Global Climate Change

A Better Path Forward

ExxonMobil

A Better Path Forward

For more than two decades, Exxon Mobil Corporation has carefully studied and worked to increase understanding of the issue of global climate change, often referred to as global warming. The company is committed to a course of action on this issue consistent with sound science, solid economics and high ethical standards.

As a science- and technology-based company, we apply the same rigor on global climate change as we do in running a 3-D seismic survey off West Africa, designing a world-scale petrochemical complex in China or developing cleaner high-performance fuels and other products for world markets.

We agree that the potential for climate change caused by increases in carbon dioxide and other greenhouse gases may pose a legitimate long-term risk. However, we do not now have a sufficient scientific understanding of climate change to make reasonable predictions and/or justify drastic measures.

Some reports in the media link climate change to extreme weather and harm to human health. Yet experts (page 13) see no such pattern.

Dr. James E. Hansen, a leading scientist instrumental in focusing national attention on global warming a decade ago, expressed scientific uncertainty in an article in *Proceedings of the National Academy of Sciences USA:* "The forcings that drive long-term climate change are not known with an accuracy sufficient to define future climate change." [1]

Although the science of climate change is uncertain, there's no doubt about the considerable economic harm to society that would result from reducing fuel availability to consumers by adopting the Kyoto Protocol or other mandatory measures that would significantly increase the cost of energy. Most economists tell us that such a step would damage our economy and almost certainly require large increases in taxes on gas and oil. It could also entail enormous transfers of wealth to other countries.

This does not mean we favor doing nothing. We have redoubled our efforts in energy conservation at our own operations around the world. We have established cooperative programs with auto companies and others to develop environmentally friendly, next-generation automotive systems and fuels with significantly lower emissions and improved efficiency.

We are also working on gasoline-powered fuel cells for automobiles. We support scientific and economic research at a number of leading institutions, such as the Massachusetts Institute of Technology and Carnegie-Mellon University.

Lee Raymond

We believe that there is a better path forward – one that will allow us both to protect our environment and to sustain economic prosperity. The whole history of our industry has been a demonstration that we can achieve both goals, and new technology will have to be the key enabler.

Satellite technologies enable us in the oil and gas industry to explore with great precision before we ever touch the earth. Horizontal drilling has revolutionized the extraction process, reducing the impact on surface areas. Fuels today are cleaner and more efficient than ever before, minimizing humans' impact on the air and the planet.

Over time, we are learning more and more about how to safeguard both Earth and the well-being of the people who live on it. Through responsible stewardship, we are finding this balance and making it a reality.

We believe that no one – now or in the future – should have to choose between an earth that sustains life itself and the tools that make modern life possible and prosperous. Through responsible use of energy, we believe we will not have to make this choice.

Climate change is an important issue. We have an obligation to ourselves and to future generations to make sure it's handled properly.

Lee R. Raymond
CEO and Chairman

Introduction

Earth's climate is one of the most complex subjects science has ever attempted to explore. Climate is shaped by numerous variables, the vast majority of them natural, including sunlight, clouds, rain, wind, ice, storms, lightning, volcanoes, comets and magnetic fields. "Climate changes substantially due to natural processes," says Professor Ronald G. Prinn, head of the Department of Earth, Atmospheric and Planetary Sciences at the Massachusetts Institute of Technology (MIT).[2]

Throughout history, climate has shown considerable natural variability, without any human influence. Over time, Earth's climate has fluctuated dramatically between periods of cooling, including the Ice Ages, and periods of warming. Some of those changes lasted hundreds of years, others hundreds of thousands.

Dr. Kenneth Green of the Reason Foundation points out: "Some 11,500 years ago, there is evidence that temperatures rose sharply over short periods of time. In Greenland, temperatures increased by as much as 7° C [Celsius] over only a few decades, while sea surface temperatures in the Norwegian Sea warmed by as much as 5° C in less than 40 years."[3]

More recently, during a natural warming period about 1100 A.D., Vikings built a settlement in Greenland, and wine grapes grew in England and Nova Scotia. About 1450 A.D., the Little Ice Age began, bringing glaciers down from mountaintops and consequently ruining crops and starving surrounding communities.

The greenhouse effect

A naturally occurring phenomenon that warms Earth by about 30° C, the greenhouse effect allows life to flourish, transforming what would otherwise be a frozen, uninhabitable planet.

The sun sends energy to Earth, mainly as visible light, which radiates back to space as invisible infrared light. The greenhouse effect occurs because some of this infrared light is absorbed by gases and clouds that act as a blanket, slowing the flow of infrared radiation and warming Earth's surface.

Water vapor, which is water in the form of a gas, is the main greenhouse gas and accounts for about two-thirds of the greenhouse effect. The second-leading cause is naturally occurring carbon dioxide, or CO_2, which comprises about 0.036 percent of the atmosphere by volume. Besides its effect on temperature, atmospheric CO_2 is essential for all life on Earth. Every living human and animal continuously breathes in oxygen and breathes out CO_2, and plants require CO_2 for photosynthesis. Other greenhouse gases include ozone, methane, chlorofluorocarbons and nitrous oxide.

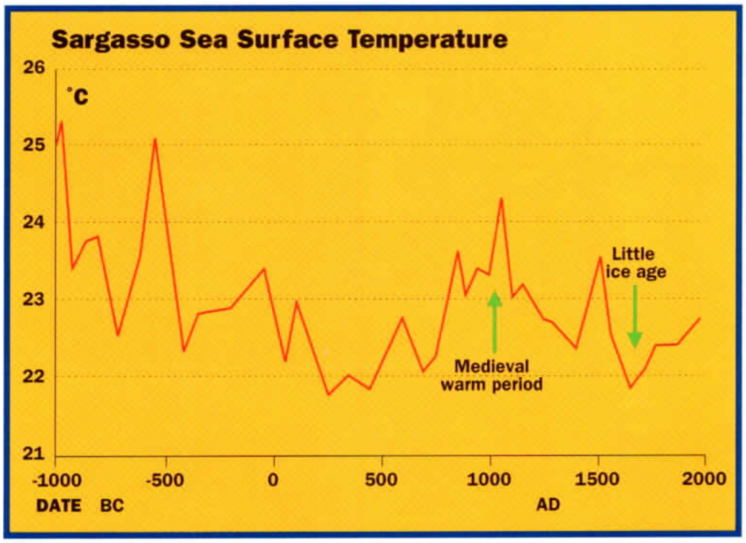
Natural versus human CO_2 emissions

Concerns about global warming arise from a potential enhancement of the greenhouse effect through burning fossil fuels – coal, oil, natural gas – and thereby releasing CO_2 and other greenhouse gases into the atmosphere. Many of the greenhouse gases are long-lived in the atmosphere. For example, it takes decades to centuries for CO_2 to disappear.

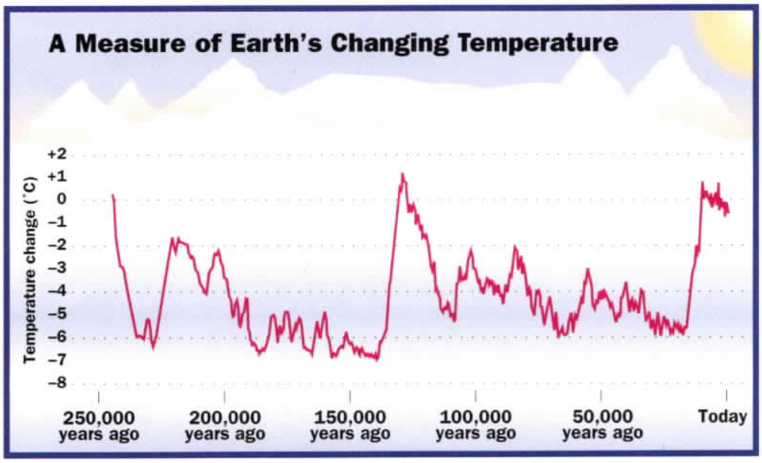
Measurements of air bubbles trapped in glacial ice show that since the mid-1850s, CO_2 levels in the atmosphere have risen from some 280 parts per million to about 365 parts per million today, a 30 percent increase. Observations at The Scripps Institute in Mauna Loa, Hawaii, have provided a precise record of the growth in atmospheric CO_2 over the past 40 years. The buildup has not been uniform. In the early 1990s, an unexplained slowdown occurred when emissions from human activities remained essentially constant.

Although emissions of CO_2 from burning fossil fuels certainly play a part in the recent buildup of

Cores from ice caps give scientists an idea of what climate was like in the distant past.



Sediments from beneath the Sargasso Sea, a calm stretch of the Atlantic Ocean between the Azores and the West Indies, provide evidence of significant natural temperature change throughout the past 3,000 years.



Ice core samples from Antarctica provide evidence of natural changes in Earth's temperature over the past 250,000 years.

CO_2, it is important to understand that the vast majority of CO_2 emissions come from natural sources. Only a relatively small amount comes from the burning of fossil fuels.

Natural atmospheric exchanges of CO_2 by photosynthesis, respiration and decay of vegetation, and by air-sea processes, release and take up about 160 gigatons (billions of metric tons) of carbon per year. By contrast, total annual emissions from fossil fuel use are about 6 gigatons, plus an additional 1 to 2 gigatons from deforestation.

Of this total human input of some 7 to 8 gigatons of carbon, about 3 gigatons accumulate in the atmosphere. Scientists are currently unable to explain what happens to the 5 gigatons that do not accumulate.

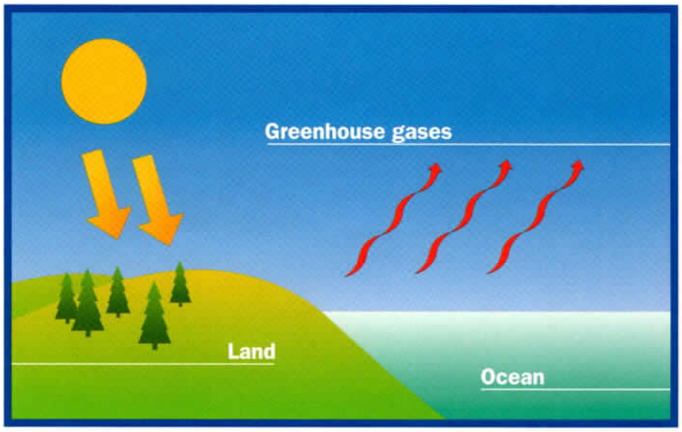
Carbon sinks

A number of natural sources, called carbon sinks, absorb carbon. For example, oceans and forests both absorb large volumes of CO_2. Trees and other vegetation breathe in CO_2 and release oxygen. Carbon dioxide is converted into pulp and stored in the trees' tissues. Also, the decaying vegetation from forests and other ecosystems enriches carbon in soils.

According to Dr. James Hansen and others, a slowdown in the growth of CO_2 concentrations in the atmosphere in the early 1990s may be due to carbon dioxide's being increasingly captured by growing vegetation.[4]

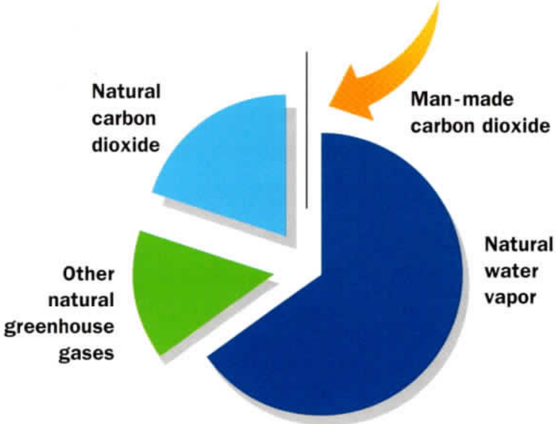
If emissions of carbon dioxide from fossil fuel use are eventually shown to contribute to global warming, one possible solution under consideration is carbon sequestration. Separating or isolating carbon dioxide from the earth's atmosphere could involve a range of strategies, from natural processes such as planting more trees to the use of technology to remove CO_2 from emissions and store it underground or in the deep ocean.

Greenhouse effect

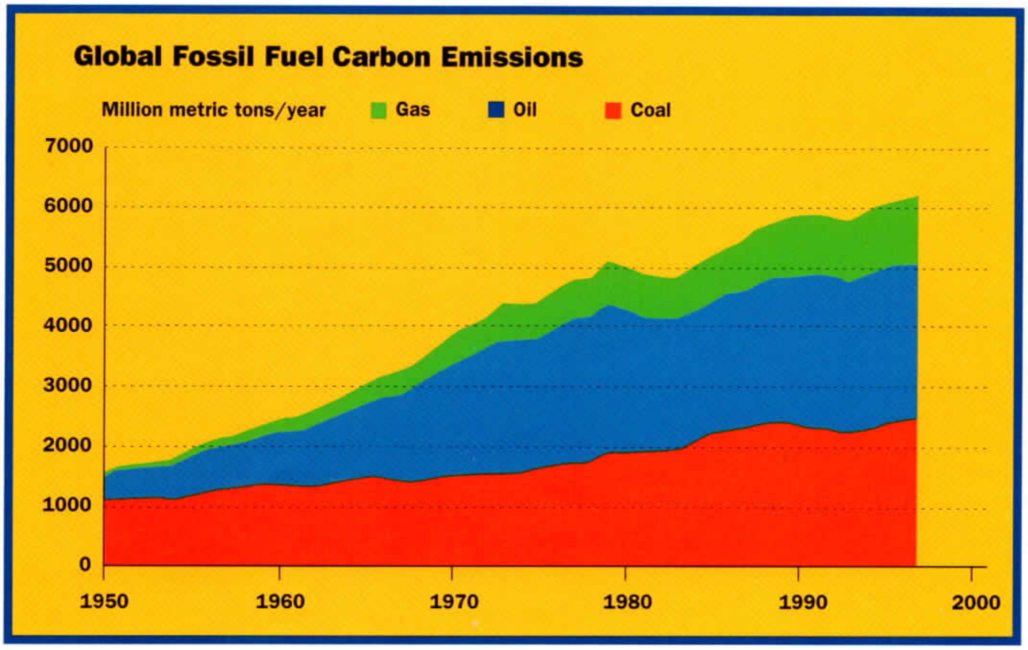


A balance between incoming solar energy and outgoing infrared radiation regulates the heat flow that powers Earth's climate. Greenhouse gases act as an insulator that warms Earth by slowing the outflow of infrared radiation.

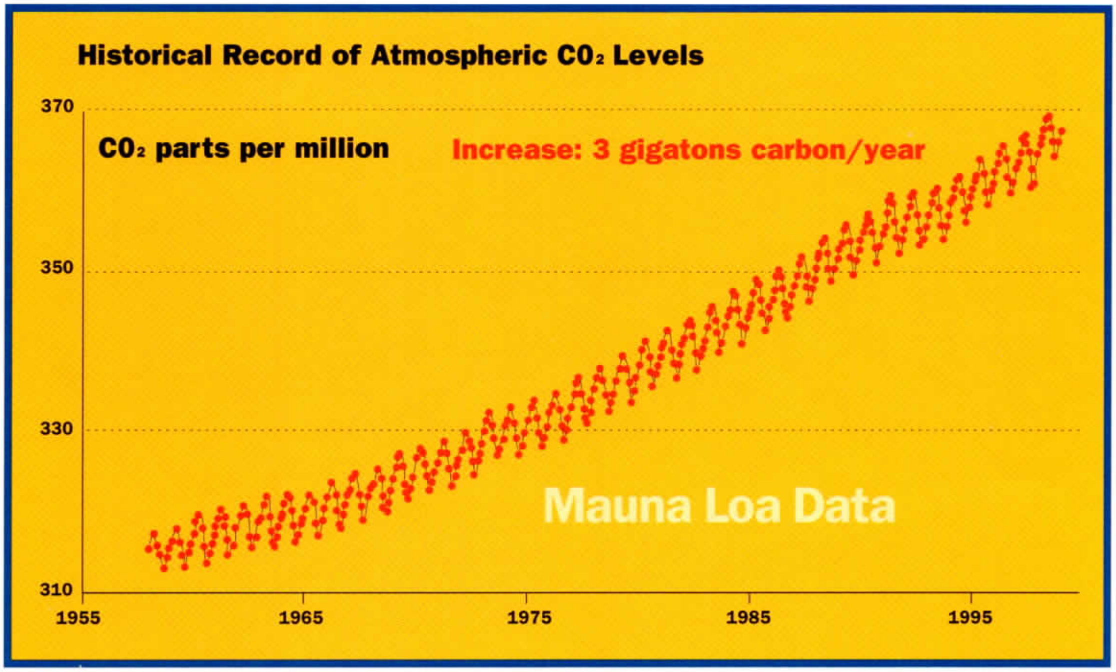
Sources of greenhouse gases



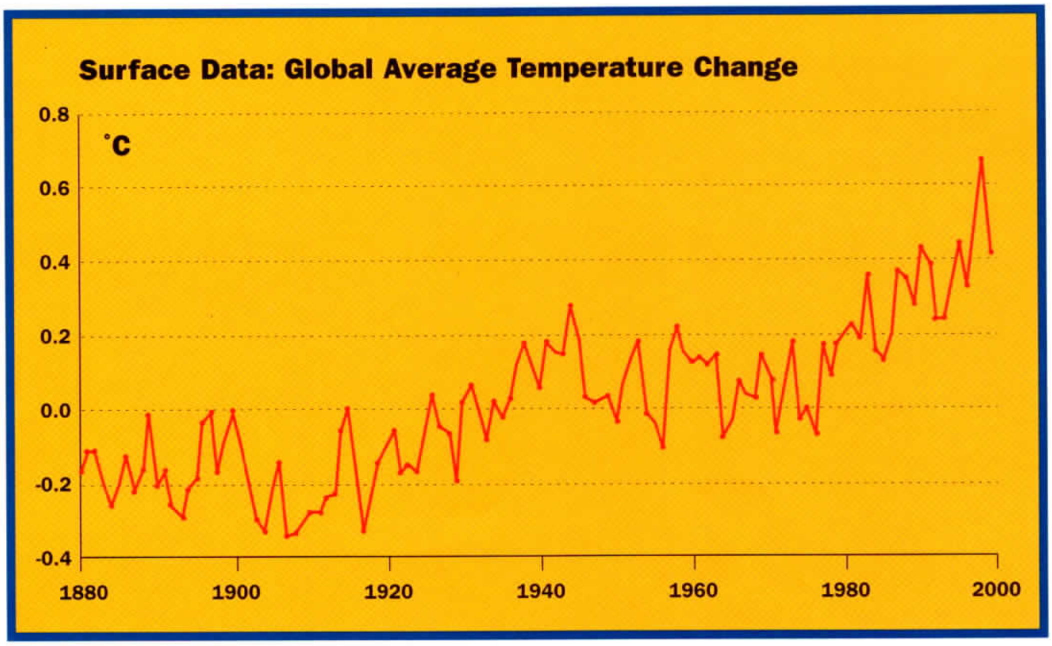
Water vapor accounts for about two-thirds of Earth's natural greenhouse effect, the remainder provided in roughly equal amounts by natural carbon dioxide and other greenhouse gases. The buildup of carbon dioxide in the atmosphere since 1850 adds to the greenhouse effect by trapping about 0.6 percent of the outgoing infrared radiation.



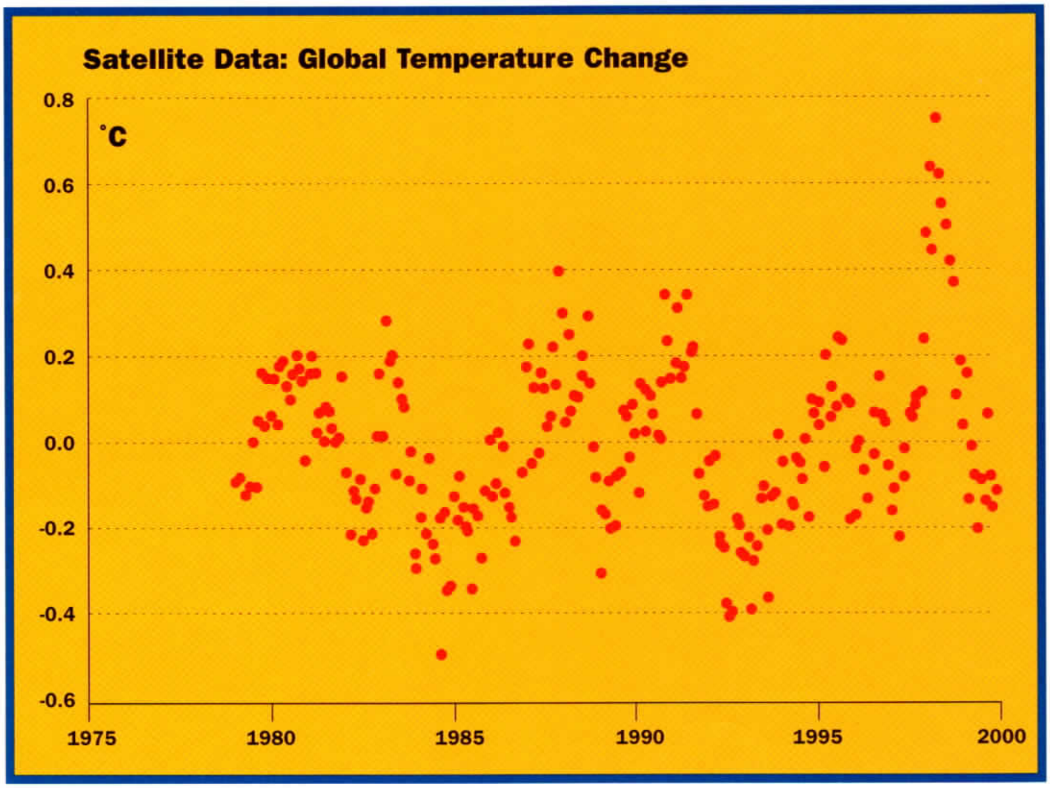
Oil and coal each account for about 40 percent of global fossil fuel emissions of CO_2, and natural gas accounts for about 20 percent.



According to measurements of atmospheric CO_2 concentrations from Mauna Loa Observatory, the average growth rate since 1955 is about 3 gigatons (billions of metric tons) of carbon per year.



Global average surface temperatures are calculated from thousands of individual station measurements spread across the globe. Observations are more complete over land in the Northern Hemisphere and since 1940.



Global average temperatures measured from satellites show little evidence of global warming from the late 1970s through 1997. An uptick in temperatures in 1998 was reversed in 1999.

CO_2 and global temperatures

With the buildup of CO_2 and other greenhouse gases under way for a century and a half, it's reasonable to ask whether we've detected any warming yet. The answer is that, over the past century, we've seen a slight warming of one-half degree Celsius (about one degree Fahrenheit).

Dr. Green of the Reason Foundation observes: "The warming is not uniform, either in chronology or distribution. More of the change occurs over land than over water. More of the warming happens at night, resulting in warmer nighttime temperatures, rather than hotter daytime temperatures. More of the warming is noticeable as a moderation of wintertime low temperatures, rather than as an increase in summertime high temperatures." [5]

Interpreting the meaning of the increase is complicated by several factors. One is that, for reasons scientists do not understand, Earth went through a Little Ice Age from about 1450 to 1850. Therefore, a natural period of warming may have started about the end of that time.

Another complication is the role of solar activity. Changes in the sun's energy output may be enough to cause average global temperatures to rise or fall. According to Dr. Judith Lean of the Naval Research Laboratory, "half the climate change from 1850 to now can be accounted for by the sun." [6] Astrophysicist Sallie Baliunas estimates that up to 71 percent of the observed climate warming of the past century is due to solar irradiance.[7]

Measuring Earth's temperature is a complex task, involving issues of completeness, accuracy and interpretation of historical data.

Most surface temperature readings are recorded near cities in the Northern Hemisphere. These readings often require significant corrections to account for the fact that urban areas, which have grown rapidly in recent decades, trap heat. Observations were far fewer in previous times, and information is missing over oceans even today. Volcanic eruptions, El Niño and other natural phenomena may cause global average temperatures to vary significantly from year to year.

Half the climate change from 1850 to now can be accounted for by the sun.

Dr. Judith Lean
Naval Research Laboratory

Dr. Green notes: "While the Earth's climate has been evolving and changing for over four billion years, recordings of the temperature only cover about 150 years. In fact, temperature records are spotty before about 40 years ago and only cover a tiny portion of the globe, mostly over land."[8]

With all this natural climate "noise" and the complexities of measurement, science is not now able to confirm that fossil fuel use has led to any significant global warming. Studies designed to make such a determination conclude that we would need to wait at least a decade before projected warming would exceed natural variability, even assuming the models are correct.

Surface temperature

The one-half-degree Celsius rise in surface temperature over the past century does not agree with trends in greenhouse gases. Much of the rise in temperature over that period occurred before 1940, but most of the increase in the use of fossil fuels has occurred since World War II.

During the past 150 years of instrument measurements, several years in the 1990s have set records, and 1998 was by far the warmest year during this period. However, scientists agree that a powerful El Niño, an irregularly occurring flow of unusually warm surface water along the western coast of South America, had a large influence on warming. Tim Barnett, climatologist at Scripps Institution of Oceanography, says, "Hindsight shows that much of last year's [1998's] unusual warmth was due to the recent El Niño short-term climate shift."[9] Since then, temperatures have fallen significantly.

Both El Niño and its opposite, La Niña, cause abnormal rainfall and temperature patterns over certain areas of the globe.

Satellite temperature

However, only within the last 20 years have reliable global measurements of temperatures in the lower atmosphere been available through the use of satellite technology. Satellites measure a signal characteristic of temperature across the lower and middle atmosphere rather than across the surface. These measurements are calibrated to agree with thermometer measurements from balloons. Satellite measurements are considered far more accurate and reliable in giving a direct global reading than are surface measurements.

Satellite measurements of global average temperature show little evidence of global warming from the late 1970s through 1997. After a spike in temperatures in 1998 due to El Niño, satellite-based measurements fell swiftly back into the normal range.

Climate models predict that temperatures in the lower atmosphere will rise even more rapidly than land temperatures. The continuing discrepancy between surface and satellite measurements illustrates a major gap in current understanding of climate.

The Intergovernmental Panel on Climate Change

In 1995, the United Nations Intergovernmental Panel on Climate Change (IPCC), a group set up to assess global climate change, issued an extensive report on the subject. The individual chapters in the report go into great detail to explain the current uncertainty in scientific knowledge. However, the summary for policymakers, the part most people read, was heavily influenced by government officials and others who are not scientists. The scientists were careful not to state any firm conclusions about the connection between the burning of fossil fuels and global warming.

The summary, which was not peer-reviewed, states, "The balance of evidence suggests a discernible human influence on climate."[10] The negotiated conclusion in the summary was, however, widely mischaracterized in the media as a finding that global warming is under way as a result of fossil fuel use. The statement is actually a truism. No one doubts that

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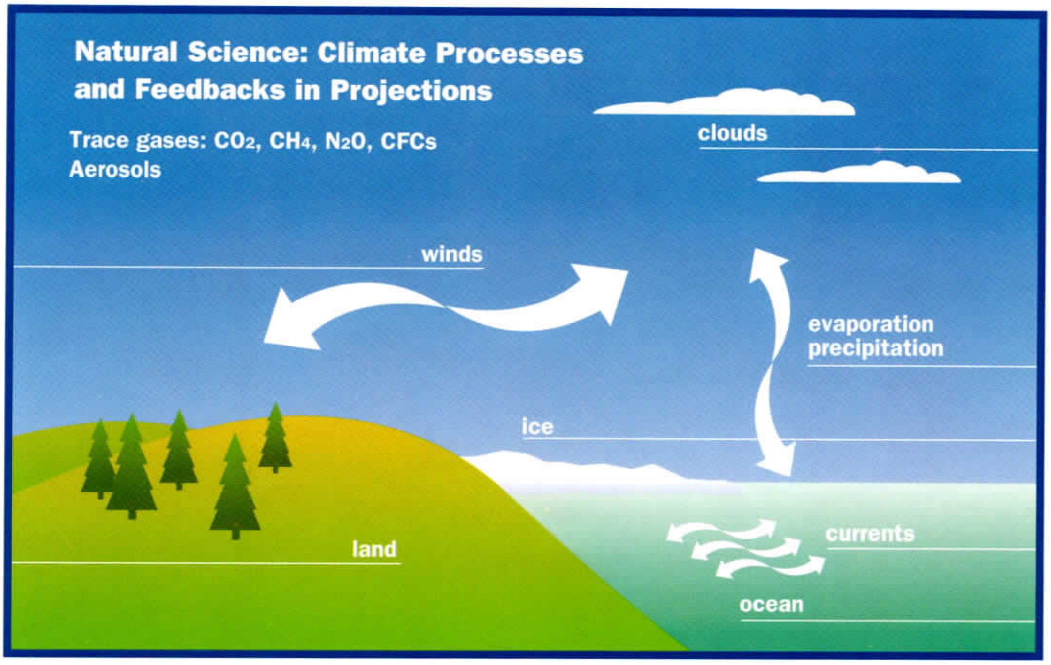
> Tim Barnett
> **Scripps Institution of Oceanography**



The climate system depends on the interaction of many complex processes which computer models attempt to take into account. Unfortunately, scientific understanding of many of these processes is insufficient to provide a reliable basis for predictions of future climate change.

humans influence climate in numerous ways, including through agriculture, deforestation and reforestation, and creation of urban heat islands.

Surprisingly, the statement does not mention greenhouse gas emissions or global warming. It speaks of the *balance of evidence* and uses the verb *suggests* instead of the more scientific terms *proves* or *demonstrates.*

Dr. Benjamin Santer, lead author of the report's chapter on detection and attribution of greenhouse warming, says: "It's unfortunate that many people read the media hype before they read the chapter. We say quite clearly that few scientists would say the attribution issue was a done deal."[11]

The IPCC is scheduled to publish another report in 2001. This report will present a summary of the latest scientific research on climate. However, government officials who are not scientists again will negotiate the conclusions in the summary for policymakers.

Does a scientific consensus on global warming exist?

Currently, there does not appear to be a consensus among scientists about the effect of fossil fuel use on climate. The IPCC report itself states: "Detection will be difficult and unexpected changes cannot be ruled out. Unambiguous detection of climate-induced changes in most ecological and social systems will prove extremely difficult in the coming decades. This is because of the complexity of these systems, their many non-linear feedbacks, and their sensitivity to a larger number of climatic and non-climatic factors, all of which are expected to continue to change simultaneously."[12]

Professor Prinn sums up: "There were a few scientists who were skeptical about the IPCC's 'balance of evidence' statement from the beginning. Now there are a growing number of scientists, including some who were involved significantly in the original IPCC conclusions, who are expressing doubts. It may be a decade or more before the human effects can be discerned above the noise of natural variability."[13]

A number of scientific forums, including the Leipzig Declaration, the Heidelberg Appeal and the open letter of the Advancement of Sound Science Coalition/European Science and Environment Forum, have questioned the evidence of a human role in climate change. A survey of state climatologists found that nine out of 10 of those surveyed agree that "scientific evidence indicates variations in global temperature are likely to be naturally occurring and cyclical over very long periods of time."[14]

These expressions of caution do not mean that concern about human-induced climate change should be rejected out of hand. The real question is whether current scientific evidence supports the theory that human-induced climate change is already occurring and that it will present a serious threat in the future.

Scientific evidence indicates variations in global temperature are likely to be naturally occurring and cyclical over very long periods of time.

Dr. Ronald G. Prinn, Chairman
Department of Earth, Atmospheric and Planetary Science
Massachusetts Institute of Technology

Climate and feedback uncertainties

From fundamental physics we know that the atmosphere must absorb more infrared radiation as greenhouse gas concentrations rise, if nothing else changes. However, other changes do occur. Once absorbed, it triggers feedbacks that can amplify or lessen warming and climate change.

These feedbacks occur as heat is transferred by winds and currents; the hydrological (water) cycle of evaporation, precipitation, runoff and groundwater; and the formation of clouds, snow and ice. Science today cannot properly describe these processes, which display enormous variability.

The inability to describe feedbacks creates considerable uncertainty in predicting climate change. For example, increasing CO_2 traps heat, warming the atmosphere slightly. The warmer atmosphere holds more water vapor, significantly amplifying warming. But this change may promote cloud formation, which can cool Earth's surface by reflecting sunlight.

The IPCC report acknowledges: "The single largest uncertainty in determining the climate sensitivity to either natural or anthropogenic changes [is] clouds and their effects on radiation and their role in the hydrological cycle. At the present time, weaknesses in the parameterization of cloud formation and dissipation are probably the main impediment to improvements in the simulation of cloud effects on climate."[15]

Aerosols, liquid or solid particles tiny enough to stay suspended in the air are another source of uncertainty. Most people are familiar with them as smoke or fog.

Their effects are complex and difficult to quantify. Sulfate aerosols reflect sunlight and therefore have a cooling effect. By contrast, soot aerosols are black and absorb sunlight, thus causing warming.

The indirect effect of most aerosols is cooling by causing formation of a greater number of smaller-sized water droplets in clouds. This increases the ability of these clouds to reflect sunlight.

Professor Prinn writes: "Scientists have only a low level of confidence in estimates of the magnitude of these aerosol forcing effects, but *in toto*, they could offset much of the effects of greenhouse gas emissions."[16]

Computer models and forecasting

Forecasts of future warming come from complex computer models known as general circulation models. The models have limited resolution, with grids representing hundreds of kilometers on a side, and other drawbacks that stem from an incomplete understanding of the variables of climate and their interaction.

Lack of understanding of clouds is a serious gap in modeling climate. Observations show that models represent clouds poorly in current climate. Yet the more difficult challenge for the models is to predict how clouds will change if climate varies. With today's scientific knowledge, this is not yet possible.

Oceans present another modeling problem. We need more-reliable data on their temperatures and a better understanding of how oceans respond to possible changes in the atmosphere.

Because of these gaps in our understanding of the science of climate, the models do a poor job of matching past climate trends and current climate. They are well known to have a limited ability to predict the magnitude, timing and regional distribution of future climate change.

Lack of reliable regional forecasts prevents meaningful assessment of most potential impacts of climate change. Different models produce significantly different results, especially for critical factors such as precipitation, soil moisture, drought and storms.

Computer models try to capture the behavior of complex climate processes, including the role of oceans, clouds, ice and snow, among others.

...the typical climate model is not accounting for what happens in the real world.

Dr. John R. Christy
National Aeronautics and Space Administration (NASA)
Marshall Space Center, Huntsville, Alabama

In recent years, as models have improved, predictions of future warming have dropped substantially. In 1990, the IPCC estimated a 3.3° C temperature increase by 2100. Five years later, that estimate had been lowered by more than one-third, to 2° C.

At a meeting of the American Meteorological Society in 1998, climate modeler Steve Marcus of the California Institute of Technology reported that a new, advanced general circulation model at the National Center for Atmospheric Research projected a future warming of 1.5° C.[17]

Why have forecasts of global warming been cut? Dr. Hansen has pointed out that the biosphere is absorbing carbon dioxide at a much faster rate than anticipated. He writes, "Apparently, the rate of uptake by CO_2 sinks, either the ocean, or, more likely, the forests and soils, has increased."[18] If that trend continues, Earth will take longer to warm than first thought.

The concentration of CO_2 in the atmosphere is rising by about 0.4 percent a year, instead of the 1.0 percent annual increase originally projected. The concentration of methane has actually declined. Dr. Hansen notes, "We don't know nearly as well as we'd like to why this is happening."[19]

Over the past two decades, Earth's surface temperature has risen at a rate of 0.15° C per decade. Yet climate models from the late 1980s projected that temperatures would increase three times that fast.

Satellite measurements of temperature in the lower atmosphere have risen at a rate of only 0.06° C per decade. "All global-warming models show that this atmospheric layer will warm as fast as or even faster than the surface of the Earth," says NASA's Dr. John R. Christy. "The fact that it has not suggests that the typical climate model is not accounting for what happens in the real world."[20]

Professor Mark Cane of Columbia University's Lamont-Doherty Earth Observatory sums up: "Even if the models were perfect, and even if the data coverage were extraordinarily good, it could still be the case that we're just not going to be able to predict what the state of the climate would be, a year from now or 10 years from now, or 50 years from now; just in the same sense that if I flip a coin, you can't predict whether it's going to be heads or tails.

"It's not a matter of a limit of knowledge; it's a matter of the system being such as to put limits in how precise a statement one can make on where the system is going."[21]

Potential changes in climate

The predictions of computer models are not a traditional scientific estimate bound by a known range of uncertainty. Rather, they are "best guesses" based on untestable assumptions. Even then, estimates of global warming from these unverifiable models have fallen by about 30 percent in recent years.

Recent models show warming between 0.9° and 3.5° C, with a best guess of 2° C. They predict that sea level will rise from 15 to 95 centimeters, with a best guess of 50 centimeters.

Given that these are less than scientifically reliable predictions, we can only speculate about the effects of future climate change. The 1995 IPCC report notes:

"There are inadequate data to determine whether consistent global changes in climate variability or weather extremes have occurred over the 20th century." [22]

One possibility is that higher concentrations of CO_2 in the atmosphere could boost agricultural production. It is well known that higher levels of CO_2 promote plant growth in controlled environments. Recent field experiments also show enhanced growth in natural systems.

The 1995 IPCC report concluded that society would be able to meet agricultural needs in the next century, in part reflecting confidence in the ability of farmers to adapt.

Climate models cannot predict regional climate change, however, and are especially weak in assessing hydrology (water) impacts. Hydrologist Harry Lins and mathematician James Slack of the U.S. Geological Survey concluded that floods have not increased in recent years: "We do not see any evidence of a change in large-scale national patterns." [23]

Concerns have been expressed that climate change causes extreme weather, such as hurricanes and sudden climate shifts, but these concerns are largely speculative and without scientific confirmation. The IPCC report concluded, "Overall, there is no evidence that extreme weather events, or climate variability, has increased in a global sense through the 20th century, although data and analysis are poor and not comprehensive." [24]

Dr. Christy says, "The recent fixation on extreme events as indicators of climate change is misleading because we know very little about the rates of their occurrence and we are able to publicize even marginal extremes to fantastic proportions. Perspective is often lost in the media." [25]

The IPCC report describes primarily negative human health effects from global warming, including increased heat stress and the spread of infectious diseases. However, long-term health models are in a very preliminary stage of development, and the report does not cover response options. Public health measures have been effective in controlling such threats throughout the developed world.

Recent estimates of negative impacts have fallen considerably, with positive effects gaining. Some studies show that means of adaptation exist to counter many of the perceived threats.

The many uncertainties in the science of climate have led Professor Prinn of MIT to conclude, "There is no doubt that our present understanding of climate – and our ability to predict climate – are inadequate to provide a sharp focus for policymaking." [26]

In ExxonMobil's view, enough is known about climate change to recognize that it may pose a legitimate long-term risk, and that more needs to be learned about it. The challenge is to take responsible action and recognize the uncertainty while not damaging prosperity.

There is no doubt that our present understanding of climate – and our ability to predict climate – are inadequate to provide a sharp focus for policymaking.

Dr. Ronald G. Prinn, Chairman
Department of Earth, Atmospheric and Planetary Science
Massachusetts Institute of Technology

The Kyoto Agreement

In December 1997, representatives from many governments met in Kyoto, Japan. Ultimately, they put together an agreement to curb carbon dioxide and other greenhouse gas emissions in some countries. The agreement would commit 38 developed countries to reduce their combined emissions an average of 5 percent below 1990 levels between 2008 and 2012. For the United States, the proposed reduction is 7 percent. The protocol excludes more than 130 developing countries from any commitments.

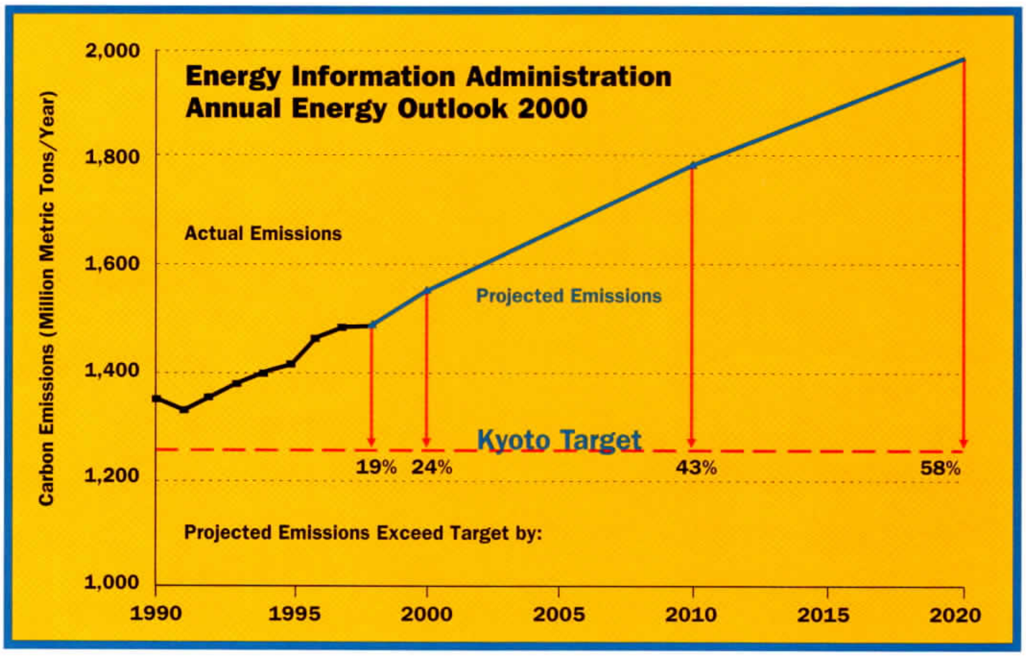
For the protocol to take effect, it must be ratified by at least 55 countries, and these must include countries responsible for at least 55 percent of 1990 CO_2 emissions from developed countries.

Although 5 percent may sound like a small reduction, it is important to understand that as a result of economic growth and increasing populations, emissions are increasing in nearly all countries. Relative to where emissions are projected to be, the target will be extremely difficult to meet in most countries.

For most nations the Kyoto Protocol would require extensive diversion of human and financial resources away from more immediate and pressing needs in health care, education, infrastructure and the environment – all critical to the well-being of future generations.

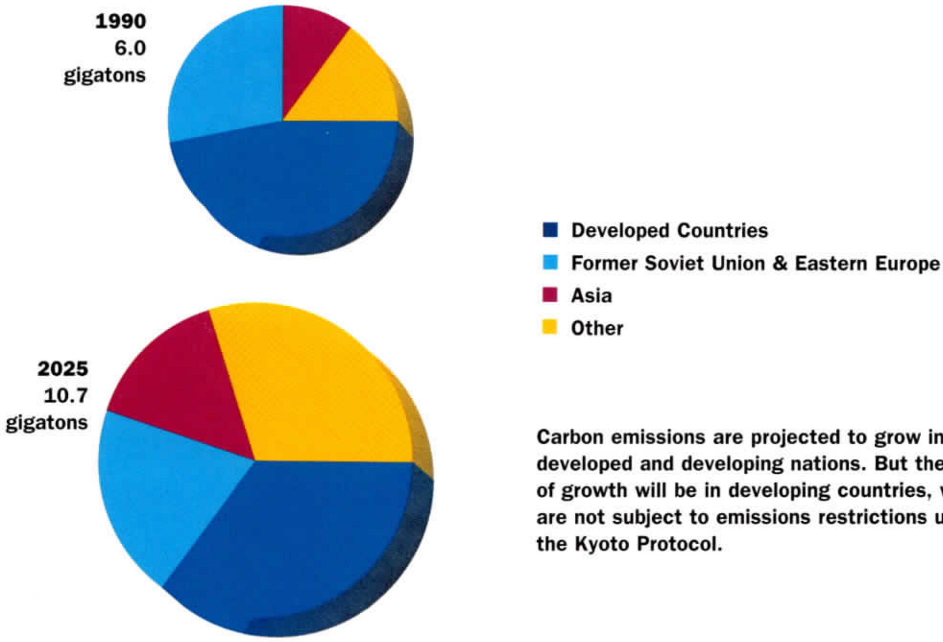
Effects of reducing CO_2 emissions

A recent analysis by the American Society of Mechanical Engineers concludes that, using current technology,



In 1998, carbon emissions in the United States exceeded the Kyoto target by 19 percent. They are projected to grow to 43 percent above the proposed Kyoto target by 2010. The economic recession in 1991 had only a small negative effect on carbon emissions.

Projected Global Fossil Fuel Emissions



Carbon emissions are projected to grow in both developed and developing nations. But the majority of growth will be in developing countries, which are not subject to emissions restrictions under the Kyoto Protocol.

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the United States will fall "far short" of the greenhouse gas emission cuts set under the Kyoto Protocol.[27]

Official U.S. government forecasts project that emissions in the year 2010 will exceed the Kyoto target by 43 percent.[28] To reach the target, the United States would have to take steps that would be equal to stopping all driving, closing all electric power plants or shutting down every industry.[29] Obviously, these are not realistic options.

A government study of six key U.S. industries found that meeting the Kyoto targets would cause production and employment to drop significantly.[30] Many other industries not included in the study would also be hurt.

Nearly all developed countries would have to impose substantially higher fossil fuel taxes, rationing, or lifestyle changes, such as mandatory carpooling.

Effects on developing countries

Projections show that developing countries, including China, Mexico, Brazil and India, all excluded from the protocol, will account for almost 70 percent of total carbon emissions growth from 1990 to 2025. Those four nations alone hold about 40 percent of the world's population. If burning fossil fuels proves to be a significant factor in global climate change, excluding developing nations from the agreement raises the question of whether that agreement is fair – and more important, whether it will work.

For developing countries, the impacts of Kyoto would be mixed. Energy-exporting countries would suffer serious losses.

Kyoto restrictions would lower demand for goods in industrialized nations, decreasing the imports from most developing countries. That could significantly disrupt global trade and economic growth. Because they would be exempt from requirements to cut carbon dioxide emissions, developing nations might attract more industry and jobs from industrialized countries that restrict fossil fuel consumption. That means fewer jobs in countries that do impose such limits.

Developing countries face enormous challenges, such as alleviating poverty and raising living standards, extending life expectancy and expanding educational opportunities. These countries, which are growing rapidly, desperately need energy to improve the welfare of their people. They have not agreed to limit their energy use and could not do so without undermining growth.

Gaps in the Kyoto Protocol

Many provisions of the Kyoto Protocol remain to be resolved in future negotiations:

- The protocol is silent concerning compliance, a factor that many governments regard as essential before making commitments that affect their economic security.

- Some people have expressed concerns about national sovereignty. Enforcement of the protocol would require an international bureaucracy that could affect a nation's security if fossil fuel restrictions were applied to military forces.

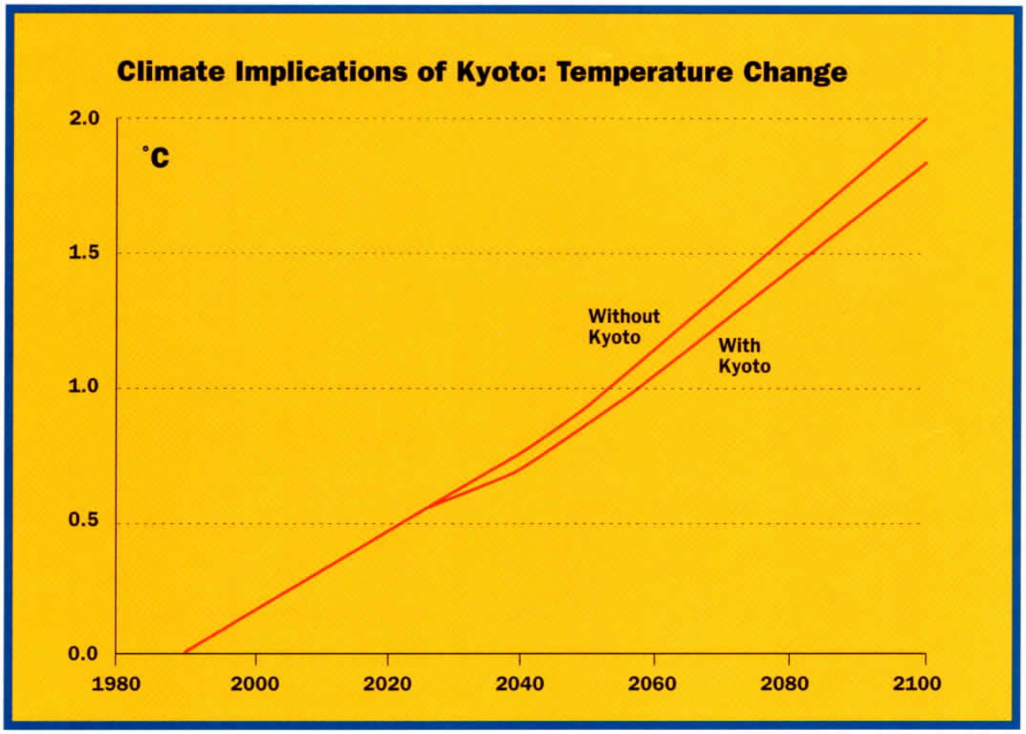
- The agreement authorizes nations to utilize mechanisms such as emissions trading and credits from projects with developing countries to meet commitments. However, procedures must be negotiated, and nations' views on key issues vary considerably.

- Similarly, ways to account for changes in forests and other CO_2 sinks must be worked out.

- Developing nations have been unwilling to make commitments to limit their CO_2 emissions.

Meetings were held in Buenos Aires in 1998 and Bonn in 1999 to resolve these and other issues related to the Kyoto Protocol. However, there has been little progress – an indication of how complicated and unworkable the protocol is.

"Kyoto is a short-term solution to a political problem. What we need is a long-term approach to an issue involving science and economics."
Dr. Richard Schmalensee, Dean,
Sloan School of Management,
Massachusetts Institute of Technology (MIT)



Because most of the growth in carbon emissions will occur in developing countries, the Kyoto agreement, if adopted, would have little impact on future climate.

Climate implications of the Kyoto Protocol

Climate change is truly a long-term issue that requires a long-term approach. The net effect of the Kyoto Protocol on global temperature is quite small. In effect, the protocol would delay by only some 10 years the warming projected to occur by 2100.

Unrealistic as the Kyoto limits may be to achieve, far more onerous emissions reductions would be necessary if climate change proves to be serious. Clearly, any effective approaches would need to limit global emissions, and that would require involving developing countries. Such severe limits would also require the development and global deployment of new, currently noncommercial technologies for energy supply and use. Changes of this magnitude would require decades to achieve.

Professor Richard Schmalensee, a noted economist at MIT and dean of its Sloan School of Management, points out: "With our current understanding of the science and economics of climate, we know enough to take the global warming issue seriously. We don't, however, know enough to do anything drastic."[31]

What should we do?

Enough is known about climate change to recognize it may pose a legitimate long-term risk and that more needs to be learned about it.

A responsible path forward must be marked by rational scientific, economic and technical analysis. And it must include actions now on several fronts:

- **Continued research to understand the climate system**
- **Cost-benefit analyses of proposed responses**
- **Promotion of energy efficiency**
- **Research on and development of promising technology**
- **Removal of regulatory tax restrictions that hamper introduction of new technology and present barriers to its widespread application**

Let's take a closer look at each item.

Improve scientific understanding

First, we need a thorough scientific understanding of climate change so we can have a strong foundation on which to base policy.

Fortunately, all indications are that climate change is a very long-term phenomenon. The U.S. Congress Office of Technology Assessment has concluded, "Delaying the implementation of emissions controls for 10 to 20 years will have little effect on atmospheric concentrations of greenhouse gas emissions."[32]

We can make good use of that time. Researchers will be able to gain a better understanding of climate science. A lot of research is going on – about $2 billion worth a year in the United States alone.

ExxonMobil has funded studies by a number of major research organizations:

- **Massachusetts Institute of Technology**
- **Marine Biology Laboratory**
- **Bermuda Biological Station for Research**
- **Stanford Energy Modeling Forum**
- **Carnegie-Mellon University**
- **Arizona State University**
- **United Kingdom Meteorological Office (Meteorological Research Flight and Hadley Centre for Climate Prediction and Research)**
- **University of Manchester Institute of Science and Technology**
- **Columbia University's Lamont-Doherty Earth Observatory**
- **International Energy Agency's Greenhouse Gas R&D Programme**
- **Battelle-Pacific Northwest Laboratories**

As part of the International Petroleum Industry Environmental Conservation Association, ExxonMobil helped fund cloud research at the Hadley Centre in the United Kingdom. Researchers used a C-130 Hercules, with a specially fitted long nose, to probe clouds and study how they trap heat and reflect sunlight.

A cogeneration facility at ExxonMobil's refining and chemical manufacturing complex in Baytown, Texas, makes steam and electricity simultaneously, using about 30 percent less energy than required to make them separately. The company operates or has interests in cogeneration facilities at 24 locations around the world. Together, the electricity generated would meet the residential needs of 3 million people.

Conduct cost-benefit analyses of proposed response options

While the Kyoto Protocol is portrayed as an environmental agreement, in fact its restrictions on energy use would affect economic growth, competitiveness, employment, trade, investment and individual lifestyles while doing very little to address climate change. We believe that citizens have a right to know the consequences of suggested government policies before they are implemented, so proposals must be thoughtfully analyzed to assess their costs as well as their benefits to society. It is important to recognize that policy mistakes can be serious, and they may even limit our opportunity to respond effectively later.

Accelerate improvements in efficiency

Third, industries should continue their voluntary market-driven efforts to identify and implement cost-effective ways to reduce energy use, and thus lower emissions.

In its own refineries, chemical plants and other operating facilities, ExxonMobil has been recovering and reusing heat, increasing insulation, reducing processing temperatures and conducting energy-efficiency surveys for many years.

The company established a task force in 1998 to develop a comprehensive and global Energy Management System to further improve energy efficiency at all ExxonMobil refineries and chemical plants. Our objective is to continue as an industry leader in energy utilization and efficiency.

Cogeneration enables the company to make steam and electricity simultaneously, providing operational efficiencies and environmental benefits. Typically, these projects reduce energy consumption by about 30 percent. Worldwide, ExxonMobil's cogeneration capacity is more than 2,000 megawatts, enough electric power to meet the needs of 3 million people.

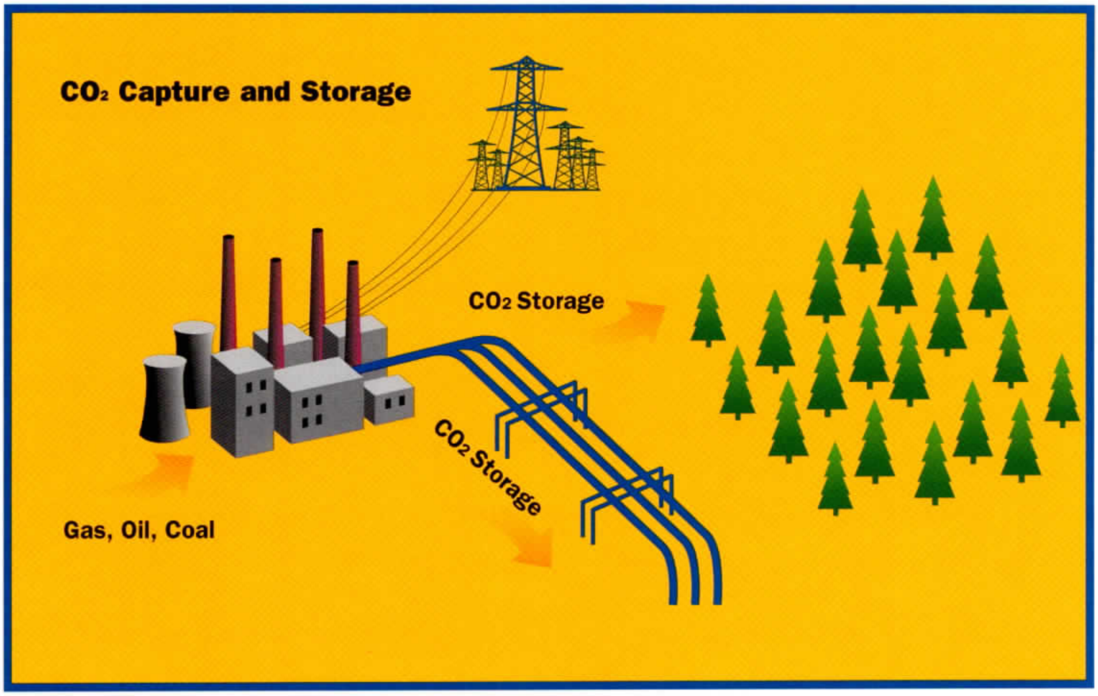
We've substantially reduced flaring of gas at production facilities since 1990. A number of factors have contributed to this result. They include gas sales, economic gas reinjection and operational emphasis on flare minimization (e.g., improved machinery reliability, shutdown coordination).

ExxonMobil is participating in the Natural Gas Star program of the U.S. Environmental Protection Agency (EPA). The program advocates best-management practices to reduce methane emissions, including installation of no-bleed or low-bleed pneumatic valves and collection of flash gases from glycol reboilers. The company has also installed vapor recovery systems on storage vessels, eliminated a number of storage tanks and converted instrument gas systems to compressed instrument air.

We've also implemented a number of lighting improvements and efficiency steps at major office and manufacturing complexes since the mid-1980s.

In recognition of our efforts to save energy, the Environmental Protection Agency awarded ExxonMobil its "Green Light Partner of the Year" award in 1994 and its "Energy Star Buildings Partner of the Year" award in 1998.

Our refineries and chemical plants continue to improve energy efficiency through innovations in technology, cogeneration of electricity and steam, and better management practices. Greater energy efficiency reduces emissions, saves natural resources and makes good business sense.



CO_2 capture and storage can significantly reduce CO_2 emissions from fossil fuel power generation.

Develop and apply new technology

Fourth, if it is determined that we do need to scale back CO_2 emissions, one of the best ways is through new technology.

As it becomes economical to do so, industry is applying advanced technology to reduce both energy use and CO_2 emissions. Long-term research should continue to render substantial improvements in energy efficiency.

ExxonMobil has participated in research partnerships with Ford Motor Company and General Motors Corporation since 1996 to develop gasoline-powered fuel cells for automobiles. Fuel cells combine hydrogen and oxygen to produce electric current for use as a power source. The company is also working with Ford on advanced diesel engines to optimize fuel, engine and engine controls.

The goal of the fuel cell program is to develop a small, reliable onboard gasoline reformer to generate hydrogen for use by a fuel cell. This approach would allow the existing infrastructure of service stations to provide fuel for automobiles of the future that would be powered by fuel cells.

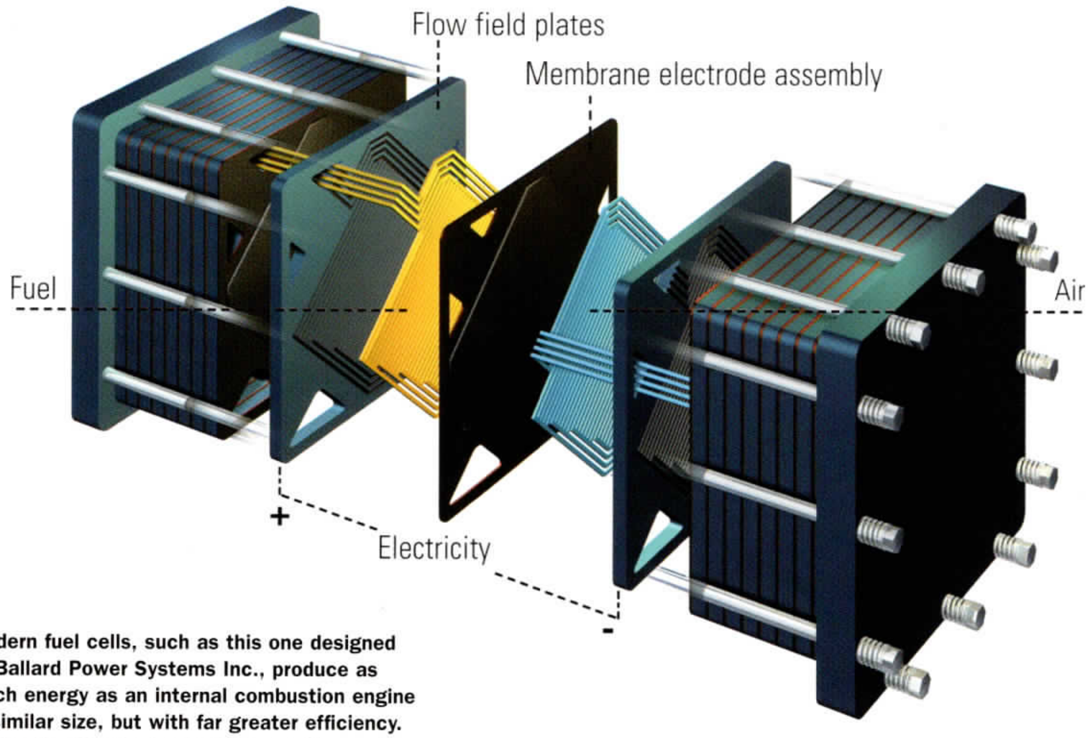
ExxonMobil is participating in a long-term alliance with Toyota Corporation to develop environmentally friendly, next-generation automotive systems with significantly lower emissions and improved efficiency.

This joint effort brings together expertise in the petroleum and automotive industries to accelerate the pace of development for advanced internal combustion engines and hybrids, along with the fuels and lubricants these technologies will require. ExxonMobil and Toyota have worked together to provide high-performance products for more than 25 years.

ExxonMobil also has had a long-standing technical relationship with Peugeot S.A. Since 1994, we have worked with Peugeot and catalyst manufacturer Englehard Corporation on reducing nitrogen oxide (NOX) emissions from diesel engines. This effort is expected to lead to wider acceptance of diesel engines, which offer improved fuel efficiencies.

ExxonMobil has long been a leader in developing lubes that improve fuel economy. Current research in automotive engine oils is expected to improve retention of fuel efficiency over the life of the oil. Industrial lubricant and grease research also contributes to enhanced energy efficiency in a wide variety of transportation and industrial equipment.

Although the potential of technology is significant, everyone offering solutions to environmental challenges should bear two cautions in mind.



Modern fuel cells, such as this one designed by Ballard Power Systems Inc., produce as much energy as an internal combustion engine of similar size, but with far greater efficiency. Fuel cells offer the potential to provide much higher fuel economy than possible in today's automobiles.

- **Research on promising projects does not always succeed.** For consumers to accept new technology, it must meet many demands, including affordability, performance, safety and environmental impacts, among others. In short, markets – not politicians – will inevitably decide which products are successful.

- **New technology requires time to develop and deploy.** Consequently, even when a technology proves that it can work and is cost-effective, it may take years for its use to become widespread. Moreover, to address climate change, new technologies must spread over the entire globe. We cannot pursue high-cost options just for the developed world. To affect global emissions, technology must be affordable everywhere.

Remove regulatory and tax barriers

Apart from their technical and economic merits, investments in energy efficiency and the deployment of new technologies, including their export to other nations, are influenced by government policies. These policies, which are embodied in regulatory and tax provisions, should not hamper these initiatives, and barriers should be removed.

Other steps

Almost all greenhouse gas emissions related to our products come from customer use. Nevertheless, ExxonMobil and its affiliates are participating in a variety of programs to study methodologies for consistent industry reporting of greenhouse gases associated with the manufacture of our products.

Scientists are also looking at ways to capture CO_2 emissions from fossil fuel use by absorbing them. One way is to plant more trees, which absorb CO_2 naturally and provide many other environmental benefits.

...we support a wide range of research and other activities designed to help people and industries use energy more wisely and efficiently now and in the future.

ExxonMobil is helping to fund American Forests' Global Releaf program, which plants trees in the United States and other countries. To date, we will have helped to plant more than 3 million trees throughout the world.

Conclusion

Enough is known about climate change to recognize that it may pose a long-term risk and that more needs to be learned about it. We believe that research to reduce the scientific uncertainties is essential. In the meantime, we support a wide range of research and other activities designed to help people and industries use energy more wisely and efficiently now and in the future.

By applying sound science, solid economics and high ethical standards to this issue, we are optimistic that the world can discover solutions that both protect the environment and keep economies healthy and growing.

Notes

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