Global Climate Change

Esso Italiana
September 14, 1996

Brian P. Flannery
Exxon Research & Engineering Co

VG-1 (Title) Good Morning. It is a pleasure to have the opportunity to discuss Global Climate Change with you. First, let me explain my background. I am a scientist. I have participated in climate research since joining Exxon in 1980, also I am a long term industry observer of the international political process. In the early 1980s I helped develop the models now used to project temperature and sea level change by the Intergovernmental Panel on Climate Change (IPCC), and our published work on stabilization of carbon dioxide (CO_2) and detection of climate change is included in the latest IPCC assessment. In the jargon of the media and politics that surrounds much of the climate change debate I am neither a contrarian nor an alarmist.

However, I am concerned that the policy debate isolates climate change as an environmental issue. For instance, at COP 1 in Berlin last year and at COP 2 this summer nearly every government speaker was an environment minister. Yet, the proposed responses to climate change involve fundamental, mainstream policy in economics, labor, energy, agriculture, industry, transport, trade, and security. I would like to encourage a more rational policy debate. One that recognizes that choices involve trade-offs, one based on a realistic appreciation of what we know and what we don't know.

My talk will focus on two areas:

- scientific and technical analyses of climate change, and
- proposals for international action under the Climate Convention.

Many politicians and environmental groups would like us to believe:

1) that the science is now set, that it demonstrates a *proven, unacceptable risk*, and,
2) that there are readily available opportunities to *eliminate the threat of climate change* through economically viable energy efficiency and deployment of renewable energy.

However, that is not the case. Scientific, technical, and economic understanding remain limited by enormous uncertainty. Not the type of uncertainty where findings are known within some limited precision, plus or minus some factor. Rather we are simply ignorant. We don't know how to describe what may happen. Descriptions of impacts of climate change are based either on unverified models full of untestable assumptions, or often on sheer speculation. Similarly, in choosing response options, society faces trade-offs, not easy choices. Proposals, such as those of the European Union to stabilize CO_2 concentrations at 550 ppm or less, will be costly. They may not be feasible technically, economically, or politically. They must rely on development and global deployment of unproven non-commercial technologies. Even with well funded, long term research and development there is no guarantee that alternative energy technologies will be environmentally, socially, and economically acceptable. Past experience with large, government-funded energy programs in nuclear and synthetic fuels should be sobering examples to those now advocating major programs in renewables. They will be costly.

I'll start with a discussion of the science...

The Natural Greenhouse Effect exerts a powerful influence on Earth's temperature and climate, warming the surface by about 30°C. It occurs because trace atmospheric gasses inhibit the flow of infrared (IR) radiation to space that balances heating by sunlight. These are primarily water vapor (H_2O), carbon dioxide (CO_2), and ozone (O_3). Concerns arise about a potential enhancement of this effect from human activities that have contributed to increases in several greenhouse gasses, especially CO_2, methane (CH_4), chlorofluorocarbons (CFCs), and nitrous oxide (N_2O). In the time available my talk will focus on CO_2 and energy related greenhouse gas emissions. However, other gasses also affect greenhouse concerns, and options exist to address their emissions that may be more environmentally and economically attractive to implement than options related to CO_2.

The next three slides illustrate the most important observational evidence about possible human influence on climate.

VG-2 Here is the famous Mauna Loa record of increasing atmospheric CO_2. Observations at The Scripps Institute began in 1958 as part of the International Geophysical Year. The curve shows a steady increase in CO_2 with an obvious annual cycle. The cycle occurs because CO_2 is drawn down during the growing season and released in fall and winter. CO_2 has risen from 315 ppm in 1958 to over 355 ppm, today. CO_2 mixes rapidly in the atmosphere, so results for CO_2 growth are similar across the globe. Net accumulation of carbon as CO_2 in the atmosphere is about 3 gigatons (billions of metric tons) per year (GtC/yr). Measurements of air bubbles trapped in glacial ice show that the recent buildup began with the industrial era. Growth is about 28% since the mid 1800s when CO_2 was about 280 ppm (±10 ppm).

<u>VG-3</u> The second data set shows *recent trends in CO_2 emissions from fossil fuels. Today gas accounts for about* 20% of CO_2 emissions, with oil and coal accounting for about 40% each. Total annual emissions today are about 6 GtC from fossil fuel use, plus an additional 1-2 GtC from deforestation. Estimates of deforestation are quite uncertain. There is no quantitative explanation why the annual accumulation is 3 GtC when emissions are 8 GtC. Note that growth is not uniform. There was a noticeable slowdown in the early 1990s when emission rates remained high. Likely this occurred from some change in the large natural fluxes of CO_2 in and out of the atmosphere. Atmospheric exchanges of CO_2 by photosynthesis, respiration and decay of vegetation, and by air-sea processes release and take up about 160 GtC/yr, amounts far larger than human inputs. This is completely unlike the situation for CFCs, for example, where humans emissions are the only sources and where molecules are destroyed in the atmosphere. Factors that control natural fluxes of CO_2 are not well understood. There is no reason to expect that existing trends between emissions and atmospheric buildup will continue in the future.

<u>VG-4</u> The buildup of greenhouse gasses has proceeded for well over a century, so it is reasonable to ask whether we have detected warming from an enhanced greenhouse effect. Observations still do <u>not</u> confirm that human activities have led to any global warming. The third data set shows the record of global average surface temperature change. This is a statistical concept. There are complex issues concerning completeness, accuracy, and interpretation of historical data. There are fewer measurements at earlier times, and information is especially missing over oceans,

even today. The most obvious feature is the large scatter of a few tenths of a degree from year to year. This natural "climate noise" arises in part from specific events like the Pinatubo volcano and changes in oceanic upwelling (such as El Niño), and in part also from random natural fluctuations.

Warming amounts to about 0.5 °C over the last 140 years. This increase is entirely within the range of natural variability. The pattern of warming with time does not agree with trends in greenhouse gasses. Most obvious is the cooling from the 1930s to 1970s when models predict warming. Also, much of the warming results from increases in nighttime low temperatures, rather than increases in daytime highs. Satellite measurements begun in 1979 show little evidence for global warming. Although they measure a different signal, corresponding to mid-tropospheric temperature, they are far more accurate and reliable in giving a direct global measurement.

Studies of the amount of warming that would have to occur to confirm "detection of manmade climate change" conclude that it will be at least a decade before projected warming would exceed natural variability enough for a definitive finding, even if models were correct.

Unfortunately, observational evidence provides little insight about future change. Projections are based on unverified models of natural and social science, that I will now describe.

VG-5 The diagram illustrates some of the complex processes in climate. From fundamental physics we are certain that the atmosphere must absorb additional IR radiation as greenhouse gas concentrations rise, if nothing else changes. However, other changes will occur. Once heat is absorbed, it triggers numerous complex feedback processes that can amplify or reduce warming and climate change. By the way, climate refers to the average trend of regional weather, including its variability.

Models must account for processes like global scale heat transfer by winds and currents, the hydrological cycle involving evaporation, precipitation, and groundwater, formation of clouds snow and ice, all of which display enormous natural variability. We know that science today cannot properly describe these processes.

Limited scientific ability to describe the response of climate dominates uncertainty in predicting climate change. For example, consider some effects of increasing CO_2. Added CO_2 traps heat, warming the atmosphere by a small amount. The warmer atmosphere will hold more water vapor, significantly amplifying warming... but increases in moisture may promote cloud formation that can cool the surface by reflecting sunlight. Cloud changes could significantly reduce warming, or, depending on types and properties of clouds, they might also amplify warming. Other effects not well understood, like changes in ocean currents and the biosphere, could also amplify or reduce warming.

OL Predictions rely on results from mathematical climate models known as General Circulation Models (GCMs). They are so complex that they are maintained by institutions, not individuals— there are only half a dozen major institutions running full fledged GCMs today. They have well known limitations:

- GCMs have limited resolution. To fit even in the most advanced computers resolution is limited to grid blocks hundreds of km on a side, say one block for Italy, several for the US. Consequently, models must approximate effects, such as clouds and hydrology, that occur on smaller scales.
- GCMs are incomplete in their scientific basis. Models have limited ability to forecast progressive change over 100 years. Most available results still only compare two types of climate: one at today's conditions, one at doubled CO_2. Evaluation of transient climate change requires far more reliable representations of oceans and the response of the biosphere. Clouds are a most serious gap. Satellite data demonstrate that GCMs represent clouds poorly in <u>current climate</u>... yet the more complex need is to understand how clouds might change if climate varies.
- Data and methods to validate model results are quite incomplete. Oceans especially lack adequate measurements. This is a critical scientific need.

Consequently, GCMs do a poor job matching past climate trends and current climate. And they are well known to have 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 GCMs produce significantly different projections of climate change, especially for critical factors such as precipitation, soil moisture, drought, and storms.

<u>VG-6</u> Forecasts require models not only of <u>natural science</u> but also of <u>human activities</u>. These results for CO_2 emissions

come from the *business as usual* scenario developed by the Intergovernmental Panel On Climate Change (IPCC). Results through 2025 are in line with many recent studies, such as those of the International Energy Agency. In 1985 global emissions were 5.2 billion metric tons of carbon as CO_2 (GtC). Projections for 2025 give emissions of 12.4 GtC. Results depend on many assumptions, especially concerning:

- population growth,
- economic development, and
- technological change.

Labels refer to regions including North America (NA), Western Europe (WE), and so on. In 1985 Developed Countries produced over half the world's CO_2 emissions, but their relative share is falling with time. Developing Countries dominate growth in emissions, and will exceed emissions from OECD Countries early in the next century. Growing use of abundant, cheap, domestic coal is essential for development, especially in India, and China.

VG-7 This slide shows results from the same scenario in per capita emissions. While developing countries dominate absolute growth, their per capita energy use in 2025 still remains far below today's levels for industrialized countries. This highlights an enormous political difficulty. Options that control emissions only in the developed world have little impact on future global emissions. However, energy use and emissions will grow in developing countries to meet development expectations of rapidly growing populations.

A final remark on emissions scenarios. Climate forecasts require emissions projections over much longer periods, where results are completely determined by *untestable* *assumptions*. It is impossible today to predict technologies for energy supply and use that society might develop and deploy over the next 100 years. The IPCC Scenarios for CO_2 emissions in 2100 range from 5-35 GtC/yr. Our own long range forecasts rarely need to exceed 20 years, and are not used for detailed planning.

VG-8 This slide summarizes important climate changes predicted to occur through 2100.

GCM results show warming between 0.9-3.5 °C, with a best guess of 2 °C, and that
Sea level will rise from 15-95 cm, with a best guess of 50 cm.

First, note that estimates have fallen by about 30% since the 1990 IPCC assessment.

Second, these findings cannot be treated as a traditional scientific estimate bounded by a known range of uncertainty. The term "best guess" means based on untestable assumptions. There is too much ignorance in the science to allow a rigorous analysis of uncertainty. These are the range produced by available, unverifiable models.

Climate change affects agriculture and ecosystems, for instance, by altering the growing season and availability of water. Most plants also grow more rapidly and use less water with higher CO_2. This fertilization effect can be quite positive both for agriculture and for ecosystems. However, climate models cannot predict regional climate change, and are especially poor on hydrology, so impacts are poorly known. IPCC concluded that society could meet agricultural needs in the next century. In part, this reflects confidence in the ability of farmers to adapt.

Impacts depend on the rate as well as the magnitude of change.

Concerns have been expressed about catastrophes like increases in hurricanes and sudden climate shifts. These are largely speculative without scientific confirmation.

IPCC describes primarily negative human health effects, through increased incidence of heat stress and spread in the range and seasonality of vector borne diseases. Long term health models are in a very preliminary stage of development, and the report did not highlight available response options.

Potential impacts are not all negative. Models predict winners and losers— but not with useful reliability. Recent estimates of many impacts have fallen considerably. It appears that adaptation could counter many impacts on managed systems in wealthy nations.

The IPCC Assessment does include strong caveats about ability to project impacts, but that discussion tends to be buried in the lengthy, underlying chapters. In the attention grabbing Policy Makers Summaries the overwhelming emphasis is on consequences as found in best available models, without a clear statement of model limitations.

<u>VG-9</u> This chart summarizes current scientific understanding of climate change.
Data confirm that:

- greenhouse gasses are increasing in the atmosphere;
- human activities contribute to their growth;
- detection of human-induced climate change is difficult since climate displays large natural variability;
- While there is still no evidence of warming that can be *attributed* to an Enhanced Greenhouse Effect,
- the 1995 IPCC Policy Makers Summary concludes that: *The balance of evidence suggests that there is a discernible human influence on global climate.* (I will return to this point in a moment)

Results from climate models are known to be wrong:

- they are inconsistent between different models;
- they disagree significantly with current climate and in matching historical trends.

It is impossible today to project impacts from future climate change:

- the magnitude, timing and regional distribution of any change are uncertain;
- improved assessment will require reliable forecasts at the regional level;
- assessment also requires reliable models of the response of ecosystems.

The uncertainty arises because of profound gaps in scientific knowledge concerning critical climate processes.

Progress to advance the science will require major effort and many years of study. One measure of the effort is the U.S. research budget. In 1980 approximately $10 million was marked for Greenhouse Research. Today, the budget is nearly $2 billion.

Let me now discuss two of the most important new IPCC results:

- Detection of climate change
- Stabilization of CO_2 concentrations

VG-10 Without doubt the most politically sensitive new result in the IPCC 1995 Assessment is the finding that there is a discernible human influence on climate. Four results were cited:

- the global average temperature rise of 0.5 °C,
- greater warming in the southern hemisphere than northern,
- spatial patterns in northern hemisphere,
- change in atmospheric temperature profile with height:
  + warming in lower atmosphere,
  + cooling in upper atmosphere.

Let us examine each of these in turn. First, the observed surface warming remains within the range of natural variability. In itself this is insufficient for the claim of detection. The next two patterns are caused far more by aerosols (small airborne particles that scatter sunlight) than by greenhouse gasses. Their regional distribution predominantly affects the northern hemisphere. The final feature, changes in the vertical temperature profile, are unlikely to have significant consequences on climate at ground level.

As a scientific finding, the IPCC statement on detection is weak. It speaks of the "balance of evidence;" uses the verb "suggests" rather than "proves" or "demonstrates," and there is no way to quantify the claim. Nor does the statement signal out greenhouse gas effects, or global warming. Most of the evidence concerns cooling from aerosols. The statement does not address the most important issue: confirmation of serious impacts. As is clear in the report, detection of a human influence is not the same as attribution of cause, or confirmation of models.

VG-11 The next slide summarizes questions that scientists hope to answer when they consider evidence of human effects on climate; and where we stand in the campaign. Establishing a claim of detection and attribution requires three types of information:

- Observations: An adequate set of well characterized data,
- Predictions: Credible model-based predictions of the observed climate variables,
- Statistics: A method to compare observations and predictions.

Unfortunately, we do not have the necessary scientific basis for any of the these. Worse yet, they depend on one another. Models remain unreliable for predictions of climate at the regional scale. We cannot characterize the variability in climate data. Statistical analysis depends on the nature of the observations and the anticipated climate change, including especially natural climate variability.

If we were successful in matching observations and predictions, we would be able: to quantify the degree to which climate change exceeds natural variability, to attribute the change to human influence, and to make an observational determination of climate sensitivity to increases in greenhouse gasses. Measurement of climate sensitivity would allow us to test how well models perform in predicting the real world, and give us more confidence about future projections. Unfortunately, we cannot achieve this goal any time soon. The science is still too uncertain to quantify human influence, or to put bounds on expected changes in the future. IPCC answers to the critical questions:

- maybe we have detected a human influence on climate,
- we cannot quantify the amount,
- we cannot yet determine climate sensitivity to increases in greenhouse gasses.

The IPCC finding is far more cautious than what I have heard from speaker after speaker at international meetings since the December IPCC Plenary. Inevitably they transform the weak IPCC statement about "discernible human evidence" into strident claims about scientific confirmation for damaging consequences. For example, Liz Dowdeswell, Executive Director of UNEP, says that: "the scientists have spoken... the effects of global change are upon us." This is nonsense. I have discussed this with Professor Bolin, Chair of the IPCC. He has given me his permission to quote him in saying that Liz Dowdeswell's remarks are an inappropriate distortion of the IPCC finding.

Next I will discuss stabilization of atmospheric CO_2 concentrations. This will lead to a discussion of economic analyses. My comments are best made in light of the United Nations Framework Convention on Climate Change (FCCC).

<u>VG-12</u> Two essential features of the convention are its *commitments* and *objective*.

Article 4 specifies commitments of Parties that ratify FCCC. All must report emissions inventories. Annex 1 Countries (OECD members and Countries in Transition) agree to:

1) adopt emissions reduction programs;
2) file National Action Plans describing programs and their effects through 2000;
3) provide new and additional assistance to Developing Countries.

Emissions commitments are expressed as *aims* to return to 1990 levels by 2000, not mandatory targets. Most OECD nations have set domestic goals to stabilize or reduce emissions, but they are not required by the Convention. (Most will not achieve their aim.)

Article 2 gives the ultimate objective: stabilization of greenhouse gas atmospheric concentrations at a level that prevents dangerous human interference with the climate system.

There is a profound distinction between stabilization of emissions and concentrations. Current scientific understanding suggests that global CO_2 emissions would need to be *reduced by* 60-80% from 1990 levels to stabilize atmospheric concentrations. Let me explain in more detail the scientific information we have about CO_2 stabilization.

VG-13 To eliminate risks of climate change from an enhanced greenhouse effect, we would need to stabilize concentrations of greenhouse gasses. The 1990 IPCC assessment provided these estimates of reductions to bring the atmosphere into immediate balance. Long-lived gasses require very large cuts. Several studies at the time showed that CO_2 would be stabilized if emissions were reduced instantly to about 2 GtC/yr, and fell even lower in the future.

<u>VG-14</u> This chart puts CO_2 stabilization into context. The central IPCC scenario (IS92a) gives values for population and emissions. In 1990, 5 billion inhabitants emitted 7 GtC, or about 1.4 tons per person. Projections till 2100 led to 11 billion inhabitants emitting 20 GtC, 1.8 tons per person. If emissions were 2 GtC/yr, then per capita emissions would fall to 0.4 tons, today, and 0.2 tons in 2100. For comparison, the lower table shows per capita emissions in several countries, today. Emissions are directly linked to energy use and economic prosperity. This illustrates the magnitude of the challenge to stabilize CO_2 concentrations. Energy demands for economic development would have to be met globally with emissions on average less than those of China, today.

<u>VG-15</u> In 1994 IPCC developed a range of scenarios to examine stabilizing CO_2 at various levels from 350 to 750 ppm. The upper panel shows the set of <u>arbitrary</u> concentration profiles they assumed. Each leads gradually to stabilization in about 2200. Using simple models of the carbon cycle, not climate models, they derived CO_2 emissions that would be consistent with the assumed concentrations. The lower panel shows computed emissions. Trends fall well below projected levels. For instance, the central IPCC scenario projects annual emissions to be 12.4 GtC in 2025 and 20 GtC in 2100. Efforts to limit future emissions should be considered against this anticipated increase in the base case.

So far we have looked at CO_2 stabilization from a scientific perspective, we next consider economic implications.

VG-16 Several OECD Nations, including the US, have set goals to stabilize or reduce future emissions. Economic analyses of these proposals show that they would be very costly, inhibit economic growth, and have major impacts on specific sectors. These results are from DRI McGraw-Hill. They assumed that costs could be calculated by identifying the carbon tax that achieved the emissions target.

- DRI finds that costs to stabilize US CO_2 emissions at 1990 levels by 2000 require a carbon tax equivalent to 16$/B ($134 per tonne of carbon). Its impact reduces GDP by 1.4% per year, and results in cumulative GDP losses of 500 B$ through 2000. By the way, the tax would raise revenues of about 180B$/year.

- DRI finds that a reduction in US CO_2 emissions by 20% in 2020 requires a carbon tax equivalent to 95$/B ($804 per tonne of carbon). This reduces GDP by 3.0% per year, with cumulative GDP losses of 6,000 B$ through 2020.

In fact, these estimates are likely to be optimistically low. In practice policies can never be implemented as efficiently as assumed in idealized economic models. While any benefits from such policies are highly uncertain, and would not be realized for decades, such emissions restrictions result in large, near term costs that inhibit economic growth now. and that negatively affect competitiveness and employment.

On the other hand, economic studies show that costs would be far lower if emissions restrictions were phased in more slowly, and if they were implemented globally. We will discuss these in a few minutes. A phased approach also allows for improvements in science which might demonstrate whether or not climate change actually poses a serious threat.

In spite of scientific uncertainties, and the likelihood of large costs to reduce CO_2 emissions, some believe that the risk of climate change and the precautionary principle justify strong actions now. Negotiations are proceeding under the Climate Convention to establish legally binding emissions limits on OECD Nations in the period after 2000.

VG-17 This slide summarizes developments in the Climate Convention since the first meeting of the Conference of Parties (COP) last year in Berlin.

For different reasons all Parties agreed that existing commitments are inadequate.

Developed countries argued that commitments were inadequate because:

- they will not result in stabilization of CO_2;
- there are no obligations beyond 2000;
- there are no commitments on emissions by developing countries.

Developing countries argued for inadequacy because:

- most developed countries would not meet their aims to limit emissions, and
- financial assistance was inadequate.

To address *inadequacy* COP commissioned negotiations to develop post 2000 commitments. The following provisions of the Berlin Mandate guide the negotiations:

- Annex 1 (Developed) countries aim "to set quantified *(emission)* limitation and reduction objectives within specified time frames such as 2005, 2010, and 2020;"
- no new commitments on developing countries;
- results to be adopted at COP3 in 1997.

Despite pressure by some OECD countries, developing countries refused to enter into any restrictive agreement on their emissions.

COP also remains unable to agree on rules of procedure. Differences concern:

- voting majorities for substantive issues, such as adoption of protocols, and
- composition of the Bureau, the officers of COP.

To protect their national interest OPEC countries insist on unanimity for substantive issues, and a seat on the Bureau... The deadlock on rules exists, in part, because UN procedures require that rules themselves must be adopted unanimously.

Without question the Berlin Mandate has created <u>*expectations*</u> that Developed Countries will agree to binding restrictions on future greenhouse gas emissions, and that the agreement will be ready for COP3 in Kyoto Japan, in December 1997. These agreements could have significant economic and social consequences for Europe and the rest of the OECD countries, as well as for developing countries through impacts on trade and investment.

<u>VG-18</u> This slide summarizes positions a few key positions in the negotiations:

- The Alliance Of Small Island States (AOSIS) calls for a protocol with Annex 1 parties reducing CO_2 emissions 20% below 1990 levels by 2005.

- The European Union calls for a legally binding protocol:
  + with policies and measures, including some common to all Annex 1 Parties;
  + with specific, uniform targets and timetables in 2005, 2010, and 2020 (However, the EU has been unable, so far, to agree on levels);
  + and with CO_2 ultimately stabilized at 550 ppm, or less.

- Differences are apparent among EU members, with Germany taking the strongest line calling for emissions reductions of 10-20% by 2010.

- After maintaining a non-committal position for months, at COP 2 the US announced a major policy shift, calling for legally binding commitments, with:
  + national flexibility in policies,
  + a midterm emissions target,
  + emissions trading within Annex 1,
  + progressive involvement of developing countries.

The US said it would state a specific target following completion of its analysis and assessment later this year (i.e. after the election). The US differs from the EU in several ways. The US opposes common measures, and near term targets, and referred to existing reductions proposals as unrealistic. The call for government-to-government emissions trading introduces a major new element into the negotiation.

- Developing countries insist that they will accept no new commitments. Also, in light of recent economic studies, they recognize that Annex 1 commitments will hurt them economically, and they call for compensation for any negative impacts.

VG-19 As listed here, a vast array of policy options are under consideration nationally and internationally to respond to climate change. Numerous policy think tanks, government agencies, and intergovernmental organizations are actively analyzing their pros and cons. Most examine them in theoretical, academic terms without regard to their political acceptability, or to the effectiveness of a policy after it emerges from give and take of political compromise. For instance, in the US there is powerful grass roots opposition to carbon/energy taxes, as seen in the defeat of President Clinton's BTU Tax proposal, and in Germany voluntary accords with industry preclude introduction of a carbon tax..

The EU call for harmonized common policies and the US support for government-to-government emissions trading both raise significant questions about the nature of international institutions to be established under the banner of climate change. While most law makers are reluctant to cede domestic power to international agencies, stabilization of CO_2 concentrations along the lines of the EU proposal implies the need for a strong international apparatus. It would need substantial authority and capability to allocate, administer, monitor and enforce legally binding agreements that could result in energy rationing and massive transfers of wealth from north to south. (As an aside note that significant illegal CFC trading is an unfortunate byproduct of the Montreal Protocol.)

VG-20 Given our understanding of climate change and available response options, the EU call to limit CO_2 to 550 ppm or less seems premature and unrealistic. In this figure the top three curves show IPCC scenarios through 2050. IS92a shows anticipated emissions without policy constraints, the next two curves show stabilization at 550 and 450 ppm. Global CO_2 emissions must fall significantly below projected levels for stabilization. However, developing countries have no obligation to reduce emissions, so limits on developed countries would be extremely severe. The lower three curves show Annex 1 emissions for the upper three cases. For stabilization Annex 1 emissions must decline sharply and *vanish completely* before 2050.

- First, note that even advocates state that 550 ppm is a "political target," there has been no scientific determination of a "dangerous" level of greenhouse gas concentrations.
- Second, such massive reductions require large scale development and deployment of currently non-commercial renewable energy to meet Annex 1 country needs.
- Third, stabilization at such low levels could not be met without participation by developing countries who will only entertain that possibility with substantial financial incentives. This begs the question: who will pay to meet their needs, especially if economic growth in Annex 1 slows with emissions constraints.

Recognizing the enormous cost and challenge of reducing CO_2 emissions through binding targets and timetables a number of studies have recently examined other approaches to address climate change. They find that costs can be dramatically reduced by taking a more flexible course.

VG-21 This slide summarizes features of a base case quite like the EU proposal and three additional cases aimed at achieving similar CO_2 emissions reductions, but with more flexibility in the timing and number of countries participating in the cuts. The studies were conducted by economic modeling groups as part of the Stanford Energy Modeling Forum. Participants include MIT, Stanford, the Electric Power Research Institute, and Pacific Northwest National Laboratories.

- In the base case, labeled "No Flex," OECD countries return emissions to 1990 levels by 2000, then reduce emissions 20% more by 2010 and maintain them at that level.
- In the second case emissions reductions are identical to the base case, but "where" flexibility allows cuts to be taken anywhere in the world, not just in the OECD.
- In the third case cumulative CO_2 emissions through 2050 in the OECD are identical to the base case, but "when" flexibility allows reductions to shift to later periods.
- The fourth case allows for both "where" and "when" flexibility.

Changes in global temperature are essentially identical in all four cases.

VG-22 Results are summarized in this slide. Each group ran its own model to compute costs for all four cases. While absolute answers differed among the groups relative results for the four cases were similar. Costs to meet the base case objective are very large: 2$ trillion to 8$ trillion depending on the modeling group. Also note that while costs are borne primarily in the OECD Countries where emissions cuts occur, there are also costs to developing countries. Primarily these occur through trade: economic losses in OECD countries reduce demand for imports from developing countries. As shown in the figure these very large costs can be dramatically lowered with "where" and "when" flexibility.

- In the "where" case costs are 70% lower.
- In the "when" case they fall by 40%.
- Combining "where" and "when" flexibility lowers cost by 90%.

VG-23 The reasons for dramatic cost reductions are straightforward.

- Relative costs of emissions reductions vary widely in different regions. The same impact on global emissions can be achieved by implementing less costly emissions cuts in developing countries rather than more expensive cuts in the developed world.
- Several factors contribute to "when" flexibility.
    - + Much of the infrastructure for energy supply and use is long lived. It makes economic sense to time investments in new, more efficient equipment to coincide with the normal turnover of capital stock, rather than to bear the costs of replacing capital equipment prematurely.
    - + Second, technological progress results in the availability of more efficient options as time passes.
    - + Finally, nature provides an interesting benefit. For a given input of CO_2 to the atmosphere, the amount

remaining decreases as time passes. This effect discounts early emissions relative to later ones.

Recall that for all cases the net effect on climate is identical, but the cases with flexibility reduce costs by trillions of dollars.

In the face of such large costs to society, and such obvious advantages to alternative proposals, it is difficult to understand how negotiators can continue to pursue an approach based on near term targets and timetables for developed countries. I believe that the nature of the international process is partly responsible.

VG-24 I'd like to make some observations about the international process and climate change that are important for the public policy issue.

- activists use international process to frame the issue: including likely impacts & appropriate choices for response:
  - activist governments address climate change largely as an environmental issue. They assign the portfolio to the environment minister, or in the US to Al Gore and Tim Wirth. There is little involvement from those responsible for economic performance, security, trade, or labor;
  - for these groups the precautionary principal is the touchstone;
  - energy policy proposals far beyond "no regrets" dominate mitigation options
    + favorites include restrictions: carbon and energy taxes, tradable CO2 emissions permits, regulations, standards,

+ RD&D and subsidies for renewables, energy efficiency.
+ A mind set favoring targets and timetables, no doubt a holdover from the Montreal Protocol experience, stifles debate about other response options

- Developing countries stress development issues. They see climate change as a means to obtain significant new financial aid, technology transfer & capacity building, but they insist that they cannot and will not undertake any commitments on future emissions

- In the international debate there is almost no discussion or even recognition that responding to climate change involves trade offs and politically sensitive choices in:
  - economic and social consequences of mitigation
  - sovereignty and international institutions

This final point rarely enters the discussion of climate change. But the proposed response options imply massive transfers of wealth, at a time when many governments are significantly cutting back on foreign aid. Also the machinery to implement many of the proposed international agreements would involve powerful new international agencies, for example to allocate emissions permits, and to administer, monitor and enforce any deals.

I would like very much to encourage a broader discussion of climate change with fuller participation by those affected, including industry, in national deliberations and, especially, in the international process. The current environmental perspective that dominates the debate is unlikely to lead to effective long term action. It generates polarization rather than promoting effective consensus.

VG-25 In closing I'd like to highlight a few recommendations to address climate change that are appropriate given the current state of knowledge:

- We must continue to improve scientific, economic, and technological understanding about climate change, its impacts, and response options. This requires significant, long term funding and effort. Many scientists and economists argue that there is ample time to improve our knowledge about climate change risks before agreeing to potentially unworkable and unnecessary long term commitments. Among other tasks, governments need to promote routine, long term monitoring of climate, climate process, and major ecosystems. In spite of calls to do this since the 1970s not enough progress has been made. While many scientists are asking for the job to be done, few are asking to do it. The task is not glamorous ,yet it requires care and long term attention.

- Conduct R&D to improve the performance and lower costs of options for future energy supply and end use, and to remove and store emissions of carbon dioxide. Opportunities exist in all sectors to improve performance. However, we should not prejudge the outcome of research and development programs. Apparently attractive options do not always succeed technically, economically or in the marketplace.

- Implement "no regrets" options, such as economically justified: energy efficiency, fuel switching, co-generation, and protection and expansion of forests. No regrets options are not do nothing. Indeed they require major effort, and cost to plan and implement. For instance, fuel switching from coal to gas in a utility often requires massive changes in infrastructure that may or not be economically justified, depending on the outcome of careful analyses.

A number of options exist that can make it easier for best practice and innovation to enter the market and reduce future emissions. The most important of these are to:

- eliminate energy demand subsidies, and
- promote free trade & open markets.

Implemented globally these would encourage the spread of efficient technology and practices into developing countries. However, the barriers to be overcome are not simple. Implementing current best practice requires significant time, effort and capital investment.

- Finally, in light of the long time scales involved and the difficult nature of climate change decision making and implementation nationally, regionally, and internationally, it is essential to build a flexible institutional framework that can respond as knowledge improves.

As for the longer term, at this point it is too soon to be taking hard and fast decisions about the climate change... flexibility should be the hallmark.