishing Co., NY, 1996]

INDUSTRY/MANUFACTURING

• **GM** Corp "unveiled a 10-year, multibillion dollar agreement to buy substantial amounts of **aluminum** from Alcan Aluminum Ltd... The agreement's real significance lies in the commitment that the No. 1 auto producer is making to design much more aluminum into vehicles, displacing steel and other materials....Montreal-based Alcan calculates that every one-ton reduction in the weight of vehicles results in a 20-ton reduction over the vehicles life in emissions of carbon dioxide....Alcan is the No. 2 global aluminum producers, behind Aluminum Co. of America... .Aluminum can cost as much as 3 to 5 times more than steel. ...The agreement also calls for GM and Alcan to set up a joint research program...to invent new ways to use aluminum in autos and to make aluminum parts as recyclable as soda cans. ...Steel still accounts for an average of 55% of the weight of cars and trucks in the U.S. ...To counter auto makers' increasing interest in aluminum, the steel industry is working on thinner, stronger, lighter forms of steel." [*MSNBC* (www.msnbc.com/news/), 11/27/98]

• From 1991 to 2000, **Dupont** will have reduced its GHG emissions by 45% below their 1990 level, mostly by reducing emissions of **nitrous oxide** and **fluorocarbons**. (Nitrous oxide, $N_2O$, holds 310 times more heat than $CO_2$, while fluorocarbons are hundreds to thousands times more potent than $CO_2$). [*C&EN* 27 Sep 99]

• **Motorola** plans to reduce its emissions by cutting its use of **perfluorocarbons** in half by 2010, by switching to different methods of etching and cleaning silicon chips in semiconductors. (Perfluorocarbons are extraordinarily dangerous GHGs, affecting atmospheric warming 7,000 to 24,000 times more strongly than $CO_2$, and remaining in the atmosphere essentially indefinitely once emitted.) [*C&EN* 27 Sep 99]

• **United Technologies Corporation**, with 225 facilities in 365 countries, frames their reduction goals in terms of energy per dollar of product produced. They plan to reduce the energy consumed per dollar of product by 25% by 2007, from a 1997 baseline. [*C&EN* 27 Sep 99]

• "Twelve U.S. magnesium companies have formed a partnership with EPA to reduce emissions of **$SF_6$**". "Without reduction measures, $SF_6$ emissions would rise substantially because automakers are increasingly choosing lightweight magnesium parts to improve fuel economy." [*C&EN* 4 Oct 99]

• The World Semiconductor Council announced at its annual meeting in May 1999 that the worldwide semiconductor industry will reduce its emissions of **perfluorocarbons** (PFCs) 10% from their 1995 level by 2010. "Some companies, such as Motorola, will cut their emissions much more than 10%,...while less technologically advanced companies may do nothing." "The 10% reduction goal is more ambitious than it sounds because the production of semiconductors is expected to grow sixfold during the next decade." [*C&EN*, 4 Oct 99]

• 24 manufacturers of semiconductors, including Eastman Kodak, joined in a partnership with EPA to address ways to reduce emissions of perfluorocarbons and hydrofluorocarbons. [Business Wire, 5 Feb 1998]

**TRANSPORTATION**

• "**Toyota** Motor Co. announced last fall that it would become the first automaker to market a **hybrid gasoline-electric car** with its Prius." It will go "on sale in the U.S. in 2000, will be four times cleaner than required by California standards and also get 66 miles a gallon." "American Honda Motor Co....is working on a hybrid car that is 10 times cleaner than required by California." [Detroit News, 12/5/98 (http://detnews.com/1998/autos/]

• David Cole, director of University of Michigan's Transportation Research Institute, said there has been "really quite a transformation" in the last year or so in the **auto industry**'s attitude toward climate change. He said "The attitude now is, rather than complain about it, we might as well develop competitive technology". "Although auto representatives sent representatives to Buenos Aires to try to delay forced reductions in the use of fossil fuels, 'from a technology standpoint they're busting their tail,' Cole added." "Advanced technologies are on the agenda for every automobile company in the world, there's no question about it," said Dennis Minano, GM's vice president for public policy and chief environmental officer. [*Detroit Free Press*, 11/20/98] [see the file "fuelcell.doc" for how automakers and others are working hard on fuel cell vehicles.]

• Honda Motor Co. plans to spend about $300 million to streamline production and conserve energy at its Japanese plants. [*Sacramento Bee* (via AP), 7 May 1999]

**FUEL CELLS**

• "Royal Dutch/Shell Group, the parent company of Shell Chemicals, has launched **Shell Hydrogen**, a business targeted at the 'exciting opportunities that are developing in the technology, infrastructure, and applications' of **fuel cells**. Shell Hydrogen plans to announce major projects later this year." [*C&EN* 15 Feb 1999]

## GCC DIPLOMACY AND POLITICS; QUOTES

• The 1992 UN FCCC does not contain legally binding carbon emissions targets because of strong opposition by the Bush Administration. [According to: Christopher Flavin, "Last Tango in Buenos Aires", *World Watch*, Vol. 11, No. 6 (1998), p. 13]

• Only **Fiji** and **Antigua & Barbuda** have ratified the Kyoto Protocol so far (as of late 1998), though Argentina may become the third, as a bill to ratify has passed the Senate and (as of 11/14/98) was before their Lower House. In 1998, **South Korea** announced that it will voluntarily assume GHG emissions limits beginning in 2018, becoming the first developing country to make such an announcement. **Argentina** and **Kazakhstan** will accept binding limits on their emissions, and **Mexico** and **Chile** "are said to be considering comparable steps". [The last statement from: *Washington Post*, 11/15/98]

• The **U.S.** signed the Kyoto Protocol during COP-4, the 60th nation to sign and the last major developed country to do so. According to U/S Stuart Eizenstat who lead the U.S. delegation in Buenos Aires, the announcement was a high point in the negotiations because "the feeling was that perhaps the [U.S.] domestic opposition was so stiff that we were going to back off" the Protocol. [NYT, 11/13/98]

• We learned from the ozone experience that although developing countries at first strongly oppose requirements to adhere to international environmental restrictions, they do so willingly when alternative technologies and funding become available. For example, China and India refused to join the Montreal Protocol until they realized that market forces and the Multilateral Fund would provide them with access to the newer technologies. Richard Benedick, chief U.S. negotiator for the Montreal Protocol, said that "as soon as cost-effective technologies become available, the developing countries will be eager to acquire them, mainly through the market, rather than be left behind in the march of progress." [Seth Dunn, "Can the North and South Get in Step", *World Watch* Vol. 11, No. 6 (1998), p. 25]

• *Value of Buenos Aires accomplishments:* "The plan established deadlines for finalizing the outstanding details of the Kyoto Protocol so that the agreement will be fully operational when it enters into force sometime after the year 2000." [FCCC Press Release at www.cop4.org, 11/14/98] The outcome may have "seemed merely procedural", but in reality it "went to the heart of the politically charged question of how fast the world can and should move to deal with the prospect of climate change". "Many developing countries, seeing the prospect of reaping new investment in their economies, wanted the rules and regulations for the clean development mechanism to be worked out first, on an accelerated schedule, with those for emissions trading completed later. The United States and other rich countries feared that if the CDM received first priority, developing countries would then refuse to approve rules and regulations for emissions trading....The U.S. therefore insisted that the two mechanisms move toward operational status on parallel tracks. The agreement requires "that 'substantial progress' on rules for the operational mechanisms be demonstrated a year from now, with a firm decision in two years".
[New York Times, 14 Nov 1998, "Key Questions Remain at Global Warming Talks"]

• "Environmentalists are concerned by the possibility that letting developing countries into the Protocol 'big league' will allow them to declare ambitious development targets and then their unused emissions permits...to offset continued pollution in the U.S.". [Buenos Aires Herald, 11/16/98]

• "Saudi Arabia, Kuwait, Qatar and other OPEC members are determined to preserve wording in the Kyoto agreement that would allow for compensation to countries suffering adverse economic effects from actions taken by developed countries to reduce their emissions. The text is aimed at

providing assistance to developing countries that are forced to adapt to carbon-curbing measures and new technologies, and particularly to low-lying regions and island states most susceptible to climate change and accompanying rising sea levels."
[Buenos Aires Herald, 11/16/98]

• At Kyoto, "President Jose Maria Figueres of Costa Rica announced that by the year 2010, his country planned to get all of its electricity from renewable sources". [Lester Brown, *Worldwatch 12*(2): 19 (1999)]

• ASIA: At 8% growth, 80% of the industrial sector plants in Asia that will exist in 2025 have yet to be built. [An oft quoted statistic by WRI, World Bank, etc., obtained by extrapolation.]

**Nay Sayers**
• U.S. Senator Chuck Hagel (NB-R) "stressed that not all scientists agreed that man-made carbon emissions were the root cause of apparent warming of the earth and said any new climate change effort "should be predicated on clear, sound science'. [Reuters, 11/23/98]

• "There is no conclusive scientific evidence of global warming or of human activity as a contributing factor." [*Journal of Commerce*, 11/20/98, "Kyoto Puts Us at Risk", Dana Joel Gattuso, director of research at the Pacific Research Institute, a San Francisco-based public policy organization.]

• Nay-sayers: Dr. Richard S. Lindzen, Dr. Pat Michaels, Dr. Robert Balling, Dr. Sherwood Idso, and Dr. Fred Singer. [A book: "Global Warming: Can Civilization Survive?", Paul Brown, Sterling Publishing Co., NY, 1996]

• Western Fuels Association: a consortium of coal suppliers and power station owners that have been aggressively trying to sell GCC as bunk. [A book: "Global Warming: Can Civilization Survive?", Paul Brown, Sterling Publishing Co., NY, 1996]

• Pat **Michaels**, who teaches climatology at the University of Virginia, has received over $115,000 over the past four years from coal and energy interests, World Climate Reviews, a quarterly he founded that routinely debunks climate concerns, was founded by Western Fuels. Over the past six years Robert **Balling**, from Arizona State University, has received $200,000 from coal and oil interests in the U.K., Germany and elsewhere. Richard **Lindzen**, a distinguished [official title?] professor of meterology, charged oil and coal interests $2500 a day for his consulting services and a 1991 trip he made to testify before the Senate was paid for by Western Fuels.

**QUOTES**
• "Rarely have the rhythms of the natural world been so out of synch with those of the political world." [Christopher Flavin, "Last Tango in Buenos Aires", *World Watch*, Vol. 11, No. 6 (1998), p. 11-12]

• "The problem with this experiment is that if it turns out badly...we cannot undo it. We cannot even abruptly turn it off." [*New Zealand Press*, 11/24/98, quoting Kevin Trenberth, head of the climate analysis section at the National Center for Atmospheric Research in Boulder]

•. "Although the new business created by the move away from fossil fuels is likely to roughly equal the business lost, the potential losers are far better organized." [Christopher Flavin, "Last Tango in Buenos Aires", *World Watch*, Vol. 11, No. 6 (1998), p. 17--but he gave no source for this.]

• *The General State of the Environment:* "The Earth's forests are shrinking, fisheries are collapsing, water tables are falling, soils are eroding, coral reefs are dying, atmospheric CO2 concentrations are increasing, temperatures are rising, floods are becoming more destructive, and the rate of extinction of plant and animal species may be the greatest since the dinosaurs disappeared 65 million years ago." [Lester Brown, *Worldwatch 12*(2): 14 (1999); Mar/Apr]

• "For years I labored with the idea of reforming the existing institutions of the society, a little change here, a little change there. Now I feel quite differently. I think you have got to have a reconstruction of the entire society, a revolution of values." -- Martin Luther King, Jr.

## ECONOMICS OF ENERGY EFFICIENCY AND GLOBAL CLIMATE CHANGE

**EVIDENCE THAT REDUCING ENERGY USE DOES NOT SLOW ECONOMIC GROWTH:**

• "Between 1973 and 1985, energy use in America remained relatively constant, and at the same time our gross domestic product increased by 35%". [Democratic Leadership Council E-Mail Service, 3/8/99]

• Emission figures from the Energy Information Administration show that fossil fuel use by U.S. industry fell 1.4% from the 1997 level, even as the gross domestic product grew 3.9%. ["Case Grows for Climate Change", *Chemical & Engineering News*, 9 Aug 1999]

• "Worldwide carbon emissions fell 0.5% last year while the world economy expanded 2.5%, according to figures from BP Amoco and the Worldwatch Institute." [*C&EN*, 9 Aug 1999]

• In industry, most production costs are beyond the control of the firm. However, pollution prevention, material recovery, recycling and reuse, motor and process efficiencies, and waste minimization are not, and can save firms considerable money. "Annual energy savings that could be attained by U.S. industry over the next two decades ranges from 11% to 27% of the demand that would otherwise occur, and potential savings may reach as high as 38%." Not counting the energy needed to process, treat, and/or dispose of waste and pollution, or to fabricate and obtain raw materials, electric motors "consume 70% of all energy in a typical [U.S.] manufacturing facility", and "more than 80% of the energy savings available to U.S. industry comes from electric motor systems improvements". [Energy Foundation report: "Boosting Prosperity: Reducing the Threat of Global Climate Change Through Sustainable Energy Investments", 1997.] {See this report for many specific examples in U.S. companies.}

• **Seminconductors:** "While chip output doubled from 1995 to 1997, the electricity bill declined. Adjusting for chip size, the per cost per chip fell 60%". [Joseph Romm, "Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions", Island Press: Washington, D.C., 1999, p. 100.]

**EXAMPLES OF ECONOMIC BENEFITS OF EFFICIENCY:**

• Improved lighting technology in its factories saves **Boeing** 270 million kW-h of electricity per year. These upgrades paid for themselves in 2 years and avoided the emission of more than 100,000 tons of GHGs. [Joseph Romm, 1 August 1999, Wash Post]

• "Toyota Auto Body of California cut its energy bill by one-third even as it doubled production. New systems to control air flow into its paint booths cut energy use in half and reduced defective paint jobs from three in every hundred to one tenth of one percent." [Joseph Romm, 1 August 1999, Wash Post]

• Chicago's McCormick Place Convention Center uses a cogeneration system (one which captures waste heat and outs it to use) that can exceed 90% efficiency, compared to about 30% for a conventional power generation system. The system saves the company one million dollars annually in energy and operating costs, avoiding as much as 24,000 tons of GHG emissions. [Joseph Romm, 1 August 1999, Wash Post]

• **Role of NGOs** in developing/transition economies:
Assist with business development, ensure transparency of policy implementation, advocate policy, disseminate info, organize communities

• A country must understand markets and have a functioning market system before they can participate effectively in a workable market-based instrument.

• VP Gore, in an article he wrote for Newsweek International, said that "if the U.S. can lead the world in the estimated $400 billion market for technologies that clean up the environment, then we can protect our natural resources in a way that actually creates jobs and makes American industry more competitive." [*Newsweek International*, 11/23/98, "Finding a Third Way"]

• Enron's head, Ken Lay, said he "sees his company, and more broadly the natural gas industry, playing a central role in the conversion from a fossil fuel-based energy economy to a solar/hydrogen energy economy." [Lester Brown, *Worldwatch 12*(2): 18 (1999); Mar/Apr]

• *Carbon Taxes:* Denmark, Finland, the Netherlands, Sweden, Spain, and the UK "began restructuring their taxes during the 1990s in a process known as tax shifting—reducing income taxes on environmentally destructive activities such as fossil fuel burning, the generation of garbage, the use of pesticides, and the production of toxic wastes." "Public opinion polls on both sides of the Atlantic show 70% of the public supporting tax shifting." "Germany...announced a massive restructuring of the tax system...to simultaneously reduce taxes on wages and raise taxes on $CO_2$ emissions." The tax shift is meant to "help strengthen the German economy by creating additional jobs and at the same time reducing air pollution, oil imports, and the rise in atmospheric CO2". [Lester Brown, *Worldwatch 12*(2): 19 (1999); Mar/Apr]

• *Energy Star:* Every federal dollar spent on Energy Star yields more than $20 invested in energy-efficient technologies, $70 saved by businesses and consumers in avoided energy costs, and more than 2 tons of carbon dioxide saved. [Alliance to Save Energy newsletter, Vol 1, No 2, Mar/Apr 1999; citing EPA]

• Federal efficiency programs to increase investment in energy efficient technologies include: Energy Star Buildings, Energy Star Labeled Products, Green Lights, Motor Challenge, Steam Challenge, and industrial energy assessments

• EFFECT ON EMPLOYMENT AND PRODUCTIVITY: "The output and employment in most sectors tend to increase as a result of a more efficient economy. There are direct new business

opportunities for those sectors involved in supplying the energy efficient investment goods, including construction (both new and retrofitting), motor vehicles, commercial and household appliances, lighting, HVAC systems, and industrial equipment. These business opportunities more than offset the lost output from lower production and distribution of fossil fuels." [A paper presented at the Electric Utilities Environment Conference, by Skip Laitner, Kathleen Hogan, and Donald Hanson, 11 Jan 99]

## ECONOMICS and MECHANICS of PROTOCOL MARKET-BASED MECHANISMS

• With CDM, "starting in 2000, the companies will receive certificates showing the amount of carbon dioxide they have prevented from entering the atmosphere. These certificates could eventually be sold to power companies in industrialized countries who want to emit more than they would otherwise be allowed under the governments' agreed emissions targets".

• The CDM could eventually have a turnover of $17 billion a year, says Robert Hamwey, an economist at the International Academy of the Environment in Geneva." [*New Scientist*, 11/21/98]

• Kyoto Protocol issues remaining to be defined include:
- what proportion of targets may be met through the flexibility mechanisms
- which projects (including existing AIJ projects) may be counted
- whether there should be a special consideration for sustainable development in projects
- what baselines should be used for establishing additionality
- when projects can start to be counted (i.e., before 2000?)
- who will be on the executive board?
- measurement accuracy
- the permanence of reductions
- which land use mitigation options will qualify

• "A continuation of the present rate of U.S. economic growth unaccompanied by a complementary reduction in carbon emissions within these four sectors [transportation, industrial, building, and electric power utility] over the next decade or so, would yield approximately 551 million metric tons of carbon emissions in excess of that allowed for the U.S. by the Protocol". [From a statement by the American Society of Mechanical Engineers, Dec 1998, on the "Technology Implications For the U.S. of the Kyoto Protocol"]

### DEVELOPING AND TRANSITION COUNTRIES

• "Argentina believes it could earn 700 million dollars a year as payment for maintaining carbon absorbing forests alone." "By the year 2000—when most of Argentina's thermoelectric energy plants will have been converted to energy-saving combined cycle technology, the country will also have become the world's cleanest producer of this type of energy", according to Argentine President Carlos Menem. [Buenos Aires Herald, 11/16/98] "Argentinean companies have ambitious plans for expanding renewable energy, especially in windy Patagonia." [*New Scientist*, 11/21/98]

• "Environmentalists are concerned by the possibility that lettings developing countries into the Protocol 'big league' will allow them to declare ambitious development targets and then their

unused emissions permits...to offset continued pollution in the U.S.". [Buenos Aires Herald, 11/16/98]
[*New Scientist*, 11/21/98]

• "Kazakhstan's CO2 emissions are currently 45% below 1990 levels."
[*New Scientist*, 11/21/98]

• *The concern about selling hot air:* It is estimated that in Russia and Ukraine, GHG emissions fell 30% below 1990 levels due to economic decline, while their official Kyoto reductions targets are 0% below 1990 levels. [*Environment*, Vol 40, No. 9, Nov 1998] Their CO2 emissions in 2008 to 2012 will be far below these targets. "When the economies rebound, so will emissions. Yet, by selling their excess permits in the interim, Russia and Ukraine might reap a $100 billion windfall while doing nothing to limit future emissions." [*Washington Post* Commentary and Analysis, "The Kyoto Shell Game", David G. Victor, 11/20/98]

• The paper "After Buenos Aires: A Development and Environment NGO Perspective" said:

> "The 'quantified commitments' taken on by industrialized countries (article 3.1 of the Protocol) became *de facto* 'property rights' for those countries since they can freely exchange them (as their 'assigned amount'). This right is not given to developing countries, who can only exchange emission reductions through the CDM. The effect is that only indebted countries (those required to reduce) have the power of exchange over their debt, while supposedly unrestricted countries (with no reduction requirement) find themselves excluded from the market, or restricted to the residual second market of the CDM."

The paper argues that voluntary commitments are a "non-issue" for developing countries, yet the economic reality conveyed in the above passage is precisely the argument why they should sign on, and why Argentina and Kazakhstan have done so.

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Updated 12/23/99

# *Climate Update*

January 31, 2000

Science News

- The National Climatic Data Center released data near the end of 1999 showing that in the last quarter-century, the rate of warming has been more than double that of the 20th century average, and since the mid-1970's, the global temperature has risen at a rate of about 0.35 degrees per decade, or 3.5 degrees per century. (Complete text of a front page *New York Times* story about the findings is attached.)

- The National Academy of Sciences released a major new study on January 13, which was reported on by *the Washington Post, LA Times, CNN, CBS* and other outlets. The study found that the warming trend over the past two decades "...is undoubtedly real and is substantially greater than the average rate of warming during the 20th century." The report also downplayed a long-standing dispute over temperature data (while ground monitors have shown a sharp increase in Earth's temperatures, satellite and weather balloon observations have shown little or no warming), noting that while this discrepancy cannot yet fully be explained, it "in no way invalidates the conclusion that the Earth's temperature has been rising."

- 1999 will be the fifth warmest year on record, according to a British Meteorological Office study released December 15, 1999. Seven of the 10 hottest years on record occurred in the 1990's, which was the hottest decade of the millennium, the report said. Furthermore, the report suggested a "high probability" of 2000 being even warmer, as the cold Pacific (La Nina) warms again naturally.

- New satellite data released by NASA January 19, 2000 shows that part of the Pacific Ocean may be undergoing a cooling which could influence U.S. weather patterns over the next years and even decades. This newly identified climate pattern, known as Pacific-Decadal Oscillation (PDO), is a natural oscillation of northern hemisphere Pacific Ocean temperatures that occurs over decades, similar to the international El Nino-La Nina cycle in the tropical Pacific. The research suggests that the U.S. entered the "cool" phase of the PDO (similar to the La Nina phase) about 2 years ago. The tendency of this phase is to cool some regions of the earth, and while this could serve to "mask" or "dampen" global warming signals, it is not evidence that global warming is not occurring. For example, 1998 and 1999 set records as the warmest and 5th warmest years this century during the same period that scientists believe a "cool" PDO phase may have been starting.

Industry and Technology Update

- Following the lead of Ford in December 1999, DaimlerChrysler Corp. this January withdrew from the Global Climate Coalition (GCC), the major business lobbying group opposed to the

Kyoto climate treaty. This leaves GM as the only American carmaker still in the GCC. BP/Amoco, Sunoco and Shell all left the GCC within the last two years.

- In first week of January, a coalition of 42 religious and environmental organizations in 17 states unveiled "Campaign ExxonMobil" (CEM), an effort aimed at pressuring ExxonMobil to reform corporate practices that contribute to global warming, to acknowledge that human activity is causing global warming, and to quit anti-Kyoto lobbying groups such as the Global Climate Coalition. The religious and environmental groups' primary tactic is shareholder resolutions. In addition to ExxonMobil, they are also targeting GM, Cinergy, Goodyear, Duke Power, CSX, Southern Co., Chevron, Texaco, and Allegheny Energy.

- At the Detroit Auto Show the first week of January 2000, virtually every major manufacturer unveiled prototype hybrid cars that get better than 70 mpg. Ford's entry, the Prodigy, is "a family car that gets nearly 80 mpg without sacrificing performance or functionality," according to company documents. GM's Precept has similar qualities. Both were developed under the Partnership for a New Generation of Vehicles program. Chrysler is slated to display their entry later this year.

- A new hybrid gas and electric car which gets more than 60 mpg arrived at Honda dealers in the U.S. in December, 1999, the first such vehicle priced under $20,000 to be available to American consumers. Drivers fill it with unleaded gas and an electric motor is charged by the car's brakes so it never needs to be plugged in—one of the big drawbacks to cars that are entirely electric. Toyota will release a similar vehicle in 2000, selling for $17,000 and getting 66 mpg.

- Cargill Inc. and Dow Chemical announced in mid-January a $300 million program for full-scale commercial production of a new kind of plastic made from plants instead of petroleum. The new product is being called "Natural Plastic."

International Developments

- The World Bank in mid-January announced the creation of a fund to finance a market for greenhouse gas emissions. Four governments—Finland, Norway, Sweden and the Netherlands—and nine companies have committed $85 million so far to the fund, which will begin operating in April 2000. Reports in the *Washington Post* and *Wall Street Journal* speculated that the initiative reflects the World Bank's concern about the vulnerability of poor, low lying nations to coastal flooding as a result of global warming.

- France unveiled a program to fight global warming containing 96 measures, including an energy consumption tax on industries due to take effect in 2001, proposals to encourage vehicles to economize on fuel, the development of new public transport, reduction of energy consumption in buildings, and the promotion of research into renewable energy sources. The proposal, announced the week of January 17 also includes a domestic emissions trading system, despite the European Union's strong criticism of trading systems.

Recent Editorials

- January 9, 2000—*The Washington Post*
  "Warming to Reality" (complete text attached)

- January 15, 2000—*The Courier-Journal*
  "Global Warming"

- Headline: January 16, 2000—*The Detroit News*
  "Global Warming?"

- January 17, 2000—*The Indianapolis Star*
  "Still Not a Crisis"

- January 17, 2000—*The Washington Post*
  "More Hot News"

- January 18, 2000—*The Atlanta Constitution*
  "Global Warming Facts Ignored at Our Peril"

Other Media Coverage

- *CBS News* aired six separate global warming stories over three nights the week of January 10-16 featuring clips from President Clinton's January 11th statement at the Grand Canyon, two interviews with Dr. James Baker of NOAA, and an interview with White House Chief of Staff John Podesta. All the stories emphasized that global warming science is becoming conclusive, and included impacts as diverse as farming problems in the Central Valley of California and increased incidence of jellyfish blooms worldwide. On Wednesday, January 12, Dan Rather began the CBS lead story with this statement: "A CBS News Exclusive: a new study finds global warming is real and getting worse as the White House plans to unveil an ambitious new program to fight it."

- *NBC Nightly News*, devoted an "In-Depth" segment on January 4, 2000 to the latest global warming data, indicating that since the mid-1970's global temperatures have risen .35 degrees Fahrenheit a decade. The following week, NBC ran two additional stories emphasizing the increasing certainty in the science of global warming.

The New York Times



# 1999 Continues Warming Trend Around Globe

By WILLIAM K. STEVENS

At the New York Botanical Garden in the Bronx, fragrant white blooms with a pink blush are breaking out on specimens of a popular landscaping shrub called the Koreanspice viburnum — four to five months early. Snowdrops, among the earliest bulbs to send up shoots when winter ends, have already poked up their noses. In some New York suburbs, yellow forsythia blossoms have brought a premature touch of spring to December.

"There's a little confusion out there," said Wayne Cahilly, an arborist at the botanical garden, and he expressed no doubt as to the reason: abnormal warmth. Or is it so unusual? "I think this warm weather is becoming normal," Mr. Cahilly said.

Certainly it seems that way of late. Last month was the warmest November in 105 years of record-keeping in the contiguous 48 states, and the fourth-warmest in the Northeast. The trend continued into December in most of the country; as of Friday, the average temperature for the month in New York, for instance, was 5.7 degrees Fahrenheit above normal.

But that is almost the least of it. Federal scientists reported last week that in the contiguous 48 states and on other global land masses, including Europe and Asia, 1999 is certain to join 1998 as one of the two warmest years on record, continuing a

*Continued on Page 18*

Richard L. Harbus for The New York Times

KEEPING TRACK

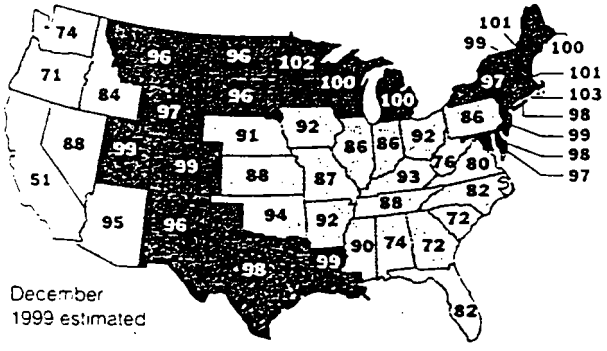
## Warmer and Warmer

Scientists are reporting that 1999 will join 1998 as one of the two warmest years on record across the contiguous United States.

**For 1999 . . .**

*Numbers are 1999's temperature rank since 1895.*
**105=Warmest, 1=Coldest**

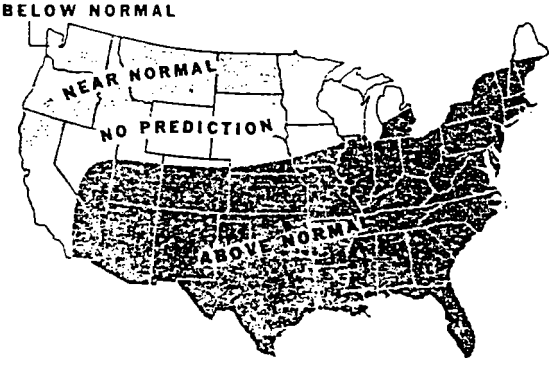
**Much above normal** *(104-95)* **Above normal** *(85-94)* **Normal** *(11-84)*




Source: National Oceanic and Atmospheric Administration

**. . . and for the next three months**

*Predictions for January, February and March of 2000 based on statistical analysis of past climate and current trends.*




The New York Times

ing climatic and agricultural zones.

The United States experienced record-breaking warmth in both of the two most recent winters, said scientists at the government's Climate Prediction Center in Camp Springs, Md. The center predicted last week that on average, most of the country would be warmer than normal over the January-through-March period just ahead.

In the winter of 1997-98, circulation patterns influenced by El Niño played a crucial role in the warmth. Last winter, different circulation patterns associated with La Niña had a similar effect. Both La Niña and El Niño modify North America's climate by changing the position of the jet stream, the high-altitude river of air that generally runs from west to east and marks the boundary between cold northern air and warm southern air.

In a La Niña winter, the jet stream typically plunges down through Montana and the northern Plains and then into the central part of the country before curving northeastward. This curve would normally take place in the East, but in a La Niña year it tends to take place farther west, leaving the Eastern Seaboard on the warm side of the warm-cold division marked by the jet stream.

Eventually this whole pattern drifts eastward, bringing cold weather to the East. An influx of cold northern air is in fact expected for the latter part of this month in the Northeast, said Fred Gadomski, a meteorologist at Pennsylvania State University. This progression happens repeatedly. Sometimes in a La Niña regime, the course of the jet stream temporarily flattens out and whisks warm Pacific air all the way across the continent. Mr. Gadomski said he would not be surprised if such a nationwide warm spell developed after the upcoming cold snap passes.

Other factors, too, are shaping the winter, scientists at the prediction center say. In addition to the general warming of the atmosphere, for instance, year-to-year flip-flops in circulation patterns over the North Atlantic can have a major effect on weather in the Eastern part of the country.

*The warmest decade in a century of record-keeping.*

If this so-called North Atlantic oscillation is in one mode, typified by low atmospheric pressure over the ocean, the East tends to be warm. If high pressure dominates, said Vernon Kousky, a research meteorologist at the prediction center, the jet stream tends to follow a southerly course into the ocean in the vicinity of Virginia and North Carolina. North of that, big snowstorms can develop, Mr. Kousky said, as happened in 1995-96, a La Niña winter in which a January blizzard dropped record snows from Washington to New York, essentially shutting down the nation's capital for days.

The North Atlantic oscillation's effect "never makes itself felt till the end of December or early January," Mr. Kousky said, adding that forecasters at this point cannot predict its behavior this winter.

A similar oscillation in the North Pacific may influence next summer's American weather, he said. The sea-surface temperature there flips back and forth between warm and cool states similar to those of El Niño and La Niña, but stays in one phase for several years. Researchers believe that it may recently have flipped into its warmer state. If it has, Mr. Kousky said, it could set off atmospheric chain reactions next summer that will bring a repeat of last summer's drought in much of the country's Northeastern quadrant, as well as a more active Atlantic hurricane season.

"We're trying to alert people to that possibility," he said.

Last summer's drought established records for dryness in the Northeast, the Middle Atlantic and the Ohio Valley, Mr. Karl's group reported last week. The April-to-July period was the driest or second-driest in all states from West Virginia to Maine. The drought was followed by record rainfall as hurricanes Dennis and Floyd struck the East Coast. Intensified drought and heavier rain are both expected to result from global warming, although no particular weather event of any kind can be attributed to it.

The Washington Post

AN INDEPENDENT NEWSPAPER

# Warming to Reality

BIT BY bit, industry is facing up to global warming. Last month Ford Motor Co. withdrew from the Global Climate Coalition, a lobbying group opposed to the Kyoto climate treaty. On Thursday DaimlerChrysler Corp. quit too; British Petroleum, Shell Oil and Dow Chemical left a while back. But as corporations move on, some politicians are lingering behind. On the campaign trail, Sen. Orrin Hatch routinely denounces the Kyoto accord, and Gov. George Bush has said that he opposes it. In Congress an ostrich caucus still insists that the scientific evidence for global warming is inconclusive.

For most of the world, 1997, 1998 and 1999 were the three warmest years on record. That is no mere blip: Since the mid 1970s, the world seems to have been warming at a rate of 3.5 degrees per century. Given that the world warmed by less than 10 degrees in the 20,000 previous years, the current rate is alarming. The unpleasant consequences may well include more extreme weather, a disruption to agriculture and rising sea levels that cause coastal flooding.

This warming is at least partly the consequence of human behavior: Cars, factories and coal fires produce carbon dioxide and other gases that accumulate in the atmosphere and alter climate patterns. A serious effort to reduce such emissions is therefore needed. Last year the administration promised to cut the federal government's fossil fuel emissions by 30 percent by 2010, and to triple national production of non-greenhouse "biomass" fuels derived from farm products.

But there is a limit to what the administration can do without the cooperation of Congress. For the past four years, Republican budget riders have prevented the administration from raising fuel-efficiency levels for vehicles. Congress has killed tax credits for fuel-efficient vehicles and air conditioners. The Senate has made it clear that it will not ratify the Kyoto climate accord. It will not even pass modest versions of the Kyoto idea, which would give industry an incentive to reduce greenhouse emissions.

The oil industry claims that compliance with the Kyoto accord would cost the average American family $1,500 to $3,000 a year. The Clinton administration declares that the extra cost of fuel-efficient machines is largely offset by the savings from reduced fuel purchases, rendering compliance all but free. The truth may lie somewhere in between. But reckless inaction in the face of global warming is the costliest of all options.

**Karin Vergoth <KVergoth@npr.org>**
02/18/2000 12:19:56 PM

Record Type: Record

To: Paul Bledsoe/WHCCTF/EOP

cc:

Subject: 2/18 Science Friday on Global Climate Change and Human Values

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Dear Paul,

Nice talking to you. Glad we can work together on this ....

Here's a short description of the symposium as it was presented this morning at the AAAS meeting. I've starred (*) the guests who will be on our show.

See below for info on our location for today's broadcast.

> Global Change, Earth Systems Science/ Global Climate Change and Human
> Values
>
> Organized by George W. Fisher, Johns Hopkins
> University;
> Devra Lee Davis, World Resources Institute
>
> Friday, February 18, 2000, 9:00am - 12:00noon
>
> SPEAKERS:
***Michael C. MacCracken, U.S. Global Change Research Program
> Certainty Versus Uncertainty: Explaining Global
> Warming to the Public
> *****Devra Lee Davis, World Resources Institute
> Climate and Health: Back to the Future-Donora
> and Mexico
> Adrian Fernandez, National Institute of Ecology,
> Mexico
> Co/W Davis
> ***** Francis G. Hilton, Loyola College
> Economic Values and Global Climate Change Policy
>
> ****Michael MacCracken, U.S. Global Change Research Program
> John Haught, Georgetown University
> Religion and the Natural World: Assumptions and
> Responses
>
> Decisions about how to respond to the consequences of
> global climate change depend upon a complex interplay
> between science and human values. Identifying the

> impact of
> alternative courses of action and assessing their
> effectiveness
> requires that we know all that we can about the
> relevant
> science. But our responses to anticipated impacts
> ultimately
> depend on our value systems. Our dependence upon
> values is
> most obvious when the science is uncertain. But even
> when
> the science is relatively clear-cut our values will
> play an
> important role in deciding how much importance to
> give
> questions such as equity of energy consumption,
> preservation
> of resources for future generations, and impact of
> our
> decisions on other cultures.
>
> This symposium will explore the interplay of science
> and
> human values from the perspectives of the science of
> climate
> change; the public health impact of climate change;
> the
> economic implications of climate change and proposed
> mitigation policies; the impact of climate change and
> climate
> change policy on the community of nations; and the
> relevance
> of religious and ethical thought. Speakers will
> outline what their
> area of expertise can contribute to understanding the
> implications of climate change and how it can help to
> articulate
> and appraise the value questions raised by global
> change.
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We'll be broadcasting from the Cotillion Ballroom North, located on the Mezzanine Level of the Marriott Wardman Park Hotel (2660 Woodley Road). This discussion will take place in the first hour of our show, from 2:00 to 3:00 pm. We'd like to have the guest here by about 1:45, and he/she will be done by 3:00.

Talk to you soon,

Karin

Karin Vergoth
Senior Producer, Science Friday

Paul Bledsoe
02/18/2000 12:56:48 PM

Record Type: Record

To: Karin Vergoth <KVergoth@npr.org>

cc:
Subject: Re: 2/18 Science Friday on Global Climate Change and Human Values

1. Can you tell us about the President's recent budget initiative to fight climate change, and especially about its emphasis on technology development as a way to delink greenhouse gas emissions from economic growth?

2. In recent months there has been a significant shift among major businesses, in the US and abroad, toward recognising a responsiblity to reduce greenhouse gas emissions. Can you talk about your efforts with the business community and how you see this shift changing the political atmosphere on climate change issues?