The Winners of the Blue Planet Prize

2010

Dr. James Hansen (USA)

Sir Bob Watson (UK)

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Director at Goddard Institute for Space Studies (NASA)
Adjunct professor in the Department of Earth and Environmental Sciences at Columbia University

Sir Bob Watson (UK)

Chief Scientific Adviser of the UK Department for Environment, Food and Rural Affairs (DEFRA)
Chair of Environmental Science and Science Director at Tyndall Centre for Climate Change Research, the University of East Anglia

PRAY:
This blue planet where we live
Does not belong to us only

All the children to be born on this planet,
All living beings on the planet,
All have the holy right
To rejoice in the happiness
Of being born on this planet
We as one of those given life on this planet,
By rendering thoughts to all the life rejoicing in their lives
In the future of this planet,
Can recreate our linkage
Between all of those lives and us.

If the film helps to allow you
To refresh you to rejoice in the happiness
Of passing this blue planet to the future generations,
By rendering thoughts to the blessings of the Earth,
The Planet of Life
We are more than delighted

Selected from the Slide Show Presented at the Opening of the Awards Ceremony

His Imperial Highness Prince Akishino congratulates the laureates

Their Imperial Highnesses Prince and Princess Akishino at the Awards Ceremony

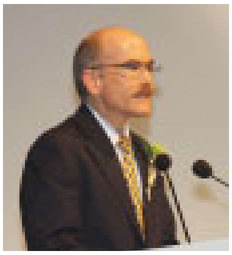
Tetsuji Tanaka, Chairman of the Foundation delivers the opening address

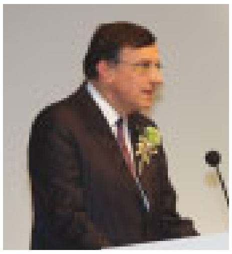
The prizewinners receive their trophies from Chairman Tanaka

Dr. James Hansen

Sir Bob Watson

Dr. Hiroyuki Yoshikawa, Chairman of the Selection Committee explains the rationale for the determination of the year's winners





Mr. James P. Zumwalt, Deputy Chief of Mission of the United States of America (left) and Mr. David Warren, United Kingdom Ambassador to Japan, congratulate the laureates

Blue Planet Prize Commemorative Lectures

Profile

Dr. James Hansen

Director at Goddard Institute for Space Studies (NASA)
Adjunct professor in the Department of Earth and Environmental Sciences at Columbia University

Education and Academic and Professional Activities

1941	Born in USA
1963	Receives a bachelor's degree in physics and mathematics at the University of Iowa
1965, 1967	Receives a master's degree in astronomy and a doctorate in physics at the University of Iowa
1967-1969	A researcher at Goddard Institute for Space Studies (New York)
1969	Post-doctoral fellow at Leiden Observatory (Netherlands)
1969-1972	Researcher at Columbia University (New York)
1972-1981	Manager of the planetary atmospheres program at Goddard Institute for Space Studies
1978-1985	Adjunct professor in the Department of Earth Sciences at Columbia University
1981-present	Director at Goddard Institute for Space Studies
1985-present	Adjunct professor in the Department of Earth and Environmental Sciences at Columbia University
1996	Elected to United States National Academy of Sciences
2001	John Heinz Environment Award
	Roger Revelle Medal, American Geophysical Union
2006	Duke of Edinburgh Conservation Medal, World Wildlife Fund (WWF)
2007	Laureate, Dan David Prize for Outstanding Achievements & Impacts in Quest for Energy
	Leo Szilard Award, American Physical Society for Outstanding Promotion & Use of Physics for the Benefit of Society
	Haagen-Smit Clean Air Award
	American Association for the Advancement of Science Award for Scientific Freedom and Responsibility
2009	Carl-Gustaf Rossby Research Medal, highest award of American Meteorological Society
2010	Sophie Prize

(As of June, 2010)

Based on the concept of radiative forcing to indicate the flow of radiation energy in the atmosphere, Dr. Hansen et al. succeeded in developing a practical climate model that was proven by tests such as the Pinatubuo volcanic eruption – they predicted global cooling to follow, which proved quite accurate – there are other verifications, and pioneered understanding and forecasting of the climate system. At a time when there was a noticeable temperature decline because of the impact of the sun and volcanic activity, Dr. Hansen predicted global warming in the future based on the climate model. In 1988, he got more attention with strong statements at an appropriate time to testify before committees and subcommittees in the US Senate and House of Representatives and provided the public with an early alert to the dangers of global warming and to call for actions. Later he claimed that the climate had a "tipping point," and warned that an average temperature increase of even a few degrees would very probably cause irreversible and unrecoverable climate change and produce destructive results for life on Earth. Dr. Hansen called on the governments and the public to take immediate action to reduce and mitigate the impact of climate change. He has consistently emphasized the need for unprecedented international cooperation and significantly contributed to enlightening the whole world about global environment issues.

From Astronomy to Climate Science
Study of Planetary Atmosphere

Dr. Hansen was born on a farm, located in Charter Oak township, Iowa in 1941. Attracted to the renowned space science program of Professor James Van Allen of the University of Iowa, he received a master's degree in astronomy and a doctorate in physics at the university. While attending the University of Iowa, he came to Japan and did researches on astrophysics and astronomy at the University of Kyoto and the University of Tokyo, respectively. Professor Sueo Ueno of Univ. of Kyoto kindly introduced Dr. Hansen to his methods of computation called "invariant imbedding", which is one of the techniques Dr. Hansen used for radiative transfer in planetary atmospheres.

In 1967, he analyzed the data on Venusian temperature and published a thesis arguing that the high temperature of Venus was attributable to a trap of thermal energy caused by aerosol in the atmosphere. In 1974 and 1975, he studied the composition of clouds in the Venusian atmosphere, which completely veil the planet so that its surface cannot be seen. He reported that the clouds consisted of very small spherical droplets of nearly uniform size – he also was able to measure the index of refraction of these droplets and how this index changed from ultraviolet to green to red and infrared wavelengths – this precise information was used by others to conclude that the hazy veil shrouding Venus must be sulfuric acid. The Pioneer Venus spacecraft launched in 1978 confirmed the properties that Dr. Hansen had inferred from telescopic observations and confirmed that the haze was sulfuric acid. The validity of the finding was proven by the Pioneer Venus Orbiter in 1978. In 1981, Dr. Hansen reported that the clouds consisted of sulfuric acid airborne droplets and sulfur dioxide.

Other researchers reported that Venus had been rich in water until several billion years before and that the water had disappeared from the surface of the planet due to the runaway greenhouse effect that subsequently occurred.[1] Later, Dr. Hansen warned that an occurrence of this kind of runaways warming could expose Earth to a harsh environment like it did to Venus, through the evaporation of water.[2]

Then Dr. Hansen shifted the focus of his study to climate change that is caused by human activities which change the composition of Earth's atmosphere. He utilized NASA's satellite observation data in studying the thermal radiation of Earth's atmosphere, which led to the development of a global-scale atmospheric circulation model and significantly contributed to a detailed understanding, analyses and predictions of climate change that included the impact of human activities.

Study of the Earth's Climate

In 1987, Dr. Hansen et al. summarized and published the data on the atmospheric temperature of Earth mainly during the period between 1880 and 1985 obtained from global weather stations. Accurate data on atmospheric temperature from the last 100 years showed a rise of 0.5 - 0.7 degrees in the average temperature. The recorded figures of average temperature increase, updated in 2006, reached 0.8 degrees/100 years, showing that the tendency toward global warming was an undeniable fact and was not merely a result of urbanization.

In a thesis published with Dr. Menon et al., Dr. Hansen argued that there is the existence of atmospheric black carbon effects in the climate of some local regions. He showed that black carbon in the atmosphere brought convection and rain by heating the atmosphere and would ultimately lower temperatures over large areas by reducing the amount of sunlight reaching the ground. As an example, he explained a climatic abnormality observed in northern China in 1988. Then Dr. Hansen joined Dr. Makiko Sato in conducting a study using the solar photometer of AERONET (AErosol RObotic NET work) and showed that the impact of black carbon doubled the value that would normally be estimated from it. Black carbon in the atmosphere rapidly increased in the 1880s when the Industrial Revolution was at its peak. The increase slowed down from the 1900s to the 1950s and leveled off. Even at present, the emissions of black carbon are increasing in China and India, which are in the midst of their rapid economic growth.

Impact of Human Activities on Climate Change

In 2003, Dr. Hansen published an essay titled "*Can We Defuse the Global Warming Time Bomb?*" He warned that the climate change resultant from human activities has currently overcome natural climate change and, if this persists for extended periods, could grow to an enormous level causing great disasters. He also said that actions to prevent or mitigate global warming and other undesirable climate change phenomena need to be taken immediately, and that unprecedented kinds of international cooperation would be called for. He also stressed that such mitigating actions would be feasible and would benefit the health of humankind as well as agriculture and the environment.

In 2006, Dr. Hansen et al. suggested that the average temperature of Earth should be regarded as a yardstick of the degree of impact of human activities on the Earth's atmospheric system. He emphasized that the rise of the average temperature was inevitably accompanied by "a rise in the sea level" and "extinction of species" and that an increase in the average temperature of even one degree would produce highly destructive results for life on Earth. According to him, a CO_2 level of 450ppm or greater in the atmosphere would pose a great deal of danger and powerful measures to reduce CO_2 and other greenhouse gases are important and must be taken immediately.

Advocating Conservation of the Global Environment

In 1988, Dr. Hansen published a thesis on climate predictions using a general atmospheric circulation model based on some scenarios of greenhouse gas emissions. He concluded that the global warming caused by human activities would grow to a level well above the level of natural climate variability within the next few decades. In the same year, Dr. Hansen testified before committees and subcommittees in the U.S. Senate and House of Representatives and provided the public with an extensive alert to the dangers of global warming.

In 2007, he used his knowledge of paleoclimatology to show that the sea level of 35 million years ago (when the average temperature of Earth was two or three degrees higher than today) was 25 meters higher than the current level and that the IPCC's estimate, 59 centimeters, was far from correct. In 2008, he gave a lecture and explained the definition of a tipping point, a threshold of climate change that humankind must not exceed, as 1) a tipping level: the level at which a large climate change occurs even when greenhouse gases do not increase any further; and 2) a point of no return: the point at which the climate system causes an uncontrollable and irreversible change on the climate. According to paleoclimatology, ice in the polar areas would dissolve suddenly instead of dissolving gradually. This can be interpreted as an example of a tipping point. Dr. Hansen uses multiple lines of evidence to conclude that the world has already reached a dangerous level of atmospheric greenhouse gases, but he admits that it is difficult to determine how long the world can be in the dangerous zone before the effects become large and irreversible. However, he argues further that if emissions continue at current or increased levels for a few decades large climate changes and impacts will proceed out of humanity's control.

Dr. Hansen recommends that all nations should determine their responsibilities for greenhouse gas emissions based on a historical viewpoint, more specifically, the cumulative amount of their CO_2 emissions. According to this yardstick, United Kingdom would be the largest cause of greenhouse gas emissions followed by the United States and Germany. He urges nations to base their actions on the extent of their responsibilities.

Last year, Dr. Hansen urged the US government to set an example and lead the world in taking actions against climate change, because humankind should no longer postpone the implementation of anti-global warming measures. To ensure the next generations a better future, Dr. Hansen continues to explain to government officials and the public about the danger of global warming and to advocate early actions for reduction of greenhouse gases with the aim of conserving the global environment.

Notes

1. Kasting J.F. (1988) "Runaway and moist greenhouse atmospheres and the evolution of earth and Venus" Icarus 74 (3): 472–494.
2. Climate Threat to the Planet: Implication for Energy Policy and Intergenerational Justice Jim Hansen December 17, 2008 Lecture at AGU

Essay

Environment and Development Challenges: The Imperative of a Carbon Fee and Dividend

Dr. James E. Hansen

Most governments have paid little attention to the threat of human-made climate change. They have acknowledged its likely existence, notably in the Framework Convention on Climate Change (1), in which 195 nations agreed to avoid "dangerous anthropogenic interference" with climate. However, the instrument chosen to implement the Framework Convention, the Kyoto Protocol, is so ineffectual that global fossil fuel CO_2 emissions have increased by about 3 percent/year since its adoption in 1997, as opposed to a growth rate of 1.5 percent/year in the decades preceding the Kyoto Protocol [http://www.columbia.edu/~mhs119/Emissions/, which is an update of a graph in (2)].

This feckless path cannot continue much longer, if there is to be hope of preserving a planet resembling the one on which civilization developed, a world that avoids the economic devastation of continually receding shorelines and the moral nightmare of having exterminated a large fraction of the species on Earth. The science is clear enough: burning most fossil fuels would invoke such consequences (3).

At least a moderate overshoot of climate change into the dangerous zone is unavoidable now, but, fortunately, prompt actions initiating a change of directions this decade could minimize the impacts on humanity and nature. The policies needed to produce a rapid phase-out of fossil fuel emissions would have a wide range of other benefits for the public, especially in those nations that recognize the advantages in being early adoptors of effective policies. So there is some basis for optimism that the political will necessary to enact effective policies could be marshaled.

However, for this to happen it is essential that the next approach not repeat the fundamental mistakes that doomed the Kyoto Protocol. If another 15 years is wasted on an ineffectual approach, it will be too late to avoid catastrophic consequences for today's young people and future generations. Therefore it is important to clarify the principal flaws in the Kyoto approach from the standpoint of climate science.

Kyoto Protocol

A fundamental flaw of the Kyoto approach is that it was based on a "cap" mechanism. This approach embodies two ineluctable problems. First, it made it impossible to find a formula for emission caps that was equitable among nations and also reduced carbon emissions at the rate required to stabilize climate. Second, it failed to provide clear price signals that would reward businesses, individuals and nations that led the way in reducing emissions.

The validity of the first assertion can be proven by comparing national responsibilities for climate change, which are proportional to cumulative historical emissions (4, 5). The United Kingdom, United States, and Germany have per capita responsibilities exceeding the responsibilities of China and India by almost a factor of ten (4). Even if the UK, US and Germany terminated emissions tomorrow, by the time China, India and other developing nations reached comparable responsibility for climate change the world would be on a course headed to certain climate disasters.

Key Points: Why a Carbon Fee and Dividend is Imperative

1. There is a limit on fossil fuel carbon dioxide that we can pour into the atmosphere without guaranteeing unacceptably tragic, immoral climatic consequences for young people and nature.
2. It is clear that we will soon pass the limit on carbon emissions, because it requires decades to replace fossil fuel energy infrastructure with carbon-neutral and carbon-negative energies.
3. Climate system inertia, which delays full climate response to human-made changes of atmospheric composition, is both our friend and foe. The delay allows moderate overshoot of the sustainable carbon load, but it also brings the danger of passing a climatic point of no return that sets in motion a series of catastrophic events out of humanity's control.
4. The ineffectual paradigm of prior efforts to reign in carbon emissions must be replaced by one in which an across-the-board rising carbon fee is collected from fossil fuel companies at the place where the fossil fuel enters a domestic market, i.e., at the domestic mine or port-of-entry.
5. All funds collected from fossil fuel companies should be distributed to the public. This is needed for the public to endorse a substantial continually rising carbon price and to provide individuals the wherewithal to phase in needed changes in energy-use choices.

It is unrealistic to think that a "cap" approach can be made global or near-global. Nations less responsible for the world's climate predicament believe, with considerable justification, that they should not have to adhere to caps on CO_2 emissions (much less steadily shrinking caps) that are comparable to caps on industrialized countries. At the same time, some industrialized countries, including the United States, refuse to bind themselves to caps that are more stringent than those imposed on developing countries. This impasse cannot be resolved under a cap approach. Indeed, the targets adopted to date with a cap approach have been but a drop in the bucket compared to the reductions required to stabilize climate.

A secondary, but important, flaw of the Kyoto approach is its introduction of "offsets". Nations are allowed to limit reduction of fossil fuel emissions by means of alternative actions such as tree planting or reduced emissions of non-CO_2 climate forcings such as methane or chlorofluorocarbons. However, these offsets are not equivalent to fossil fuel emissions, because the fossil fuel carbon will stay in surface carbon reservoirs (atmosphere, ocean, soil, biosphere) for millennia. Rapid phase-out of fossil fuel emissions, as required to stabilize climate, becomes implausible if leakage is permitted via offsets. Leakage is avoided via the flat across-the-board carbon fee on fossil fuels in the fee-and-dividend approach. Incentives to reduce non-CO_2 climate forcings will be useful, but such programs should not be allowed to interfere with the more fundamental requirement of phasing out fossil fuel CO_2 emissions.

Fee and Dividend

Fee-and-dividend (5) has a flat fee (a single number specified in $ per ton of CO_2) collected from fossil fuel companies covering domestic sales of all fossil fuels. Collection cost is trivial, as there are only a small number of collection points: the first sale at domestic mines and at the port-of-entry for imported fossil fuels. All funds collected from the fee are distri-buted electronically (to bank account or debit card) monthly to legal residents of the country in equal per capita amounts. Citizens using less than average fossil fuels (more than sixty percent of the public with current distribution of energy use) will therefore receive more in their monthly dividend than they pay in increased prices. But all individuals will have a strong incentive to reduce their carbon footprint in order to stay on the positive side of the ledger or improve their position.

The carbon fee would start small and rise at a rate that sows benefits of economic stimulation while minimizing economic disruptions from sudden change. Economic eff-iciency requires the price of fossil fuels to rise toward a level that matches their cost to society. At present fossil fuels are the dominant energy only because the environmental and social costs are externalized onto society as a whole rather than being internalized into their prices (6). Human health costs due to air and water pollution from mining and burning of fossil fuels are borne by the public, as are costs of climate change that have been estimated at \$100-1000/tCO_2 (7).

International Implementation

When the reality and consequences of the climate threat become clear enough the international community should recognize that all nations are in the same boat and that the fruitless cap-and-trade-with-offsets approach must be abandoned. The reality is that the Kyoto Protocol and proposed replacements are "indulgences" schemes (5), which allow aggressive development of fossil fuels to continue worldwide. Developing countries acquiesce if sufficient payments for offsets and adaptation are provided. This works fine for adults in developed and developing countries today, but this abuse of young people and future genera-tions must eventually end as the facts become widely apparent.

A fundamental fact is that as long as fossil fuels are allowed to be cheap, via subsidies and failure to pay their costs to society, they will be burned. Even ostensibly successful caps have no significant benefit. They simply reduce demand for the fuel, thus lowering its price and creating incentives for it to be burned somewhere by somebody. What is required is an approach that results in economically efficient phase-out of fossil fuels, with replacement by energy efficiency and carbon-free energy sources such as renewable energy and nuclear power.

Specifically, there must be a flat (across-the-board) rising fee (tax) on carbon emissions. With such a flat fee, collected by the energy-using nation at its domestic mines and ports of entry, there is no need for trading carbon permits or financial derivatives based on them. Indeed the price oscillations inherent in carbon trading drown out the price signals. The required rapid phase-out of fossil fuels and phase-in of alternatives requires that businesses and consumers be confident that the fee will continue to rise. Another flaw of trading is the fact that it necessarily brings big banks into the matter – and all of the bank profits are extracted from the public via increased energy prices.

A carbon fee (tax) approach can be made global much more readily than cap-and-trade (8). For example, say a substantial economic block (e.g., Europe and the U.S. or Europe and China) agrees to have a carbon tax. They would place border duties on products from nations without an equivalent carbon tax, based on a standard estimates of fossil fuels used in production of the product. Such a border tax is allowed by rules of the World Trade Organization, with the proviso that exporters who can document that their production uses less fossil fuels than the standard will be assigned an appropriately adjusted border duty. Border duties will create a strong incentive for exporting nations to impose their own carbon tax, so they can collect the funds rather than have them collected by the importing country.

Once the inevitability of a rising carbon price is recognized, the economic advantages of being an early adopter of fee-and-dividend will spur its implementation. These include improved economic efficiency of honest energy pricing and a head-start in development of energy-efficient and low-carbon products. The potential economic gains to middle and lower income citizens who minimize their carbon footprint will address concerns of people in many nations where citizens are becoming restive about growing wealth disparities. Note that the effect of a carbon price on upper class citizens is modest and non-threatening except to a handful of fossil fuel moguls who extract obscene profits from the public's dependence on fossil fuels. An added social benefit of fee-and-dividend is its impact on illegal immigration – by providing a strong economic incentive for immigrants to become legal, it provides an approach for slowing and even reversing illegal immigration that will be more effective than border patrols.

National Implementation

The greatest barriers to solution of fossil fuel addiction in most nations are the influence of the fossil fuel industry on politicians and the media and the short-term view of politicians. Thus it is possible that leadership moving the world to sustainable energy policies may arise in China (9), where the leaders are rich in technical and scientific training and rule a nation that has a history of taking the long view. Although China's CO_2 emissions have skyrocketed above those of other nations, China has reasons to move off the fossil fuel track as rapidly as practical. China has several hundred million people living within 25 meter elevation of sea level, and the country stands to suffer grievously from intensification of droughts, floods, and storms that will accompany continued global warming (3, 5, 10). China also recognizes the merits of avoiding a fossil fuel addiction comparable to that of the United States. Thus China has already become the global leader in development of energy efficiency, renewable energies, and nuclear power.

Conceivably the threat of impending second-class economic status could stir the United States into action, but it is imperative that the action contain no remnant of prior cap-and-trade fiascos, which were loaded with giveaways to big banks, big utilities, big coal and big oil. The approach must be simple and clear, with the fee rising steadily and 100 percent of the collected revenue distributed to legal residents on a per capita basis.

The fee-and-dividend approach allows the market place to select technology winners. The government should not choose favorites, i.e., subsidies should be eliminated for all energies, not just fossil fuels. This approach will spur innovation, stimulating the economy as price signals encourage the public to adopt energy efficiency and clean energies. All materials and services will naturally incorporate fossil fuel costs. For example, sustainable food products from nearby farms will gain an advantage over highly fertilized products from halfway around the world.

The carbon price will need to start small, growing as the public gains confidence that they are receiving 100 percent of the proceeds. If the fee begins at $15/tCO_2$ and rises $10 per year, the rate after 10 years would be equivalent to about $1 per gallon of gasoline. Given today's fossil fuel use in the United States, that tax rate would generate about $600B per year, thus providing dividends of about $2000 per legal adult resident or about $6000 per year for a family with two or more children, with half a share for each child up to two children per family.

The proposal for a gradually rising fee on carbon emissions collected from fossil fuel companies with proceeds fully distributed to the public was praised in the United States by the policy director of Republicans for Environmental Protection (11) as: "Transparent. Market-based. Does not enlarge government. Leaves energy decisions to individual choices… Sounds like a conservative climate plan."

A grassroots organization, Citizens Climate Lobby (12), has been formed in the United States and Canada with the objective of promoting fee-and-dividend. My advice to this organization is adoption of a motto "100 percent or fight", because politicians are certain to try to tap such a large revenue stream. Already there are suggestions that part of the proceeds should be used "to pay down the national debt", a euphemism for the fact that it would become just another tax thrown into the pot. Supporters of young people and climate stabilization will need to have the determination and discipline shown by the "Tea Party" movement if they are to successfully overcome the forces for fossil fuel business-as-usual.

Global Strategic Situation

Europe is the region where citizens and political leaders have been most aware of the urgency of slowing fossil fuel emissions. Given the stranglehold that the fossil fuel industry has achieved on energy policies in the United States, it is natural to look to Europe for leadership. Yet Europe, despite dismal experience with cap-and-trade-with-offsets, continues to push this feckless approach, perhaps because of bureaucratic inertia and vested interests of individuals. China, at least in the short run, likely would be only too happy to continue such a framework, as the "offsets" have proven to be a cash cow for China.

The cap-and-trade-with-offsets framework, set up with the best of intentions, fails to make fossil fuels pay their costs to society, thus allowing fossil fuel addiction to continue and encouraging "drill, baby, drill" policies to extract every fossil fuel that can be found. There is a desperate need for global political leaders who can see through special financial interests and understand the actions required to achieve a bright future for young people and the planet. Perhaps such leaders exist – the problem is really not that difficult.

Acknowledgements. I thank Shi-Ling Hsu and Charles Komanoff for useful reviews and suggestions.

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Lecture

Human-Made Climate Change: A Moral, Political and Legal Issue

Dr. James Hansen

Summary of the Situation
Human-made climate change is a moral issue. It pits the rich and the powerful against the young and the unborn, against the defenseless and against nature.

Climate change is a political issue. But politics fails when there is a revolving door between government and the fossil fuel-industrial complex.

Climate change is a legal issue. The judiciary provides the possibility of holding our governments accountable for their duty to protect the public interest.

Slide 1* - There is a huge gap between what is understood about global warming, by the relevant scientific community, and what is known about global warming by the people who need to know, the public.

It is difficult for the public to recognize that we have a crisis, because human-made global warming, so far, is small compared to day-to-day weather fluctuations. Yet the fact is: we have an emergency. Because of the great inertia of the ocean, which is 4 kilometers deep, and the ice sheets, which are 2 to 3 kilometers thick, the climate system responds slowly to climate forcings such as increasing greenhouse gases. But this inertia is not our friend, because it increases the danger that we may pass tipping points, beyond which the dynamics of the climate system takes over and rapid changes occur out of humanity's control.

The bad news is that atmospheric carbon dioxide (CO_2) has already reached a dangerous level, having increased from 280 parts per million (ppm) 200 years ago to 389 ppm today. The good news is that it is still possible to get CO_2 back below 350 ppm, if we act promptly, and there would be many benefits of taking the actions that are needed.

Slide 2 - The great ice sheets on Greenland and Antarctica provide examples of tipping points, especially the West Antarctic ice sheet, which sits on bedrock below sea level. If an ice sheet is weakened to the point that it begins to collapse, the dynamics of the process takes over. It will be out of our control – we cannot tie a rope around an ice sheet that is two kilometers thick.

Extermination of species is another non-linear problem that can accelerate, because of the interdependencies among species. Multiple stresses may cause enough extinctions that ecosystems collapse.

Methane hydrates are essentially frozen methane. If they begin to disintegrate rapidly, it could become a self-sustaining process.

* There are supplement slides *at the back of* the section.

These tipping points all have occurred during Earth's history in conjunction with warming climates. Following mass extinctions new species evolved, but it required hundreds of thousands of years. We will leave a much more desolate planet for future generations, if we destroy many species.

Slide 3 - Climate inertia and tipping points give rise to potential intergenerational injustice. Today's adults enjoy the benefits of fossil fuel use, but the impacts will be borne by young people and future generations. Our parents did not know that their actions would affect future generations. We do not have that excuse. We can only feign ignorance. It is called denial.

I showed this photo of our first grandchild in 2000, because newspapers had called me the grandfather of global warming. It was amusing to show that I really was a grandfather.

After I testified to Congress in the 1980s I had decided to stick to research and leave public communication to others. But by 2004 we had two grandchildren and the gap between what was understood about the science and what was known by the public had become huge. I decided to give one carefully prepared public talk in 2004.

Slide 4 - The talk was titled "Dangerous anthropogenic interference: a discussion of humanity's Faustian climate bargain and the payments coming due." I began with this chart comparing Mars, Earth and Venus. Mars has a thin atmosphere of carbon dioxide, Earth an intermediate amount, and Venus has a very thick carbon dioxide atmosphere. The greenhouse effect of carbon dioxide – the fact that it allows sunlight to penetrate to the planetary surface, but partially traps the planet's infrared (heat) radiation – causes each planet to be warmer than it would otherwise be, given the amount of sunlight that it absorbs – Mars by a few degrees, Earth by a few tens of degrees, and Venus by several hundred degrees.

Mars is too cold – its water is all frozen. Venus is too hot – the water has boiled into the atmosphere. Earth is just right for life to exist.

Slide 5 - The habitable zone around a star is the zone where liquid water can exist on a planet. Our sun is an ordinary star, "burning" hydrogen in its core, producing helium by nuclear fusion, slowly getting brighter. When the solar system was young the sun was 30 percent dimmer than today and the habitable zone was closer to the sun. Venus was cool enough to have an ocean. Earth was near the cold limit of the habitable zone. On several occasions Earth froze all the way to the equator. The most recent "snowball Earth" occurred about 700 million years ago.

As the sun brightened, Venus experienced a runaway greenhouse effect. The ocean evaporated, boiling into the atmosphere. Carbon dioxide baked from the Venus crust into the atmosphere. There is no going-back. Venus is permanently outside the habitable zone, locked forever in a hellish greenhouse with a surface hot enough to melt lead.

Earth is now near the middle of the habitable zone. Earth can never freeze over again. The sun is now too bright and humans have added greenhouse gases to the atmosphere. A runaway greenhouse effect will not occur naturally on Earth for several billion years. But if we burn all fossil fuels, including tar sands and oil shale, it is conceivable that we will hasten a runaway greenhouse effect.

How will climate change this century? It depends. It depends mainly on how much carbon dioxide humans put into the atmosphere.

Slide 6 - Our understanding of climate change is based most of all on Earth's history – how the climate responded in the past to changing boundary conditions such as atmospheric composition surface properties. Ongoing global observations are also valuable, showing how climate is responding to rapid changes of atmospheric composition. Climate models and theory are helpful in interpreting what is happening and they are needed to predict future changes.

Slide 7 - Why should we be concerned about human-made climate change? There have been huge climate changes in the past. Is today's climate the best one? These are reasonable questions. Indeed, they were statements made on National Public Radio in 2008 by my then boss's, boss's, boss's boss, the NASA Administrator. Earth's climate history helps answer such questions.

Slide 8 - This is the deep ocean temperature over the past 65 million years. 50 million years ago Earth was so warm that there were alligators in Alaska – the Arctic was tropical-like. There were no ice sheets and sea level was about 75 meters (250 feet) higher than today. Earth cooled over the past 50 million years. About 34 million years ago it became cool enough for an ice sheet to form on Antarctica. What caused the great warmth in the first half of this Cenozoic Era, and why did Earth then become cooler?

Slide 9 - The climate change was due mainly to change of atmospheric carbon dioxide (CO_2). Climate forcings, perturbations of the planet's energy balance, must be due to changes of the energy coming into the planet, changes within the atmosphere, or changes on the surface. The sun's luminosity increased 0.4 percent over this era, which is a forcing of 1 watt per square meter. The continents at the beginning of the Cenozoic were already close to their present latitudes, so the surface forcing was only about 1 watt. But atmospheric CO_2 varied from as little as 170 ppm to more than 1000 ppm, a forcing of more than 10 watts per square meter.

The amount of CO_2 naturally in the atmosphere-ocean system depends on the balance between the source and sink of CO_2. The balance changes over time, depending mainly on continental drift. The source of CO_2 is volcanic eruptions, which occur at moving continents subduct ocean floor. The metamorphosis of carbonates on the ocean floor into denser rocks, due to high pressure and temperature as the continent rides over the ocean floor, releases CO_2 via volcanoes. The main sink of atmospheric CO_2 is the weathering process as sediments are carried by rivers to the ocean and deposited as carbonates on the ocean floor.

Between 60 and 50 million years ago atmospheric CO_2 increased rapidly because India was moving at high speed, about 20 centimeters per year, through the Tethys (Indian) Ocean, which had long been the depocenter for major rivers and thus had a carbonate-rich ocean floor. When India crashed into Asia, pushing up the Himalayas and Tibetan Plateau, this source of

CO_2 diminished and the weathering sink increased. So atmospheric CO_2 decreased and the planet cooled over the past 50 million years.

Slide 10 - The lesson from the Cenozoic is that the amount of CO_2 in the atmosphere-ocean system changes naturally via exchange with the Earth's crust. The imbalance between the source and sink of CO_2 yields a change of atmospheric CO_2 of the order of 100 ppm in one million years, or 1 ten-thousandths of a ppm per year. Humans are now increasing atmospheric CO_2 by about 2 ppm per year, 10,000 times faster than the natural geological change.

The Cenozoic also allows us to estimate that an ice sheet began to form on Antarctica when CO_2 had declined to about 450 ppm. Some scientists estimate a higher amount of CO_2 at the transition. But it is clear that burning all the fossil fuels would produce enough CO_2 to head Earth back toward the ice-free state, a different planet than the one that humans know.

Slide 11 - Climate also fluctuates on shorter time scales, as shown by this record of Antarctic temperature for the past 400,000 years. Civilization developed during the Holocene, the relatively stable warm period, now almost 12,000 years long. During the last ice age New York was under a kilometer of ice and sea level was 350 feet lower.

The glacial to interglacial climate swings are caused by perturbations of Earth's orbit. As Jupiter, Saturn and Venus tug at our planet, Earth's spin axis tilts successively slightly more toward or away from the sun. Also Earth's orbit becomes more or less eccentric. These changes alter the amount of sunlight striking the ice sheets in the summer.

As ice sheets melt they expose a darker surface that absorbs more sunlight, causing Earth to become slightly warmer. The warming ocean releases CO_2 to the atmosphere and the greenhouse effect of this CO_2 causes additional warming. Changing ice sheet size and changing atmospheric CO_2 are slow feedbacks that amplify the climate change.

Slide 12 - Indeed, these feedbacks cause almost the entire temperature change. The sea level record in the top curve tells us how large the ice sheets were. Greenhouse gas amount is known from bubbles of air trapped in the Antarctic ice sheet as snow piled up.

Multiplying the ice sheet plus greenhouse gas forcings by a climate sensitivity of ¾ degrees Celsius for each watt of forcing yields good agreement with the actual climate change, as sown by the lower curves. This empirical climate sensitivity includes all fast feedback processes such as changes of water vapor, clouds, sea ice and aerosols – and it is much more accurate than can be obtained from climate models. The climate sensitivity for a specified greenhouse gas change becomes twice as large if we wait long enough for ice sheets to respond.

Slide 13 - The climate sensitivity and response time of the climate system are important, because humans have caused greenhouse gases to increase in the past century far outside the range of the past several million years, as shown by the expanded time scale on the right. Earth has begun to warm, as shown by the lower curve, but much of the warming is still in the pipeline, due to the long climate response time.

Slide 14 - To understand modern climate change we must know all climate forcings, that is, perturbations to Earth's energy balance. Greenhouse gases are accurately measured – they cause a large positive (warming) forcing. Human-made fine particles in the air (aerosols) reflect sunlight and thus cause cooling, but it is very uncertain, because it is not measured. Natural forcings, due to the sun and volcanoes, are probably larger now than in the eighteenth century, when the sun is believed to have been slightly dimmer and volcanic eruptions were greater. But the natural forcings are small compared to present human-made forcings.

The net climate forcing is probably between +1 and +2 watts per square meter. Carbon dioxide is the largest forcing, and as time goes on it will be more and more dominant because of its long lifetime in the atmosphere.

Slide 15 - In my University of Iowa talk in 2004 I used this photo of my daughter's children to discuss climate forcing. Sophie explains that the net forcing is about 2 watts, equivalent to two tiny light bulbs over each square meter of Earth's surface. But Connor could only count 1 watt. Connor may be right. We are not measuring aerosol forcing well enough to know for sure.

So I went back to Sophie and Connor a few years later, when they were older and wiser. I asked them "what is the net climate forcing?" They said that they don't know. Well, we can't blame them if we adults fail to make the measurements.

But my grandchildren were useful in another way. They forced me to keep speaking out. I decided that I didn't want my grandchildren in the future to say "Opa understood what was happening, but he never made it clear."

Slide 16 - The upper graph shows estimates of changing climate forcings over the past century. Greenhouse gas forcing becomes increasingly dominant. Aerosol forcing is very uncertain, because it is not well measured.

If we use these forcings in a climate model with equilibrium sensitivity ¾°C per watt of forcing, we find good agreement with observed global temperature, as shown in the lower graph. This agreement could be partly accidental: if we used a model with greater sensitivity and a smaller climate forcing, or vice versa, we might also get agreement. However, the model's sensitivity agrees with the fast-feedback climate sensitivity implied by paleoclimate data.

Slide 17 - The most fundamental check of the physics is the planet's energy imbalance. We anticipate that the planet is out of balance, more energy coming in than emitted to space. That imbalance is the signature of the greenhouse effect, the smoking gun that can confirm climate change is being driven by a forcing. Imbalance is expected because greenhouse gases reduce the planet's heat radiation to space.

How can we measure Earth's energy imbalance? Small amounts of energy go into warming the atmosphere, melting ice, and warming the upper tens of meters of the ground, but most of the excess energy must go into the ocean, which has enormous heat capacity. Measuring the ocean's heat content accurately has been a great challenge, but the data are improving as more than 2000 ARGO floats have been distributed around the world ocean. Each float regularly yoyos an instrument package to a depth as great as 2000 meters.

The best data, covering the past 6 years, indicate that the planet is out of energy balance by at least ½ watt per square meter. These data are for the time of minimum solar irradiance in the 10-12 year solar cycle. Our climate model yields an imbalance of ¾ of a watt averaged over the solar cycle. I expect we will find close agreement with the model as the observations extend over the full solar cycle and the entire ocean. The data already show that the planet is out of energy balance, confirming the expected effect of human-made greenhouse gases.

Slide 18 - Global observations reveal effects of Earth's energy imbalance. The area of Arctic sea ice began to be measured by satellites in the late 1970s. The area of sea ice at the end of the melt season has decreased about 30 percent. There are large year-to-year fluctuations because of weather variations that affect the wind direction and ocean currents. But, because of the planet's energy imbalance, the area of sea ice will continue to decrease on decadal time scales. Unless we restore the planet's energy balance, we can expect to lose all late-summer sea ice within the next few decades.

Slide 19 - The area on Greenland that has summer snow melt, shown in red, fluctuates from year-to-year, depending on the weather. But the melt area has increased about 50 percent over the past few decades.

Slide 20 - Meltwater runs to a low spot on the ice sheet and burrows a hole, a vertical shaft that goes all the way to the base of the ice sheet. This water lubricates the base of the ice sheet.

Slide 21 - Increased meltwater is one of the processes speeding up discharge of giant icebergs to the ocean. The net effect was once uncertain, because global warming also increases the amount of water vapor in the air, so snowfall over the center of the ice sheet is increasing.

Slide 22 - But beginning in 2002 the gravity satellite, GRACE, began making measurements of the Earth's gravitational field with such high precision that we can measure the change of ice sheet mass. The Greenland ice sheet gets heavier in the winter as snowfall piles up and loses mass in the melting season. But overall Greenland is now losing more than 200 cubic kilometers of ice per year. Antarctica is losing more than 100 cubic kilometers per year. The data suggest that the rate of mass loss may be increasing.

Slide 23 - Another expected effect of global warming is expansion of subtropical dry regions. The overturning circulation, rising air in the tropics with subsidence in the subtropics, which gives rise to the dry subtropics, is expected to expand poleward as the planet warms. Observations show that expansion by 4 degrees of latitude, averaged over all longitudes, has occurred already.

The expanding subtropics affects the southern United States, the Mediterranean region, and Australia, for example. It is one of the reasons that Lake Mead and Lake Powell are only half full.

Slide 24 - The expanding subtropics is also one of the reasons for the increase in fires in the western United States, Greece and Australia. With the changing climate the fires burn hotter, making it more difficult for forests to recover.

Slide 25 - Another impact of global warming is the world-wide recession of mountain glaciers. Glaciers are receding in the Rocky Mountains, the Andes, the Alps, the Himalayas. Glacier National Park in the United States will need a new name within 25 years, because it will have no glaciers if greenhouse gases continue to increase.

Loss of glaciers has a practical impact, because in the driest months more than half of the water in major rivers, such as the Indus and Brahmaputra, is provided by glacier melt water. Without glaciers, floods from spring snowmelt will be greater and rivers will tend to run dry in the driest months.

Slide 26 - Coral reefs are the rainforests of the ocean, home to more than a quarter of ocean species. Coral reefs are under stress for several reasons. Two of the most important stresses are the warming waters and ocean acidification. Warming can cause coral bleaching and death as the coral expel their symbiotic algae. The ocean becomes relatively more acid as it takes up carbon dioxide, which is a problem for animals with carbonate shells or skeletons – if the water becomes too acid it can dissolve carbonates.

Slide 27 - Such phenomena help us assess the atmospheric carbon dioxide amount required to maintain life on our planet as we know it. Each of these phenomena, including their responses to current levels of atmospheric CO_2, lead to the conclusion that the target atmospheric CO_2 amount that we must aim for is less than the current amount, which is 389 ppm in 2010.

The best, most quantitative, assessment is the need to restore planetary energy balance. Stabilizing climate, stopping global warming, requires restoration of Earth's energy balance – as long as there is more energy coming in than going out, the planet will keep getting warmer. The present imbalance is at least ½ watt per square meter. A ½ watt increase of thermal emission to space can be achieved by reducing atmospheric CO_2 by 35-40 ppm.

The optimum CO_2 may be somewhat less than 350 ppm, especially if there are future reductions in atmospheric aerosols. However, adjustments of other forcings such as methane and black soot can help balance such effects.

For policy purposes all we need to know for the foreseeable future is that the CO_2 target must be "<350 ppm", if we wish to preserve creation, the planet on which civilization developed. Bill McKibben and the young people who form the backbone of the organization 350.org have done a remarkable job of publicizing the need for this target. They have succeeded in getting more than 100 nations to agree to this target.

Slide 28 - What is the practical implication of the "<350 ppm" target? This chart shows the amount of carbon in fossil fuel reservoirs, dark purple areas being the portion that has already been burned and released into the air. There is a range of estimates for the remaining reserves, which depend in part on whether we will go after "every last drop."

In order to stop growth of atmospheric CO_2 and return to a level below 350 ppm, we must phase out coal emissions rapidly and leave most of the "other" fossil fuels, the unconventional fuels such as tar sands, in the ground. In that case atmospheric CO_2 could peak at a value between 400 and 425 ppm, depending upon how much of the remaining oil and gas we exploit.

If we do not go after every last drop of oil and gas, it will be possible to get CO_2 back below 350 ppm within several decades, provided that we also adopt improved agricultural and forestry practices that cause more CO_2 to be stored in the vegetation and soil.

Slide 29 - So it is possible to achieve the 350 ppm CO_2 target, but there are 3 essential actions. First, coal emissions need to be phased out rapidly. Second, the unconventional fossil fuels should be left in the ground. Third, we should not pursue every last drop of oil and gas.

In other words, we must move on to the clean energy future now, rather than using all the remaining fossil fuels.

Slide 30 - But what is really happening? The United States has signed an agreement with Canada for a pipeline to carry tar sands oil to Texas. New coal plants are being built all around the world, some being financed by the World Bank. Environmentally destructive mountaintop removal continues. Oil is pursued in pristine places. The environmentally destructive practice of shale fracturing is being developed and implemented to find the last bits of gas.

Slide 31 - There is a huge gap between government rhetoric and policy reality. Leaders say that we have a "planet in peril," yet their proposed policies barely differ from business-as-usual.

Greenwash is plentiful, but the leaders follow a path of appeasement of fossil fuel special interests. There is no Winston Churchill willing to stand up and tell the truth about what is needed.

International agreements are jury-rigged to allow continued business-as-usual. For example, the World Bank is allowed to finance new higher efficiency coal plants in developing countries and count these as a "clean development mechanism", which allows dirty plants in developed countries to continue. Total CO_2 emissions actually increase. The science requirement is that the coal be left in the ground, because fossil fuel CO_2 stays in the atmosphere-ocean system for millennia. It does not help to burn it more efficiently.

Slide 32 - CO_2 emissions were increasing 1.5 percent per year prior to the Kyoto Protocol. Subsequently emissions have increased 2.5 percent per year, even with the recent economic downturn.

Slide 33 - Fossil fuel use continues to increase because fossil fuels are the cheapest energy. It is as certain as the law of gravity: as long as fossil fuels are the cheapest energy their use will continue. Fossil fuels are cheapest in part because they are subsidized, but mainly because they are not made to pay their cost to society – caused by their impact on human health, on the environment, and on the future of young people.

The solution is obvious: remove subsidies and put a rising price on carbon – a fee collected domestically from the fossil fuel companies at the mine or port of entry.

Of course efficiency regulations are also needed, as is technology development – but the success of these depends on having a rising carbon price.

Slide 34 - The public will accept a substantial rising carbon fee only if the money is distributed to the public. Put the money in the hands of consumers and let the market place choose technology winners. Those citizens who do not use their resources to reduce their carbon emissions will soon be paying more in increased energy prices than they get in their green check.

A carbon fee or tax is the only viable global approach. It requires mainly that the United States and China agree upon a carbon price. Europe and Japan would surely then consent. Any country not agreeing would have a duty placed on its products made with help of fossil fuels.

Slide 35 - Cap-and-trade, in contrast, is favored by big banks and fossil fuel interests. In a multi-trillion dollar carbon market it is impossible to avoid bank involvement. Their highly skilled, secretive, trading units would make billions, without providing any added value.

Cap-and-trade is proven to be ineffectual in reducing emissions and it cannot be made global. India and China would never accept caps on their economies, nor should they.

Slide 36 - Fee-and-green-check puts money in the public's hands, a lot of money, stimulating the economy and stimulating innovation. It is the fastest route to a clean energy future. It would quickly bring mountaintop removal and tar sands development to an end – it may be the only way to do that, surely the least painful way.

Slide 37 - Back to the basic issue: stabilizing climate is a matter of intergenerational justice. Jake, my son's first child, recently was excited to have a baby sister, who was 2½ days old in this photo. My parents lived about 90 years, so Jake and Lauren Emma are likely to be around most of this century and feel the full force of climate change.

Jake likes to protect his baby sister, even though she is sometimes a nuisance. Jake is a gentle giant, for his age. If you believe long extrapolations, the charts suggest that he may be almost 2 meters tall eventually. But here is the problem: protecting Lauren Emma may be out of Jake's control, no matter how big and strong he is.

Today we have pushed the planet close to tipping points. Ice is melting in the Arctic, on Greenland and Antarctica, and on mountain glaciers worldwide. Many species are stressed by environmental destruction and climate change. If fossil fuel emissions continue unabated, sea level rise and species extinction will accelerate out of humanity's control. Increasing temperature and atmospheric water vapor will magnify climate extremes, both droughts and floods, and the storms of our grandchildren will be much more devastating.

Slide 38 - Such intergenerational injustice is foreign to all nations, cultures and religions. Yet we are saddled with governments who do nothing effective. They think they can set emissions at whatever level they choose, and they choose it with the help of the fossil fuel industry.

This situation is likely to continue until the public demands that governments do their job. But prospects for pressure from the public have been diminished by an effective campaign to discredit science by those who prefer business-as-usual.

Slide 39 - Yet I see 2 reasons for some optimism. First, China seems capable of making rational decisions and taking action. China has several incentives to move as rapidly as practical into clean energies: (1) their high levels of local air and water pollution, (2) the fact that they will suffer more from global warming than most nations, and (3) the economic advantage that they can gain by being out front in clean energy technologies. Indeed, China is aggressively investing in clean energy technologies.

Will this action by China stimulate the United States and other nations to get moving? Maybe. But, because of the undue influence of money in Washington and other capitals, I believe it is essential to involve the judicial branch of governments. As in the case of civil rights, achievement of justice probably requires people standing up for their rights and courts enforcing them.

Slide 40 - Legal scholars point out that governments have a fiduciary responsibility to manage the atmospheric trust. The executive and legislative branches of our governments are turning a deaf ear to the science, but the courts have the ability to require the government to make emission reductions that the science shows to be necessary. Stabilizing climate is a matter of intergenerational justice that can be enforced.

Young people, and older people who support them, must unite in demanding an effective approach that preserves our planet. I look forward to working with young people and their supporters in developing the scientific and legal case for young people and the planet.

To the young people I say: Stand up for your rights. Demand that the government take the actions needed to assure a future for you and your children. To the old people I say: we are not too old to fight. Let us gird up our loins and prepare to fight on the side of young people for protection of the world that they will inherit.

Slide 1

Global Warming Status

1. **Knowledge Gap Between**
   - What is <u>Understood</u> (scientists)
   - What is <u>Known</u> (public)
2. **Planetary Emergency**
   - Climate Inertia → Warming in Pipeline
   - Tipping Points → Could Lose Control
3. **Bad News & Good News**
   - Safe Level of CO_2 < 350 ppm
   - Multiple Benefits of Solution

Slide 2

Climate Tipping Points

1. **Ice Sheet Disintegration**
   - Ocean Warming → Ice Shelves Melt → Ice Streams Surge → Disintegration
2. **Species Extermination**
   - Shifting Climate Zones, Multiple Stresses, Species Interdependencies
3. **Methane Hydrate 'frozen methane'**
   - In Tundra & On Continental Shelves
   - Depends On Ocean & Ice Sheets

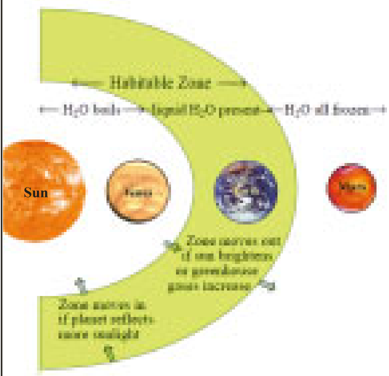
Slide 3

First Grandchild, Sophie — at Age Almost Two Years

Slide 4
Goldilocks Planets

Venus is closer to sun than Earth is, but cloud-covered Venus absorbs only 25% of incident sunlight, while Earth absorbs 70%. Venus is warmer because it has a thick carbon dioxide atmosphere causing a greenhouse effect of several hundred degrees.

Slide 5
Habitable Zone



When the solar system formed, the sun was 30% dimmer than today and Venus had an ocean. As the sun brightened, a runaway greenhouse effect caused the Venus ocean to boil away.

At times when Earth was younger, the sun brighter, and atmospheric CO_2 less, Earth froze over ("snowball Earth").

Earth is in the sweet spot today.

Slide 6
Basis of Understanding

1. Earth's Paleoclimate History
2. On-Going Global Observations
3. Climate Models/Theory

Slide 7

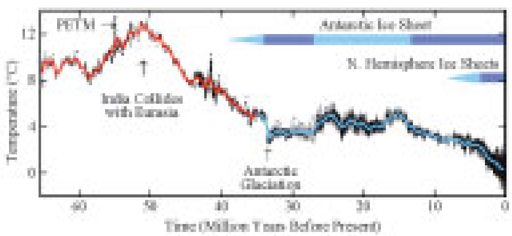
Why be concerned about human-made climate change?

There have been huge climate changes during Earth's history!

It is arrogant to think that humans can control climate or that we know enough to say that today's climate is the best one for the planet.

Slide 8

Global Deep Ocean Temperature



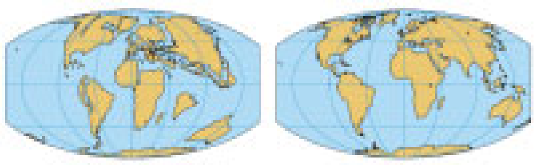
50 million years ago (50 MYA) Earth was ice-free.

Atmospheric CO_2 amount was of the order of 1000 ppm 50 MYA.

Atmospheric CO_2 imbalance due to plate tectonics ~ 10^{-4} ppm per year.

Slide 9

Cenozoic Era



End of Cretaceous (65 My BP) Present Day

Global Climate Forcings

External (solar irradiance): +1 W/m²

Surface (continent locations): ~1 W/m²

Atmosphere (CO_2 changes): > 10 W/m²

Slide 10
Summary: Cenozoic Era

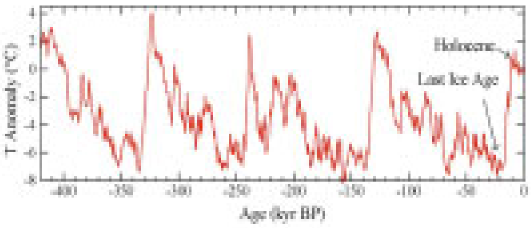
1. **Dominant Forcing: Natural ΔCO_2**
   - Rate ~100 ppm/My (0.0001 ppm/year)
   - Human-made rate today: ~2 ppm/year

Humans Overwhelm Slow Geologic Changes

2. **Climate Sensitivity High**
   - Antarctic ice forms if CO_2 < ~450 ppm
   - Ice sheet formation reversible

Humans Could Produce "A Different Planet"

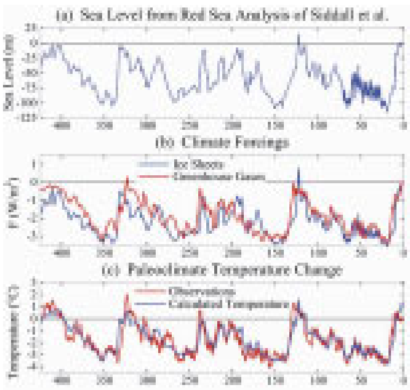
Slide 11
Antarctic (Vostok) Temperature



Earth's history provides important information on global warming.

Recorded human history occurs within the Holocene warm period.

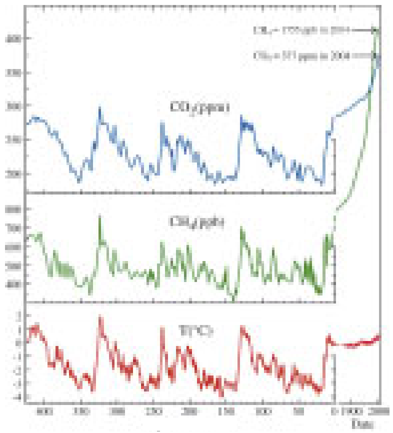
Slide 12
Kyr Before Present



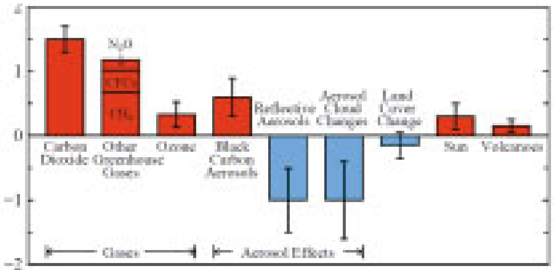
Slide 13
Kyr Before 1850

CO_2,CH_4 and estimated global temperature (Antarctic $\Delta T/2$ in ice core era) 0 = 1880-1899 mean.

Source: Hansen, *Clim. Change*, **68**, 269, 2005.



Slide 14
Climate Forcings



Change of climate forcings in W/m^2 between 1750 and 2000.
[from Hansen *et al.* *"Efficacy of Climate Forcings" J. Geophys. Res.* (2005)]

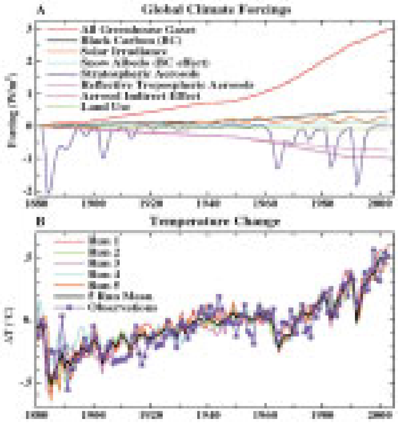
Slide 15
Sophie explains 2 watts of forcing to brother Connor.

Sophie Explains GH Warming:
"It's 2 W/m^2 Forcing."

Connor only counts 1 Watt

Slide 16
Global Climate Forcings and Temperature Change

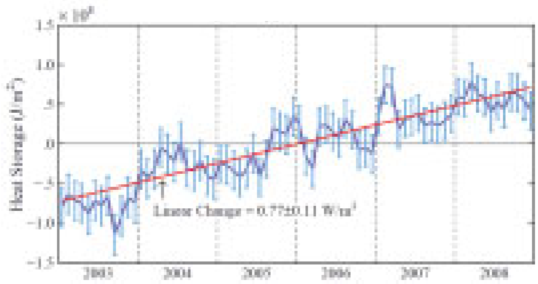
(A) Forcings used to drive climate simulations.



(B) Simulated and observed surface temperature change.

Source: Earth's energy imbalance: Confirmation and implications. *Science* **308**, 1431, 2005.

Slide 17
Heat Storage in Upper 2000 Meters of Ocean



Heat storage in upper 2000 meters of ocean during 2003-2008 based on ARGO data.

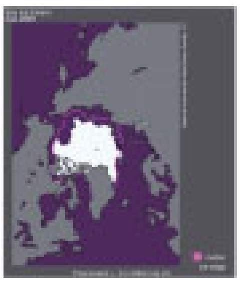
Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens.

Data must be averaged over a decade because of El Nino/La Nina and solar variability.

Energy imbalance is smoking gun for human-made increasing greenhouse effect.

Data source: von Schuckmann *et al. J. Geophys. Res.* **114**, C09007, 2009, doi:10.1029/2008JC005237.

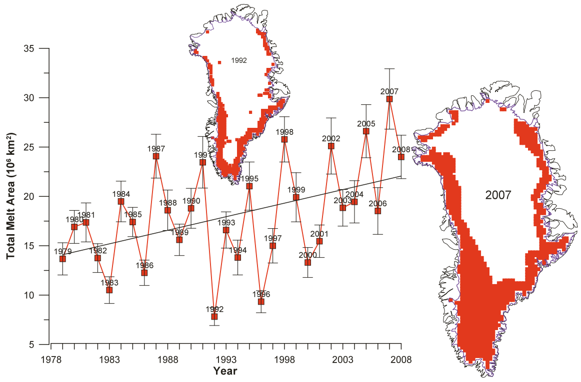
Slide 18
Arctic Sea Ice Area at Warm Season Minimum



September sea ice extent based on satellite microwave observations.

Data source: National Snow and Ice Data Center

Slide 19
Greenland Total Melt Area



Area on Greenland with snowmelt. Graph credit: Konrad Steffen, Univ. Colorado

Slide 20
Surface Melt on Greenland

Melt descending into a moulin, a vertical shaft carrying water to ice sheet base.

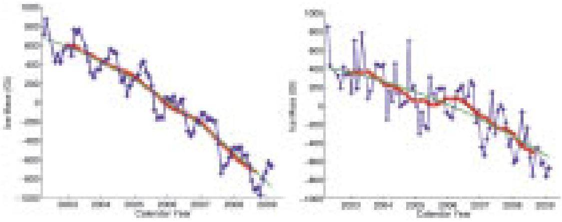
Source: Roger Braithwaite, University of Manchester (UK)

Slide 21
Jakobshavn Ice Stream in Greenland

Discharge from major Greenland ice streams is accelerating markedly.

Source: Prof. Konrad Steffen, Univ. of Colorado

Slide 22
Gravity Satellite Ice Sheet Mass Measurements



Greenland Ice Sheet | Antarctic Ice Sheet

Source: Velicogna, I. *Geophys. Res. Lett.*, **36**, L19503, doi:10.1029/2009GL040222, 2009.

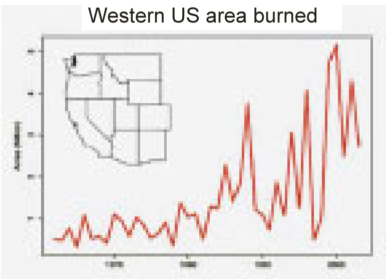
Slide 23
Pier on Lake Mead

Subtropics are expected to expand with global warming.

Observations show, on average, 4 degrees of latitude expansion.

Slide 24
Fires are increasing world-wide

Wildfires in Western US have increased 4-fold in 30 years.



Source: Westerling et al. 2006

Slide 25

Himalayan (Rongbuk) Glacier

Rongbuk, the largest glacier on Mount Everest's northern slopes, in 1968 (top) and 2007.
Glaciers are receding rapidly world-wide, including the Rockies, Andes, Alps, Himalayas.
Glaciers provide freshwater to rivers throughout the dry season and reduce spring flooding.

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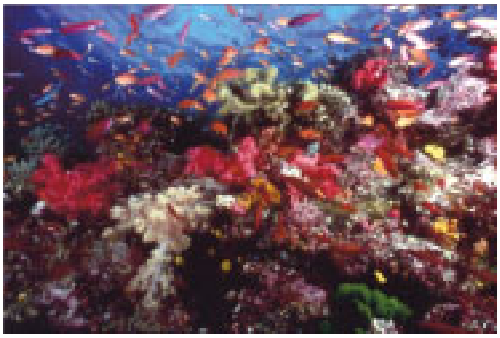
Stresses on Coral Reefs



Coral Reef off Fiji

(Photo credit: Kevin Roland)

Slide 27

Assessment of Target CO_2

Phenomenon	Target CO_2 (ppm)
1. Arctic Sea Ice	300-350
2. Ice Sheets/Sea Level	300-350
3. Shifting Climatic Zones	300-350
4. Alpine Water Supplies	300-350
5. Avoid Ocean Acidification	300-350

→ Initial Target CO_2 = 350* ppm

*assumes CH_4, O_3, Black Soot decrease

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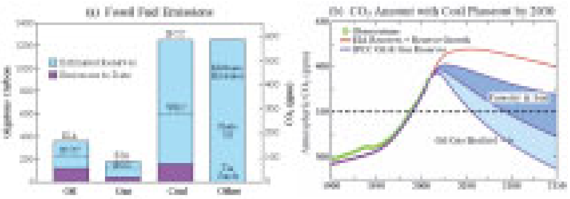
Fossil Fuel Reservoirs & CO_2 Scenarios



Scenarios assume no "Other" = Tar Sands, Oil Shale, Methane Hydrates
Coal phase-out by 2030 → peak CO_2 ~400-425 ppm, depending on oil/gas.
Faster return below 350 ppm requires additional actions

Source: Hansen *et al.*, Target atmospheric CO_2: where should humanity aim? *Open Atmos. Sci. J.*, **2**, 217-231, 2008.

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<350 ppm is possible, but…

Essential Requirements

1. **Quick Coal Phase-Out Necessary**
   All coal emissions halted in 20 years
2. **No Unconventional Fossil Fuels**
   Tar sands, Oil shale, Methane hydrates
3. **Don't Pursue Last Drops of Oil**
   Polar regions, Deep ocean, Pristine land

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What's really happening.

1. **Tar Sands Agreement with Canada**
   Pipeline planned to transport oil
2. **New Coal-fired Power Plants**
   Rationalized by 'Clean Coal' mirage
3. **Mountaintop Removal Continues**
   Diminishes wind potential of mountains
4. **Oil & Gas Extraction Expands**
   Arctic, offshore, public lands

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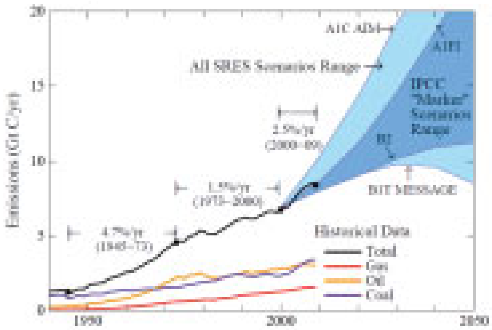
Global Action Status

1. Huge Gap: Rhetoric & Reality
   - Rhetoric: Planet in Peril
   - Policies: Small Perturbation to BAU
2. Greenwash/Disinformation Winning
   - Appeasement of Fossil Interests
   - Still Waiting for a Winston Churchill
3. Kyoto & Copenhagen Failures
   - Kyoto → accelerating emissions
   - Copenhagen → still "cap-&-trade"

Slide 32
Global Fossil Fuel CO_2 Annual Emissions



Global fossil fuel carbon dioxide emissions accelerated after Kyoto Protocol.

Date sources: Marland et al. (U.S. Dept. Energy, Oak Ridge and extended with BP Statistical Review of World Energy.)

Slide 33
Problem & Solution

1. Fossil Fuels are Cheapest Energy
   - Subsidized & Do Not Pay Costs
   - Solution: Rising Price on Carbon
2. Regulations also Required
   - Efficiency of Vehicles, Buildings,e.g.
   - Carbon Price Provides Enforcement
3. Technology Development Needed
   - Driven by Certainty of Carbon Price
   - Government Role Limited

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Fee & Green Check (Dividend)

1. Fee Applied at First Sale/Port of Entry
   Covers all Oil, Gas, Coal → No Leakage
2. Fee Specified: No Speculation, No Volatility
   No Wall Street Millionaires at Public Expense
3. Other Merits
   Only Potentially Global Approach
   Simple, Honest, Can be Implemented Quickly
   Market Chooses Technology Winners
   Most Efficient & Largest Carbon Reductions

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Cap-and-Trade Flaws

1. Designed for Banks & Fossil Interests
   Impossible to exclude big money
2. Price Volatility
   Discourages clean energy investments
3. Ineffectual
   Real carbon reductions small
4. Cannot be made global
   China/India will not (& should not) accept caps

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Fee & Green Check Addresses

1. Economy: Stimulates It
   Puts Money in Public's Hands– A Lot!
2. Energy: Fossil Fuel Addiction
   Stimulates Innovation – Fastest Route to Clean Energy Future
3. Climate
   Only Internationally Viable Approach - -
   Zero Chance of China/India Accepting a Cap
   Would Result in Most Coal & Unconventional Fossil Fuels, and some Oil, left in the Ground

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Lauren Emma (age 2½ days) and Jake (age 2½ years)

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Intergenerational Justice

Jefferson to Madison: …self-evident that "Earth belongs in usufruct to the living"*

Native People: obligation to 7th generation

Most Religions: duty to preserve creation

Governments (with fossil interests): we set emissions at whatever level we choose

Public: when will it become involved?

*Legal right to use something belonging to another

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Notes of Optimism

1. **China**

   Enormous investments in carbon-free energy (solar, wind, nuclear power)

2. **Legal Approach**

   Judicial branch less influenced by fossil fuel money (than executive and legislative branchs)

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Atmospheric Trust Litigation*

1. Atmosphere is a public trust asset

   Governments have fiduciary obligation to manage asset – it is not political discretion

2. Courts can enforce via injunction

   Require carbon accounting, with schedule specified by science

3. Force governments at all levels

* Wood, M., Atmospheric Trust Litigation, in *Adjudicating Climate Change: Sub-National, National, and Supra-National Approaches* (William C.G. Burns & Hari M. Osofsky, eds.) (2009, Cambridge University Press

Major Publications

Dr. James E. Hansen

Selected Publications:

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Profile

Sir Bob Watson

Chief Scientific Adviser of the UK Department for Environment, Food and Rural Affairs (DEFRA)
Chair of Environmental Science and Science Director at Tyndall Centre for Climate Change Research, the University of East Anglia

Education and Academic and Professional Activities

1948	Born in UK
1969	Receives a bachelor's degree in chemistry at Queen Mary College, University of London
1973	Receives a doctorate in reaction kinetics at Queen Mary College, University of London
1976-1987	Appointed as a scientist at NASA Jet Propulsion Laboratory
1980-1987	Acts as Deputy Program Scientist at NASA
1980-2006	Co-chairs scientific assessments of the Ozone Layer for World Meteorological Organization (WMO)/United Nations Environment Programme (UNEP)
1987-1990	Serves as Branch Chief for Upper Atmospheric Research and Stratospheric Chemistry Program of NASA's Earth Science and Applications Division
1989	Designated member of UNEP's "The Global 500: The Roll of Honor for Environmental Achievement"
1991-1994	Chairs the U.N. Global Environment Facility (GEF) Scientific and Technical Advisory Panel
1991	American Geophysical Union's Edward A. Flinn, III Award established to recognize individuals who personify the American Geophysical Union's motto of unselfish cooperation in research through their facilitating coordination and implementing activities (first recipient)
1992	US National Academy of Sciences Award for Scientific Reviewing
1993-1995	Chairs the Global Biodiversity Assessment for United Nations Environment Program
1993-1996	Associate Director for the Environment in the Office of Science and Technology Policy of the Executive Office of the President of the United States (under the Clinton Administration)
1993-1997	Co-chairs the IPCC Working Group II
1993	American Meteorological Society Special Award "for notable efforts in organizing and conducting international assessments in ozone depletion and global change"
	American Association for the Advancement of Science Award for Scientific Freedom and Responsibility

1996	Joins the World Bank as Senior Scientific Adviser in the Environmental Department
1997	Becomes Head of the Environment Sector Board of the World Bank and later Chief Scientist and Director for Environmentally and Socially Sustainable Development
1997-2002	Chairs IPCC
2000-2005	Co-chairs Millennium Ecosystem Assessment
2003-2008	Directs the International assessment of Agricultural Science and Technology for Development
2003	Global Green Award for International Environmental Leadership – US chapter of the Green Cross International formed by Mikhail Gorbachev Honorary "Companion of the Order of Saint Michael and Saint George" from the United Kingdom
2006	Zayed science award for the Millennium Ecosystem Assessment
2007	Appointed Chief Scientific Adviser of the UK Department for Environment, Food and Rural Affairs (DEFRA) Becomes Chair of Environmental Science and Science Director at Tyndall Centre for Climate Change Research, the University of East Anglia (England)
2007	Nobel Peace Prize for the IPCC, chaired from 1997-2001
2008	American Association for the Advancement of Science Award for International Scientific Cooperation

Sir Watson worked on the study of the creation and depletion of the Ozone Layer at the National Aeronautics and Space Administration (NASA). Leading numerous scientists, he produced scientific evidence of human-induced depletion of the Ozone Layer which led to the Montreal Protocol which incorporated the reduction of ozone depleting substances. In this way, Sir Watson has made a significant contribution to the enactment of the Protocol. Later, as Chair of the Intergovernmental Panel on Climate Change (IPCC), he took the initiative in developing the Synthesis Report of the Third Assessment Report. In particular, he played a significant role in successfully completing the detailed review by national governments from around the world of the Synthesis Report, coordinating and bridging science and policy and achieving an international consensus on the need to ratify the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). He also served as the first Chair of the Science and Technical Advisory Panel to the Global Environmental Facility (GEF), and held other important positions at the World Bank and other organizations. As Associate Director for the Environment in the Office of Science and Technology Policy under the Clinton Administration, he testified dozens of times before committees and subcommittees of the US Senate and House of Representatives on conservation issues. He emphasized the importance of environmental issues. Devoted to the facilitation of cooperation between science and government policy, he has communicated with related government officials and has helped them make policy decisions. The amount of contribution he has made to policy-making by national governments and international frameworks, a necessity and the foundation for the conservation of the global environment, is tremendous.

Depletion of the Ozone Layer and Preventive Actions

Sir Watson received a bachelor's degree and a doctorate in chemistry at Queen Mary College, University of London (England) in 1969 and 1973, respectively. Later, he worked as a postdoctoral fellow at the University of Maryland and the University of California, Berkeley (United States) before establishing a research group at the Jet Propulsion Laboratory (JPL) of the National Aeronautics and Space Administration (NASA). He was purely academic by nature. As a result of the reputation he gained with his doctoral thesis on halogen chemistry research, however, he began to work on a more realistic issue, "depletion of the ozone layer resultant from the use of chlorofluorocarbons (CFCs)." It was already a known fact that depletion of the ozone layer would increase harmful ultraviolet rays reaching the earth's surface, which could increase the occurrences of dermal cancer, conjunctivitis and other serious diseases. In this way he grew motivated to work on the important issue of the global environment.

In 1980 he moved to the headquarters of NASA located in Washington, D.C., as a manager of the upper atmosphere research program and had the opportunity to work with leading numerous scientists studying the depletion of the Ozone Layer. He developed skills and strategies to control and manage the NASA program which was growing more enormous and complex. The most important part of the strategies was the way he adeptly ran the organization by acknowledging the unique values and abilities of scientists and motivating them to a higher goal irrespective of differences in their organization or affiliation. He appealed to the pride of researchers and successfully encouraged them to deepen their involvement in the program. This approach to running the organization gained the support of numerous researchers.

To proceed with a big program aimed at the scientific elucidation of ozone layer depletion, he developed a relationship of trust with Dr. Dan Albritton, Director of the National Oceanic and Atmospheric Administration (NOAA), and helped realize the cooperation of former rivals: NASA and NOAA. The two organizations cooperated with each other and made significant achievements by communicating to policymakers the importance of scientific actions against the crisis and threat posed by a hole in the ozone layer. In cooperation with Dr. Albritton, he sent a team of scientists to the Antarctic in 1986. Dr. Susan Solomon, then an NOAA-affiliated scientist, was appointed the chief of the team. Dr. Solomon's team performed balloon observations and sample analysis experiments near the ground, and strongly suggested that the ozone layer depletion could be attributable to an artificial cause, namely chlorofluorocarbons (CFCs), rather than a natural weather phenomenon. The validity of the report was demonstrated the following year, by an analysis of upper air atmosphere performed in the stratosphere using a high-altitude plane (ER2). Their suggestion became a scientifically undeniable fact. With the latest scientific data, he joined Dr. Albritton in attending meetings for the ratification of the Montreal Protocol, which was negotiated in 1987. They explained to government officials from participating nations the fact that the cause of the Ozone Layer depletion was chlorofluorocarbons (CFCs), and endorsed ratification of the Montreal Protocol which incorporated a 50% reduction of chlorofluorocarbons (CFCs) by 2000. Then-President Reagan signed the Montreal Protocol and said it would boost the development of new technologies. He tackled ozone layer depletion, the biggest environmental issue at that time, and influenced the whole world toward the pursuit of solutions.

IPCC Third Assessment Report

From 1997 to 2002, Sir Watson chaired the IPCC and led the review of scientific, technical and socio-economic studies on global warming. In 2001, the IPCC published its Third Assessment Report. The Bush Administration ordered the US National Research Council (NRC) to review the report. The NRC said the IPCC Third Assessment Report (especially Working Group I[1] and technical summary) deserved a lot of praise as a study on climate science[2]. This statement enhanced confidence in the IPCC report.

The Third Assessment Report is important in that it included a Synthesis Report, which said there was strong evidence that the progression of global warming was undeniable and was due to human activities; that the human-induced climate change was expected to persist for centuries; and that the prevention of global warming would require comprehensive actions: continued technical development and overcoming of socio-economic difficulties. The introduction to the Synthesis Report defines the essence of the report as "integration and summarization of information that is policy-relevant and is not policy-prescriptive." The definition means that the Synthesis Report aims to cover all policy-relevant matters and to continually inform them by using expressions that contribute to policy-making, and that the Synthesis Report represents advice from the scientists' view and is not meant to tell policymakers what to do. This strongly conveys the attitude of Sir Watson toward realistically solving climate issues without deviating from his position as a scientist or limiting the role of the Synthesis Report to mere scientific remarks.

The basic details of the report were decided by scientists. The line by line wording of the report required consent by government officials from around the world. The coordination activities needed between scientists and government officials was all about putting scientific remarks into the most appropriate language for policymakers. Discussions for coordination were focused on a relationship between "accuracy, balance and clarity of message" in wording and "policies and interpretations." The approval of the Synthesis Report of the IPCC Third Assessment Report, led by Sir Watson, involved many people consisting of delegations from 100 countries, 10 non-governmental organizations and 42 scientists. Assuming leadership of this large organization, he summarized important points and submitted them to the IPCC plenary. By facilitating close exchange between science and policy, he contributed to making important policies, set an exemplary precedent for collaboration and coordination between scientists and policymakers and is now referred to as the master of uniting government officials and scientists.

Most remarkably, he drastically changed the whole world's view on climate change through the IPCC report which led to important changes of policy designed for the reduction of greenhouse gases at regional, national and international levels.

Facilitation of Environmental Policies

Sir Watson chaired the Scientific and Technical Advisory Panel of the U.N. Global Environment Facility (GEF) and the international Global Biodiversity Assessment and Millennium Ecosystem Assessment of the United Nations Environment Programme (UNEP) and has held important positions at many other international organizations. His administrative and managerial abilities were thoroughly exhibited in his commitments to the conservation of the global environment. From 1996 to 2007, he acted as Chief Scientist and Director for Environmentally and Socially Sustainable Development at the World Bank. He was devoted to revitalizing scientific programs at the World Bank. In line with the aim of the World Bank, namely relief from poverty and development of a sustainable society, he facilitated international exchanges of scientists and endeavored to help developing nations improve their scientific abilities. As Associate Director for the Environment in the Office of Science and Technology Policy under the Clinton Administration, he testified dozens of times before committees and subcommittees of the US Senate and House of Representatives on conservation issues. He explained the causal relationship among human economic activities, depletion of the ozone layer and global warming as well as the impact and damage that could result as a consequence, explaining to the whole world the graveness of environmental issues. Mr. Al Gore, former US Vice President, described Sir Watson as a “Hero of the Planet” in a letter written to a senior US government official.

The Sir Watson has devoted himself to the facilitation of cooperation between science and government policy, disseminated important information and views on science and helped government officials make policy decisions by keeping in contact with them. The size of the contribution he has made to policymaking by national governments and international frameworks, a necessity and the foundation for conservation of the global environment, is tremendous.

Notes

1. IPCC Working Group I (designed for scientific, technical and social-scientific assessment of climate change)
2. Committee on the Science of Climate Change, NRC (2001)

Essay

Current and Projected State of the Global and Regional Environment: Implications for Environmental, Economic and Social Sustainability

Sir Bob Watson

Most countries are attempting to achieve environmentally and socially sustainable economic growth, coupled with food, water, energy and human security at a time of enormous global changes, including environmental degradation at the local, regional and global scale. Key issues include climate change, loss of biodiversity and ecosystem services (provisioning, regulating, cultural and supporting), local and regional air pollution, and land and water degradation.

There is no doubt that the Earth's environment is changing on all scales from local to global, in large measure due to human activities,. The stratospheric ozone layer has been depleted, the climate is warming at a rate faster than at any time during the last 10,000 years, biodiversity is being lost at an unprecedented rate, fisheries are in decline in most of the world's oceans, air pollution is an increasing problem in and around many of the major cities in the world, large numbers of people live in water stressed or water scarce areas, and large areas of land are being degraded. Much of this environmental degradation is due to the unsustainable production and use of energy, water, food and other biological resources and is already undermining efforts to alleviate poverty and stimulate sustainable development, and worse, the future projected changes in the environment are likely to have even more severe consequences.

Understanding the interconnections among these environmental issues is essential in order to develop and implement informed cost-effective and socially acceptable policies, practices and technologies at the local, regional and global scale. Given these environmental issues are closely inter-linked we must ensure that policies and technologies to address one environmental issue, positively, and not negatively, impact on other aspects of the environment or human well-being, i.e., it is important to identify climate change response measures that are also beneficial to biodiversity and do not adversely affect biodiversity. Cost-effective and equitable approaches to address these issues exist or can be developed, but will require political will and moral leadership. While the substantial measures needed to prevent environmental degradation from undermining growth and poverty alleviation are not yet in place, a combination of technological and behavioral changes, coupled with pricing and effective policies (including regulatory policies), are needed to address these global challenges at all spatial scales, and across all sectors.

The major indirect drivers of change are primarily demographic, economic, socio-political, technological, and cultural and religious. These drivers are clearly changing: the world's population and the global economy are growing, the world is becoming more interdependent, and there are major changes in information technology and biotechnology. The world's population will likely increase from about 6.5 billion people today to 9 to10 billion people by 2050. This increase in population will be accompanied by an increase in GDP globally of a factor of 3-4, with developing countries increasingly driving global economic growth. By 2030, about half or more of the purchasing power of the global economy will stem from developing countries. Broad-based growth in developing countries sustained over the next 25 years could significantly reduce global poverty. At the same time, it must be recognized that the benefits from growth and globalization could be undermined by a failure to properly manage global environmental issues, especially mitigating and adapting to climate change, and reducing the loss of biodiversity and degradation of ecosystem services.

Climate Change

There is no doubt that the composition of the atmosphere and the Earth's climate have changed since the industrial revolution predominantly due to human activities, and it is inevitable that these changes will continue regionally and globally. The atmospheric concentration of carbon dioxide has increased by over 30% since the pre-industrial era primarily due to the combustion of fossil fuels and deforestation. Global mean surface temperatures have already increased by about 0.75°C, an additional 0.5°C to 1.0°C is inevitable due to past emissions, and are projected to increase by an additional 1.2-6.4°C between 2000 and 2100, with land areas warming more than the oceans and high latitudes warming more than the tropics. Precipitation is more difficult to predict, but is likely to increase at high latitudes and in the tropics, and decrease significantly in the sub-tropics, with an increase in heavy precipitation events and a decrease in light precipitation events, leading to more floods and droughts.

Changes in temperature and precipitation are causing, and will continue to cause, other environmental changes, including, rising sea levels, retreating mountain glaciers, melting of the Greenland ice cap, shrinking Arctic Sea ice, especially in summer, increasing frequency of extreme weather events, such as heat waves, floods, and droughts, and intensification of cyclonic events, such as hurricanes in the Atlantic.

The Earth's climate, which is projected to change at a faster rate than during the last century, is projected to adversely affect freshwater, food and fiber, natural ecosystems, coastal systems and low-lying areas, human health and social systems. The impacts of climate change are likely to be extensive, primarily negative, and cut across many sectors. Temperature increases, which will increase the thermal growing season at temperate latitudes, including in the US and Europe, are likely lead to increased agricultural productivity for temperature changes below 2-3°C, but decrease with larger changes. However, agricultural productivity will likely be negatively impacted for almost any changes in climate throughout the tropics and sub-tropics, areas with high levels of hunger and malnutrition. Water quality and availability in many arid- and semi-arid regions will likely decrease, while the risk of floods and droughts in many regions of the world will increase. Vector- and water-borne diseases, heat stress mortality and extreme weather-event deaths, and threats to nutrition in developing countries, will likely increase. Millions of people could be trapped in areas of abject poverty or displaced due to sea-level rise and flooding. These climate change impacts are most likely to adversely affect populations in developing countries. Climate change, coupled with other stresses, can lead to local and regional conflict and migration depending on the social, economic, and political circumstances.

The goal, agreed at the Ministerial session of the UNFCCC in Copenhagen in 2009, and endorsed in Cancun and Durban, to limit global temperature changes to 2°C above pre-industrial levels is appropriate if the most severe consequences of human-induced climate change are to be avoided, but it must be recognized to be a stretch target and, unless political will changes drastically in the near future, it will not be met. Therefore, we should be prepared to adapt to global temperature changes of 4-5°C. In addition, we must recognize that we cannot address mitigation and adaptation separately.

Mitigating climate change will require getting the price right, an evolution of low-carbon technologies (production and use of energy), and behavior change by individuals, communities, private sector and the public sectors (see paper by Goldemberg and Lovins). In addition to transitioning to a low carbon energy system, it is critical to reduce emissions from forests by reducing forest degradation and deforestation; and sequestering carbon through reforestation; afforestation; and agroforestry, and from agricultural systems through conservation tillage, reducing emissions from the use of fertilizers, and from livestock and rice production.

In addition, to mitigating the emissions of greenhouse gases, it will be essential to adapt to climate change. However, mitigation is essential because there are physical, technological, behavioural and financial limits to the amount of adaptation that we can achieve: there are physical limits to adaptation on small, low-lying islands, technological limits to flood defences, behavioural limits to where people live and why, and financial limits for adaptation activities. The more we mitigate, the less we will have to adapt. Nevertheless, we know that adaptation is essential and must be mainstreamed, particularly into sectoral and national economic planning in developing countries due to their heightened vulnerability to climate change impacts.

Loss of Biodiversity and Degradation of Ecosystem Services

Throughout the world, biodiversity at the genetic, species and landscape level is being lost, and ecosystems and their services are being degraded, because of conversion of natural habitats, over-exploitation, pollution, introduction of exotic species and climate change, which are in many instances causing tremendous harm to both people and the environment. In particular, the emphasis placed on provisioning services to meet the increased need for food (crops and livestock), and to a lesser extent fibre, water and energy, for an increasing population has resulted in a decline in biodiversity and degradation of many ecosystems. The Millennium Ecosystem Assessment reported that 15 of the 24 services evaluated were in decline, 4 were improving and 5 were improving in some regions of the world and declining in other regions. The UK National Ecosystem Assessment reported that between 30-35% of the ecosystem services evaluated were in decline, 20% were improving and 45-50% were relatively stable. While climate change has not been a major cause of biodiversity loss over the last 100 years it is likely to be a major threat in all biomes during the next 100 years. Climate change will likely exacerbate biodiversity loss and adversely affect most ecological systems, especially coral reefs, mountainous and polar ecosystems, potentially resulting in significant adverse changes in ecosystem goods and services. A recent assessment estimated that every 1°C increase in global mean surface temperature up to 5°C would eventually result in a 10% loss of species.

Biodiversity is central to human well-being, providing a variety of ecosystem services that humankind relies on, including: provisioning (e.g. food, freshwater, wood and fiber, and fuel); regulating (e.g. of climate, flood, diseases); culture (e.g. aesthetic, spiritual, educational, and recreational), and supporting (e.g. nutrient cycling, soil formation, and primary production). These ecosystem services, which contribute to human well-being, including our security, health, social relations, and freedom of choice and action, are being diminished.

The benefits that we derive from the natural world and its constituent ecosystems are critically important to human well-being and economic prosperity, but are consistently undervalued in economic analysis and decision-making. Effective conservation and sustainable use of ecosystems are critical for human well-being and a future thriving and sustainable green economy. Failure to include the valuation of non-market values in decision-making results in a less efficient resource allocation; however, a major challenge is to develop systems to appropriate the values of non-market ecosystem services to land managers.

Therefore, addressing the issue of biodiversity and ecosystem services requires changing the economic background to decision-making. There is a need to: (i) make sure that the value of all ecosystem services, not just those bought and sold in the market, are taken into account when making decisions; (ii) remove subsidies to agriculture, fisheries, and energy that cause harm to people and the environment; (iii) introduce payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage, that are of value to society; and (iv) establish market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way.

There is also a need to improve policy, planning, and management by integrating decision-making between different departments and sectors, as well as international institutions, to ensure that policies are focused on protection and sustainable use of ecosystems. It will require: (i) empowering marginalized groups to influence decisions affecting ecosystem services, and recognize in law local communities' ownership of natural resources; (ii) restoring degraded ecosystems and establishing additional protected areas, particularly in marine systems and providing greater financial and management support to those that already exist; and (iii) using all relevant forms of knowledge and information about ecosystems in decision-making, including the knowledge of local and indigenous groups.

Success will also require influencing individual and community behavior. Thus it will be critical to provide access to information about ecosystems and decisions affecting their services, provide public education on why and how to reduce consumption of threatened ecosystem services, and by establishing reliable certification systems to give people the choice to buy sustainably harvested products. It will also be important to develop and use environment-friendly technologies, thus requiring investments in agricultural science and technology aimed at increasing food production with minimal harmful trade-offs.

Lecture

Ozone Depletion, Climate Change and Loss of Biodiversity: Implications for Food, Water and Human Security

Sir Bob Watson

Slide 1* - There is no doubt that the Earth's environment is changing on all scales from local to global, in large measure due to human activities. The stratospheric ozone layer has been depleted, the climate is warming at a rate faster than at any time during the last 10,000 years, biodiversity is being lost at an unprecedented rate, fisheries are in decline in most of the world's oceans, air pollution is an increasing problem in and around many of the major cities in the world, large numbers of people live in water stressed or water scarce areas, and large areas of land are being degraded. Much of this environmental degradation is due to the unsustainable production and use of energy, water, food and other biological resources and is already undermining efforts to alleviate poverty and stimulate sustainable development, and worse, the future projected changes in the environment are likely to have even more severe consequences.

The issues of stratospheric ozone depletion, climate change, loss of biodiversity and degradation of ecosystem services, local and regional air pollution, and land and water degradation are inter-connected and are undermining:

- Economic growth, poverty alleviation, and the livelihoods of the poor;
- Human health; and
- Personal, national, and regional security.

Understanding the interconnections among these environmental issues is essential in order to develop and implement informed cost-effective and socially acceptable policies, practices and technologies at the local, regional and global scale. Given these environmental issues are closely inter-linked we must ensure that policies and technologies to address one environmental issue, positively, and not negatively, impact on other aspects of the environment or human well-being, i.e., it is important to identify climate change response measures that are also beneficial to biodiversity and do not adversely affect biodiversity. Cost-effective and equitable approaches to address these issues exist or can be developed, but will require political will and moral leadership. While the substantial measures needed to prevent environmental degradation from undermining growth and poverty alleviation are not yet in place, a combination of technological and behavioral changes, coupled with pricing and effective policies (including regulatory policies), are needed to address these global challenges at all spatial scales, and across all sectors.

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* There are supplement slides *at the back of* the section.

political, technological, and cultural and religious. These drivers are clearly changing: the world's population and the global economy are growing, the world is becoming more interdependent, and there are major changes in information technology and biotechnology. The world's population will likely increase from about 6.5 billion people today to 9-10 billion people by 2050. This increase in population will be accompanied by an increase in GDP globally of a factor of 3-4, with developing countries increasingly driving global economic growth. By 2030, about half or more of the purchasing power of the global economy will stem from developing countries. Broad-based growth in developing countries sustained over the next 25 years could significantly reduce global poverty. At the same time, it must be recognized that the benefits from growth and globalization could be undermined by a failure to properly manage global environmental issues, especially mitigating and adapting to climate change, and reducing the loss of biodiversity and degradation of ecosystem services.

Slide 2 - Stratospheric Ozone Depletion

The layer of ozone in the stratosphere protects the Earth from damaging ultraviolet radiation, which can cause melanoma and non melanoma skin cancer in humans and adversely affect ecological systems. Scientific research in the 1970s, 1980s and 1990s demonstrated that anthropogenic emissions of chlorine, e.g., chlorofluorocarbons, and bromine containing chemicals that reached the stratosphere are photo-dissociated. The resulting halogen atoms and halogen free radicals catalytically destroy ozone at all latitudes, except the tropics, with the greatest depletions being at high latitudes in winter. Of particular importance was the discovery of the spring-time Antarctic ozone hole and the subsequent ground, balloon and aircraft campaigns that showed that human activities were responsible and not natural phenomena. A series of international ozone assessments provided the scientific, technical and economic information needed to inform national and international policy formulation. In 1985 an International Convention to protect the ozone layer was successfully negotiated, followed by the historic Montreal Protocol in 1987, which mandated emission reductions in ozone-depleting chemicals from industrialized countries. The Montreal Protocol was quickly followed by a series of adjustments and amendments, which resulted in the elimination of emissions of nearly all short- and long-lived halogenated chemicals from both developed and developing countries, thus protecting the ozone layer from significant loss. Observational evidence shows that the Montreal Protocol is working with the atmospheric concentrations of the ozone-depleting chemicals peaking and now decreasing. The Montreal Protocol should result in the ozone layer recovering by the middle of the century.

This is clearly a success story, where national and internationally coordinated research led to an understanding of the processes controlling the abundance of stratospheric ozone. The international assessments provided decision-makers in government with a single source of information upon which to base national and international policies and the private sector information upon which to develop environmentally-friendly alternatives.

Slide 3 - Climate Change

There is no doubt that the composition of the atmosphere and the Earth's climate have changed since the industrial revolution predominantly due to human activities, and it is inevitable that these changes will continue regionally and globally. Global mean surface temperatures have already increased by about 0.75°C, and are projected to increase by an additional 1.2-6.4°C between 2000 and 2100, with land areas in the high northern latitudes increasing by 4-5°C by 2090 even under low greenhouse gas emission scenarios, and by 10°C on average under high greenhouse gas emission scenarios. Precipitation is more difficult to predict, however is likely to increase at high latitudes and in the tropics, and decrease significantly in the sub-tropics.

Changes in temperature and precipitation are causing, and will continue to cause, other environmental changes, including, rising sea levels, retreating mountain glaciers, melting of the Greenland ice cap, shrinking Arctic Sea ice, especially in summer, increasing frequency of extreme weather events, such as heat waves, floods, and droughts, and intensification of cyclonic events, such as hurricanes in the Atlantic.

The Earth's climate, which is projected to change at a faster rate than during the last century, is projected to adversely affect freshwater, food and fiber, natural ecosystems, coastal systems and low-lying areas, human health and social systems. The impacts of climate change are likely to be extensive, primarily negative, and cut across many sectors. Temperature increases, which will increase the thermal growing season at temperate latitudes, including in the US and Europe, are likely lead to increased agricultural productivity for temperature changes below 2-3°C, but decrease with larger changes. However, agricultural productivity will likely be negatively impacted for almost any changes in climate throughout the tropics and sub-tropics, areas with high levels of hunger and malnutrition. Climate change will likely exacerbate biodiversity loss and adversely affect most ecological systems, especially coral reefs, potentially resulting in significant adverse changes in ecosystem goods and services. A recent assessment estimated that every 1°C increase in global mean surface temperature up to 5°C would eventually result in a 10% loss of species. Water availability and quality in many arid and semi-arid regions will likely decrease, while the risk of floods and droughts in many regions will increase. Vector- and water-borne diseases, heat stress mortality and extreme weather-event deaths, and threats to nutrition in developing countries, will likely increase. Tens of millions of people could be displaced due to sea-level rise. These climate change impacts are most likely to adversely affect populations in developing countries. Climate change, coupled with other stresses, can lead to local and regional conflict and migration depending on the social, economic, and political circumstances.

Poverty alleviation requires climate change-resilient development, which must consist of strategies to cost-effectively mitigate human-induced climate change and adapt to the projected impacts. While developed countries remain the largest per-capita emitters of greenhouse gases today, the growth of carbon emissions in the next decades will come primarily from developing countries, especially China and India, which are following the same energy and carbon intensive development path as did their rich counterparts. Consequently, to mitigate climate change we must minimize the emissions of greenhouse gases and transition to a low-carbon economy while recognizing that access to affordable energy in developing countries is a pre-requisite for poverty alleviation and economic growth. To adapt, we must integrate current climate variability and projected climatic changes into sector and national economic planning while taking into consideration the aspirations of local communities.

Climate change-resilient development must be equitable. Climate change, like biodiversity loss and ecosystem degradation, is an inter- and intra-generational equity issue. Whereas the historical greenhouse gas emissions have come from developed countries, developing countries and poor people in developing countries are most vulnerable to the impacts of climate change. Furthermore, the actions of today will affect future generations. Mitigation and adaptation strategies must take these equity issues into account.

Slide 4 - Mitigating Climate Change

The goal, agreed at the Ministerial session of the UNFCCC in Copenhagen in 2009, to limit global temperature changes to 2°C above pre-industrial levels is appropriate if the most severe consequences of human-induced climate change are to be avoided, but it must be recognized to be a stretch target and, unless political will changes drastically in the near future, it will not be met. Therefore, we should be prepared to adapt to global temperature changes of 4-5°C. In addition, we must recognize that we cannot address mitigation and adaptation separately.

The current level of greenhouse gases in the atmosphere, accounting for the offsetting effect of aerosols, is approximately 385ppm CO_2eq*. If we succeed at stabilizing between 400 and 450ppm CO_2eq, there is a 50% chance that global temperature changes will be limited to 2°C above pre-industrial levels, with a 5% probability of 2.8°C. However, the likelihood of stabilizing at this level is low. If we stabilize at 550ppm CO_2eq, there is a 50% chance that global temperature changes will be limited to 3°C above pre-industrial levels, with a 5% chance of a 4.8°C, and if we allow the atmosphere to reach 650ppm CO_2eq then there is a 50% chance that global temperature changes will be limited to 4°C above pre-industrial levels, with a 5% chance of a 6.0°C.

To stabilize at 500ppm CO_2eq or lower, OECD countries would need to reduce their carbon emissions by at least 80% by 2050. Developing countries would also need to decrease their projected carbon emissions significantly over the same time period. Clearly a range of tools (policies, technologies and practices) are needed to stabilize greenhouse gases in the atmosphere at 500ppm CO_2eq or less.

It is often assumed that an appropriate combination of technology and policy options could provide the basis to meet our stabilization goals and mitigate climate change. However, mitigation will require a combination of pricing and technological mechanisms, as well as good policies and behavioural change, i.e., pricing carbon emissions and understanding behavioural changes is critical.

The IPCC Fourth Assessment Report shows that putting a price on carbon can lead to significant emission reductions. Pricing mechanisms include emissions trading, taxation, and regulations across national, regional, and global scales and across all sectors.

Note * ppm CO_2eq: parts per million of carbon dioxide equivalent

Technology use and transformation is needed to reduce emissions. Better use of available low-carbon technologies coupled with improved development, commercialization and market penetration of emerging technologies is required. Examples include:

- **Efficient production and use of energy:** power generation (e.g. re-powering inefficient coal plants and developing integrated gasification combined cycle (IGCC)); efficient transport (e.g., developing electric and fuel cell cars; developing mass transit; and improving urban planning), buildings, and industries;
- **Fuel shift:** coal to gas;
- **Renewable energy and fuels:** wind, wave and tidal power; solar PV and solar thermal; small- and large-scale hydropower; and bio-energy;
- **Carbon capture and storage (CCS):** capture and geological storage of CO_2 produced during electricity generation (e.g., IGCC – CCS); and
- **Nuclear fission:** nuclear power

In addition to transitioning to a low carbon energy system, it is critical to reduce emissions from forests by reducing forest degradation and deforestation; and sequestering carbon through reforestation; afforestation; and agroforestry, and from agricultural systems through conservation tillage, reducing emissions from the use of fertilizers, and from livestock and rice production.

Key mitigation technologies projected to be commercialized before 2030 include, carbon capture and storage, advanced nuclear power, and renewable energy (e.g., tidal and wave energy), second generation biofuels, advanced electric and hybrid vehicles, and integrated design of commercial buildings. However, governments and the private sector must invest more in energy RD&D to deliver these low greenhouse gas technologies. At least US$20 trillion is required globally for energy infrastructure investments between now and 2030. Investment decisions will determine emissions from the energy sector. Returning global energy-related CO_2 emissions to 2005 levels by 2030 would require a major shift in investment patterns, but initial estimates suggest that the net additional investments range from negligible to 5-10%

A suitable policy framework is needed to facilitate the emergence of appropriate pricing and technological mechanisms, as voluntary agreements alone will not work. Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to significantly invest in low-greenhouse gas products, technologies and processes, including economic instruments, regulations (e.g., standards) and government funding and tax credits. The costs of reducing greenhouse gas emissions are reduced through international trading and adopting a multi gas / multi sector strategy, hence reducing the financing needed to transition to a low-carbon economy.

A long-term (e.g. 2030–2050), legally binding global regulatory framework is needed that involves all major emitters, including the US, EU, Russia, China, Brazil, and India. The agreement should allocate responsibilities in an equitable manner and should include immediate and intermediate targets. This would stimulate a viable carbon market with a flow of funds to developing countries of tens of billions of dollars per year. The framework should expand the range of eligible Clean Development Mechanism (CDM) activities to include reduced deforestation and forest degradation (REDD), green investment schemes, and energy efficiency standards. Sectoral and programmatic approaches should be considered.

In order to stabilize the concentration of greenhouse gases in the atmosphere, emissions would have to peak and decline thereafter – the lower the stabilization level the more quickly this peak and decline would need to occur. Delaying action to reduce greenhouse gas emissions will be costly by locking in high carbon pathways, thus making it more difficult and expensive to reduce emissions in the future, as well as creating higher risks of severe climate change impacts.

Adaptation

In addition, to mitigating the emissions of greenhouse gases, it will be essential to adapt to climate change. However, mitigation is essential because there are physical, technological, behavioural and financial limits to the amount of adaptation that we can achieve: there are physical limits to adaptation on small, low-lying islands, technological limits to flood defences, behavioural limits to where people live and why, and financial limits to integrate adaptation to climate change. The more we mitigate, the less we will have to adapt. Nevertheless, we know that adaptation is essential and must be mainstreamed, particularly into sectoral and national economic planning in developing countries due to their heightened vulnerability to climate change impacts.

The estimated annual costs of inaction related to climate change cover a huge range, but are expected to fall between tens and hundreds of billions of dollars in developing countries by 2050. Furthermore, a preliminary assessment shows that tens of billions of dollars per year of Overseas Development Assistance (ODA) and concessional finance investments are exposed to climate risks. Comprehensive project planning and additional investments to climate-proof development projects will require additional funding.

While current financial instruments are technically adequate to respond to the challenge of achieving climate resilient development, the amounts of money flowing through these instruments need to be substantially increased. Issues requiring immediate work include an analysis of institutional barriers to mainstreaming adaptation into development planning and the need for new standards for infrastructure and procedures for planning. New insurance related instruments are likely to play a major role in this, including weather index insurance for activities by farmers, and risk pooling arrangements such as the Global Index Insurance Facility.

Failure to adapt adequately to current climate variability is already a major impediment to poverty reduction. Most sectors are maladapted to current climate variability. Failure to effectively mainstream adaptation to increasingly severe weather patterns and climate variability into development activities is a major threat to poverty alleviation. This requires a climate risk management approach that takes account of the threats and opportunities arising from both current and future climate variability in project design. This process must be country-driven and focus on national needs and local priorities. Delivery of adaptive responses depends on effective governance mechanisms.

Slide 5 - Loss of Biodiversity and Degradation of Ecosystem Services

Biodiversity is central to human wellbeing, providing a variety of ecosystem services that humankind relies on, including: provisioning (e.g. food, freshwater, wood and fiber, and fuel); regulating (e.g. of climate, flood, diseases); culture (e.g. aesthetic, spiritual, educational, and recreational), and supporting (e.g. nutrient cycling, soil formation, and primary produ-ction). These ecosystem services contribute to human wellbeing, including our security, health, social relations, and freedom of choice and action.

Enhancement of the goods and services provided by ecosystems tend to have multiple and synergistic benefits, but little of this potential is being used today. Indeed, throughout the world, the capability of many ecosystems to provide a range of services is being diminished, because of conversion of natural habitats, over-exploitation, pollution, introduction of exotic species and climate change, which are in some instances causing tremendous harm to both people and the environment. While climate change has not been a major cause of biodiversity loss over the last 100 years it is likely to be a major threat in all biomes in the next 100 years.

Addressing the issue of biodiversity and ecosystem services requires changing the economic background to decision-making. There is a need to: (i) make sure that the value of all ecosystem services, not just those bought and sold in the market, are taken into account when making decisions; (ii) remove subsidies to agriculture, fisheries, and energy that cause harm to people and the environment; (iii) introduce payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage, that are of value to society; and (iv) establish market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way.

There is also a need to improve policy, planning, and management by integrating decision-making between different departments and sectors, as well as international institu-tions, to ensure that policies are focused on protection and sustainable use of ecosystems. It will require: (i) empowering marginalized groups to influence decisions affecting ecosystem services, and recognize in law local communities' ownership of natural resources; (ii) restoring degraded ecosystems and establishing additional protected areas, particularly in marine systems and providing greater financial and management support to those that already exist; and (iii) using all relevant forms of knowledge and information about ecosystems in decision-making, including the knowledge of local and indigenous groups.

Success will depend on influencing individual behavior, thus it will be critical to provide access to information about ecosystems and decisions affecting their services, provide public education on why and how to reduce consumption of threatened ecosystem services, and by establishing reliable certification systems to give people the choice to buy sustainably harvested products. It will also be important to develop and use environment-friendly technologies, thus requiring investments in agricultural science and technology aimed at increasing food production with minimal harmful trade-offs.

Slide 6 - Food Security and Agricultural Production

Total food production has nearly trebled since 1960, per capita production has increased by 30%, and food prices and the percent of undernourished people have fallen, but the benefits have been uneven and more than one billion people still go to bed hungry each night. Furthermore, intensive and extensive food production has caused environmental degradation.

Food prices increased during the last two-three years for a variety of reasons that are unlikely to disappear in the coming decades, including:

- Poor harvests due to variable weather – possibly related to human-induced climate change;
- Increased biofuels use, e.g., maize in the USA;
- Increased demand, in rapidly growing economies;
- High energy prices, increasing the cost of mechanization and fertilizers;
- Speculation on the commodity markets at a time of low stocks; and
- Export bans from some large exporting countries to protect domestic supplies.

The demand for food will likely double in the next 25-50 years, primarily in developing countries. Furthermore, the type and nutritional quality of food demanded will change, e.g., increased demand for meat. We need sustained growth in the agricultural sector to feed the world, enhance rural livelihoods, and stimulate economic growth. Yet these new demands are arising at a time when – in addition to the challenges highlighted above – the world has less labour due to disease and rural-urban migration, less water due to competition from other sectors, distorted trade policies due to OECD subsidies, land policy conflicts, loss of genetic, species, and ecosystem biodiversity, and increasing levels of air and water pollution.

Agriculture affects the environment; for example, tillage and irrigation methods can lead to salinisation and soil erosion, and fertilisers and other forms of agricultural production (e.g. rice production and livestock) contribute to greenhouse gas emissions, and extensification into grasslands and forests leads to loss of biodiversity at the genetic, species and landscape level. Environmental degradation in turns reduces agricultural productivity.

We can no longer think of agriculture in terms of production alone. We must acknowledge the multi-functionality of agriculture, and place agriculture within a broad economic, social, and environmental framework.

We can feed the world with affordable food while providing a viable income for the farmer, but business-as-usual will not work. Most of today's hunger problems can be addressed with the appropriate use of current technologies, particularly appropriate agro-ecological practices (e.g. no/low till, integrated pest management, and integrated natural resource management). These must be coupled with decreased post-harvest losses.

Emerging issues such as climate change and new plant and animal pests may increase our future need for higher productivity and may require advanced biotechnologies, including genetic modification, to address future food demands. However, the risks and benefits of these tools must be fully understood on a case-by-case basis. The public and private sectors should increase their investments in research and development, extension services, and weather and market information.

Farmers must be central to all initiatives taken; local and traditional knowledge must be integrated with agricultural knowledge, science, and technology developed in universities and government laboratories. Innovation that involves all relevant stakeholders along the complete food chain is essential. As such, we must recognize the critical role of women and empower them (e.g. through education, property rights, and access to financing).

We will also need to employ global-scale policy reforms. This will include eliminating both OECD production subsidies and tariff escalation on processed products, and recognizing the special needs of the least developed countries through non-reciprocal market access. Governments should pay farmers to maintain and enhance ecosystem services.

Slide 7 - Water Security

Projections show that by 2025 over half of the world's population will live in places that are subject to severe water stress. This is irrespective of climate change, which will exacerbate the situation. Water quality is declining in many parts of the world, and 50-60% of wetlands have been lost. Human-induced climate change is projected to decrease water quality and availability in many arid and semi-arid regions and increase the threats posed by floods and droughts in most parts of the world. This will have far-reaching implications, including for agriculture: 70% of all freshwater is currently used for irrigation. 15-35% of irrigation water use already exceeds supply and is thus unsustainable.

Freshwater availability is spatially variable and scarce, particularly in many regions of Africa and Asia. Numerous dry regions, including many of the world's major "food bowls," will likely become much drier even under medium levels of climate change. Glacier melt, which provides water for many developing countries, will likely exacerbate this problem over the long term. Runoff will decrease in many places due to increased evapotranspiration. In contrast, more precipitation is likely to fall in many of the world's wetter regions. Developed regions and countries will also be affected. For example, winters will likely become hotter and wetter in the UK, and summers hotter and drier; southeast England may receive 50% less rainfall during the summer by the 2080s.

Cost recovery for water – at only 20% – poses a major problem for water management. Crucially, and controversially, we must get water pricing right. The Dublin Principles should be implemented to help address the challenges associated with water scarcity. These include the:

- **Ecological Principle:** river basin management (often transnational); multi-sectoral management (e.g. agriculture, industry, and households); and coupled land-and-water management
- **Institutional Principle:** Comprehensive stakeholder involvement (e.g. state, private sector, and civil society – especially women) in management action at the lowest level
- **Instrument Principle:** Improved allocation and quality enhancement via incentives and economic principles

Science-policy Interface

Strengthening the science-policy interface for many environmental issues is also critical. National and international, coordinated, and interdisciplinary research is the critical underpinning of informed policy formulation and implementation. There is an urgent need for strengthening the scientific and technological infrastructure in most developing countries. Independent, global expert assessments that encompass risk assessment and risk management have proven to be a critical component of the science-policy interface. These include the International Stratospheric Ozone Assessments, the Intergovernmental Panel on Climate Change, the Millennium Ecosystem Assessment, and the International Agricultural Assessment of Science and Technology for Development. Such assessments must be policy-relevant rather than policy-prescriptive. Furthermore, we need a more integrated assessment process that encompasses all environmental issues within the construct of economic growth and poverty alleviation.

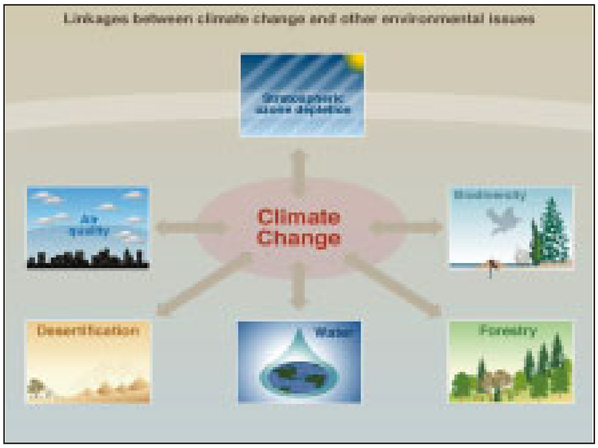
Slide 8 - Conclusion

In summary, we are changing the Earth's climate, losing biodiversity and spending Earth's natural capital, putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted. However, the future is not pre-ordained. Business as usual will lead to an unsustainable world with significant changes in the Earth's climate and a loss of critical ecosystem services. Cost-effective technologies, supported by an appropriate policy framework, can lead to more sustainable practices. Effective action needs stable and credible environmental policies that support the long-term shift to a low-carbon economy and the sustainable use of natural resources. We need not just a small improvement in resource efficiency, but a radical shift. Public and private sector decision-makers need to take a longer-term perspective. We must make advances in science and technology, with the emphasis on interdisciplinary research. We must get the economics right; this includes eliminating perverse subsidies by valuing ecosystem services and internalizing externalities.

Progress requires political will and moral leadership in the public and private sectors. The actions of today's generation will profoundly affect the Earth inherited by our children and future generations. Policymakers should recognize that there is no dichotomy between economic growth and environmental protection, and that addressing issues such as climate change provides economic opportunities to restructure and make a more efficient energy system, and can provide additional benefits such as reducing local and regional air pollution, with positive implications for human health. The benefits of limiting climate change and sustainably managing ecosystems far exceed the costs of inaction, and delaying action can significantly increase costs. Efficient resource use saves money for businesses and households, and a green economy will be a source of future employment and innovation. Similarly the conservation and sustainable use of biodiversity can have significant economic and social benefits.

Unless we act now to limit human-induced environmental degradation, history will judge us as having been complacent in the face of compelling scientific evidence that humans are changing the Earth's environment with predominantly adverse effects on human health, ecological systems and socio-economic sectors. Do we really want our heritage to be that of sacrificing the Earth's biodiversity for cheap fossil fuel energy, ignoring the needs of future generations, and failing to the meet the challenge of providing energy in an environmentally and socially sustainable manner when so many choices were available? Leaders from government and industry must stand shoulder to shoulder to ensure that the future of the Earth is not needlessly sacrificed.

Slide 1-1



Slide 1-2

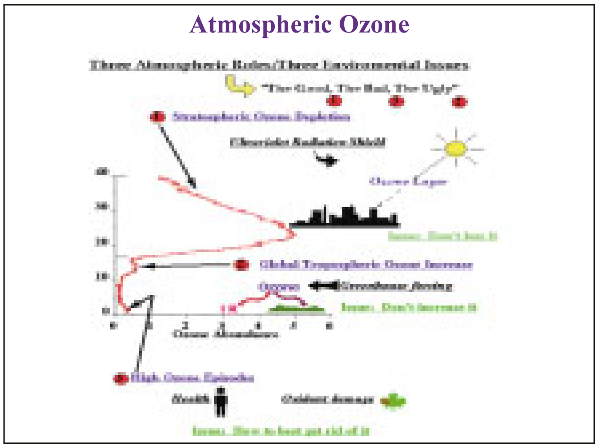
Climate change, loss of biodiversity and ecosystem degradation

- Climate change, loss of biodiversity and ecosystem degradation are environment, development and security issues, i.e., they undermine:
  - food, water and human security
  - the economy (loss of natural capital)
  - poverty alleviation and the livelihoods of the poor
  - human health
  - personal, national and regional security

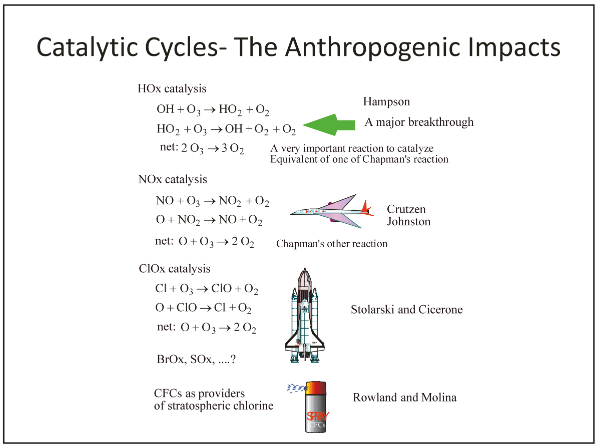
- Climate change and ecosystem degradation are inter- and intra-generational equity issues:
  - developing countries and poor people in developing countries are the most vulnerable
  - the actions of today will affect future generations

Slide 2

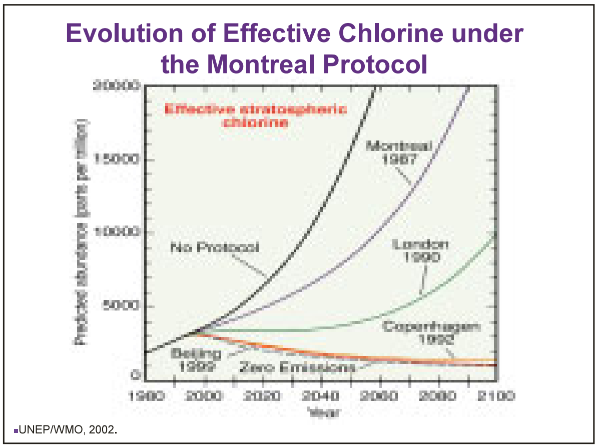
Stratospheric Ozone Depletion 1



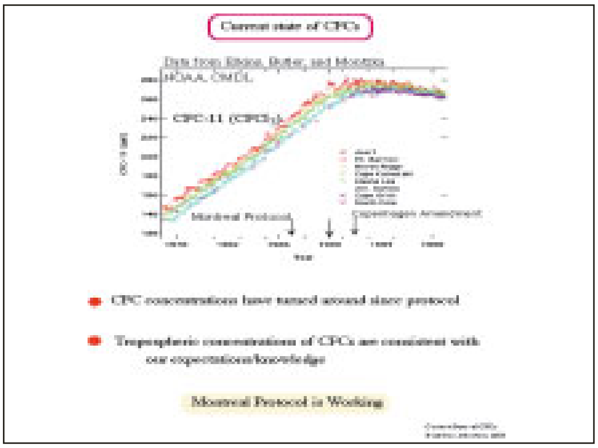
Slide 2
Stratospheric Ozone Depletion 2



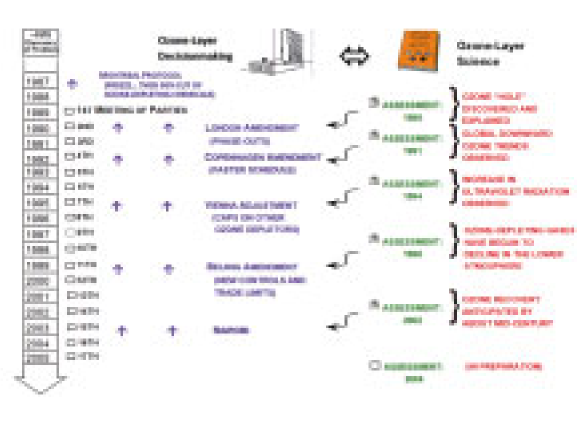
Slide 2
Stratospheric Ozone Depletion 3



Slide 2
Stratospheric Ozone Depletion 4



Slide 2
Stratospheric Ozone Depletion 5



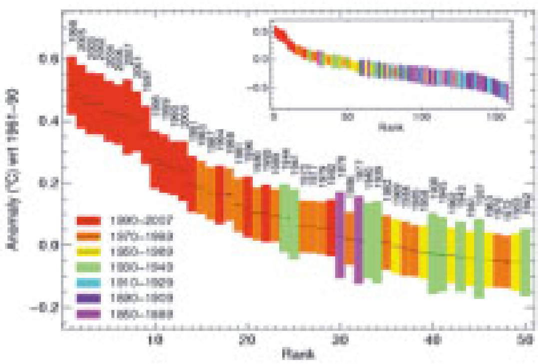
Slide 3
Climate Change 1

Climate Change

- The composition of the atmosphere, and the Earth's climate has changed, mostly due to human activities (highly certain), and is projected to continue to change, globally and regionally:
  - Increased greenhouse gases and aerosols
  - Warmer temperatures
  - Changing precipitation patterns – spatially and temporally
  - Higher sea levels – higher storm surges
  - Retreating mountain glaciers
  - Melting of the Greenland ice cap
  - Reduced arctic sea ice
  - More frequent extreme weather events
    - heat waves, floods and droughts
  - More intense cyclonic events, e,g., hurricanes in the Atlantic

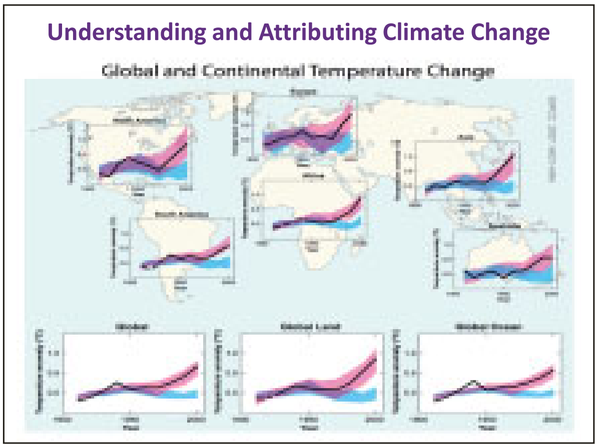
Slide 3
Climate Change 2

Climate is Warming



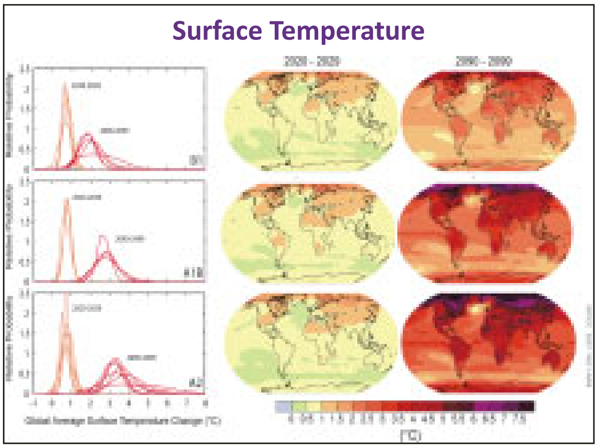
Slide 3

Climate Change 3



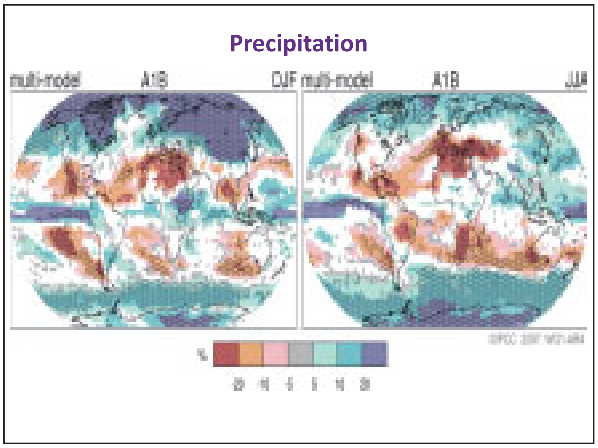
Slide 3

Climate Change 4



Slide 3

Climate Change 5



Slide 3
Climate Change 6

Projected Impacts of Human-induced Climate Change

•Adversely effect ecological systems, especially coral reefs, and exacerbate the loss of biodiversity

•Decrease agricultural productivity for almost any warming in the tropics and sub-tropics and adverse impacts on fisheries – food security

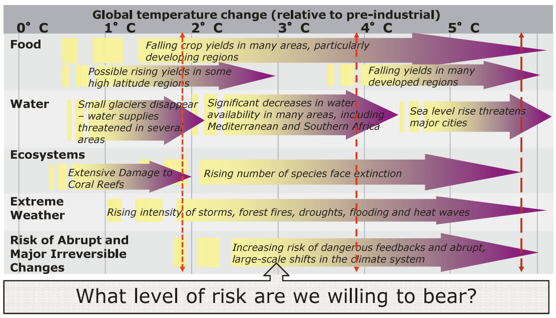
•Decrease water availability and water quality in many arid- and semi-arid regions – increased risk of floods and droughts in many regions – water security

•Increase the incidence of vector- (e.g., malaria and dengue) and water-borne (e.g., cholera) diseases, heat stress mortality, threats nutrition in developing countries, increase in extreme weather event deaths

•Adverse effects on human settlements due to flooding, coastal erosion and sea level rise

Slide 4
Mitigating Climate Change 1

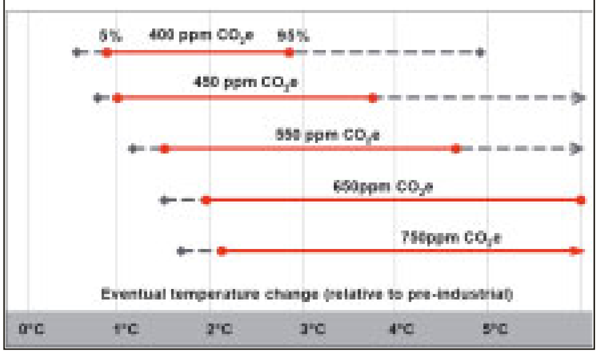
Dealing with impacts is about managing risk - economic, environmental and social economy



▪ Stern Review (2006)

Slide 4
Mitigating Climate Change 2

Emissions Paths to Stabilization



Slide 4
Mitigating Climate Change 3

Mitigation Strategy

- Putting a price on carbon through
  - emissions trading
  - taxation
  - regulation - national, regional and global
- Technology transformation
  - Carbon capture and storage
  - Future generation biofuels
- Mobilising behaviour change
  - Citizens
  - Business
  - Public sector

Slide 4
Mitigating Climate Change 4

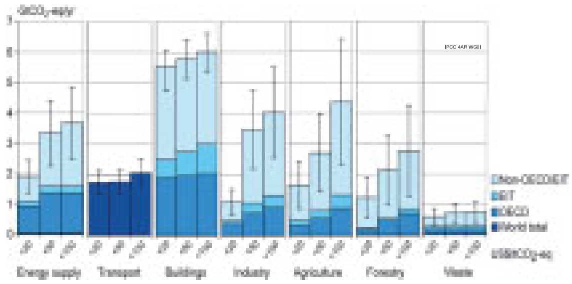
Potential technological options

- **Efficient production and use of energy:** coal plants (e.g., re-powering old inefficient plants and developing IGCC); vehicles (e.g., fuel cell cars) and reduced use of vehicles (e.g., mass transit and urban planning), buildings, and industries
- **Fuel shift:** coal to gas
- **Renewable Energy and Fuels:** Wind power; solar PV and solar thermal; small and large-scale hydropower; bio-energy
- **CO_2 Capture and Storage:** Capture CO_2 in the production of electricity followed by geological storage (e.g., IGCC – CCS)
- **Nuclear fission:** Nuclear power
- **Forests and Agricultural Soils:** Reduced deforestation; reforestation; afforestation; and conservation tillage

Slide 4
Mitigating Climate Change 5

Mitigation Potential Exists For All Sectors & Regions

At least a 50% reduction global greenhouse gas emissions by 2050 is needed for a chance of meeting the EU 2°C target



Slide 4
Mitigating Climate Change 6

Policy Instruments

- Policies, which may need regional or international agreement, include:
  - Energy pricing strategies and taxes
  - Removing subsidies that increase GHG emissions
  - Internalizing the social costs of environmental degradation
  - Tradable emissions permits--domestic and global
  - Voluntary programs
  - Regulatory programs including energy-efficiency standards
  - Incentives for use of new technologies during market build-up
  - Education and training such as product advisories and labels
- Accelerated development of technologies requires intensified R&D by governments and the private sector

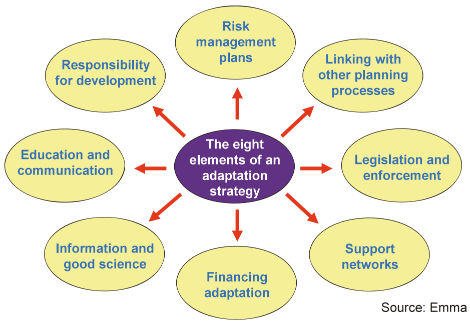
Slide 4
Mitigating Climate Change 7

Summary of the Major Mitigation Challenges

- International policy
  - A long-term (2030 – 2050) global regulatory framework, involving all major emitters, with an equitable allocation of responsibilities – with intermediate targets
  - Kyoto plus 5 years will not provide the right signals to the private sector or national governments
  - Expand range of eligible CDM activities, including avoided deforestation, green investment schemes, energy efficiency standards, and exploring sectoral and programmatic approach
  - Key challenges include engaging USA, China and India

Slide 4
Mitigating Climate Change 8

Elements of an adaptation strategy



Source: Emma Tompkins

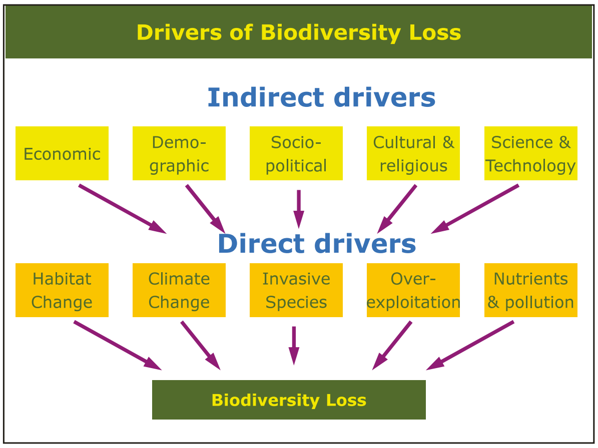
- Delivery of adaptive responses depends on **governance** mechanisms
- Adaptive capacity and society's self-organisation is determined by **governance**
- Distribution of costs and benefits in society is determined by **governance**

Slide 4
Mitigating Climate Change 9

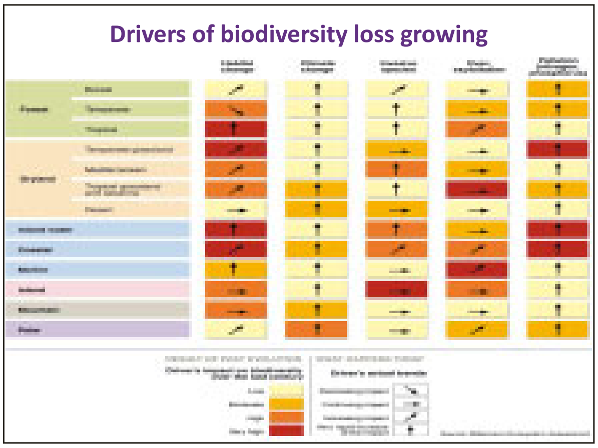
Elements of a Post-2012 framework

1. Long-term goal	(2C) 50% cut by 2050 on 1990 level
2. Developed country targets	30% cut by 2020 and 60-80 by 2050 for developed countries
3. Developing countries	Graduated approach to commitments
4. Carbon market	Broader, deeper, longer carbon market
5. Technology	Technology Protocols, IFI financing, R&D, energy fficiency
6. Adaptation	Adaptation integrated into development and finance strategies
7. LULUCF inc Deforestation	LULUCF integrated in post-2012 framework. Incentives to tackle deforestation
8. Aviation & maritime	Global sectoral approach

Slide 5
Loss of Biodiversity and Degradation of Ecosystem Services 1



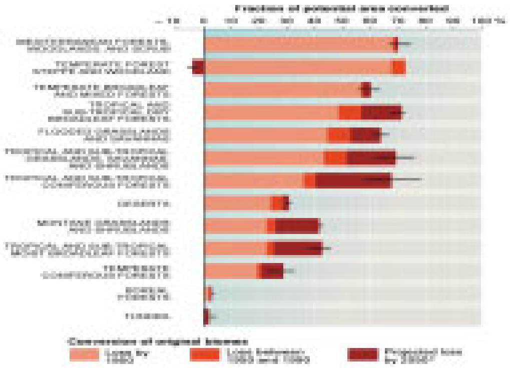
Slide 5
Loss of Biodiversity and Degradation of Ecosystem Services 2



Slide 5

Loss of Biodiversity and Degradation of Ecosystem Services 3

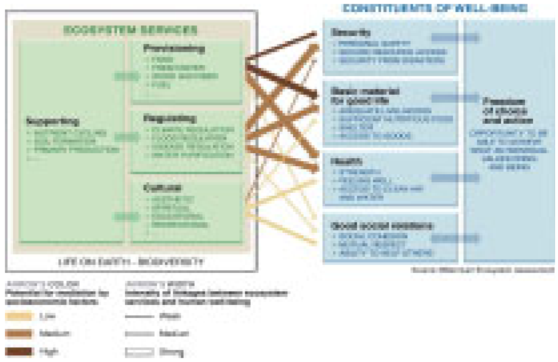
Unprecedented change: Ecosystems



Slide 5

Loss of Biodiversity and Degradation of Ecosystem Services 4

Consequences of Ecosystem Change for Human Well-being



Slide 5

Loss of Biodiversity and Degradation of Ecosystem Services 5

Climate change impacts on biodiversity and ecosystems are unavoidable

– an increasing number of ecosystems, including areas of high biodiversity, are likely to be further disrupted by a temperature rise of 2° C or more above pre-industrial levels.

– 10 per cent of species will face an increasingly high risk of extinction for every 1° C rise in global mean surface temperature (up to an increase of about 5° C).

– Wetlands, mangroves, coral reefs, Arctic ecosystems and cloud forests are particularly vulnerable to climate change.

– Without strong mitigation action, some cloud forests and coral reefs would may cease to function within a few decades.

Slide 5
Loss of Biodiversity and Degradation of Ecosystem Services 6

Change the economic background to decision-making to implement ecosystem-based activities

- Make sure the value of all ecosystem services, not just those bought and sold in the market, are taken into account when making decisions
- Remove subsidies to agriculture, fisheries, and energy
- Payments to landowners in return for managing their lands in ways that protect and enhance ecosystem services
- Appropriate pricing policies for natural resources, e.g., water
- Apply fees, taxes, levees and tariffs to discourage activities that degrade biodiversity and ecosystem services
- Establish market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way

Slide 5
Loss of Biodiversity and Degradation of Ecosystem Services 7

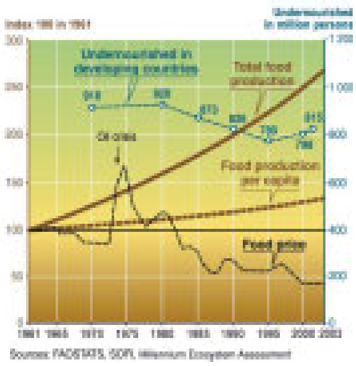
Non-financial incentives to implement ecosystem-based activities

- Laws and regulations
- Promote individual and community property or land rights
- Improve access rights and restrictions
- New governance structures to improve policy, planning, and management
  - Integrate decision-making between different departments and sectors, as well as international institutions
  - Include sound management of ecosystem services in all planning decisions
- Develop and use environment-friendly technologies
- Influence individual behavior

Slide 6
Food Security and Agricultural Production 1

Food Production

- Uneven benefits:
  - One billion people still hungry
  - Hunger has increased in several parts of the world – SSA
  - Institutional and policy environments
- Significant environmental degradation
  - GHG emissions
  - loss of biodiversity
  - land and water degradation



Slide 6
Food Security and Agricultural Production 2

Food Security

Drivers of the recent increase in food prices

– Poor harvests due to variable weather - possibly related to human-induced climate change
– Increased use of biofuels
– Increased demand , especially for meat
– High energy prices, hence higher fertilizer prices
– Speculation on the commodity markets
– Export bans from some large exporting countries

The future Challenge

• The demand for food will double within the next 25-50 years, primarily in developing countries, **and** the type and nutritional quality of food demanded will change

• We need sustained growth in the agricultural sector to feed the world, enhance rural livelihoods and stimulate economic growth, while meeting food safety standards

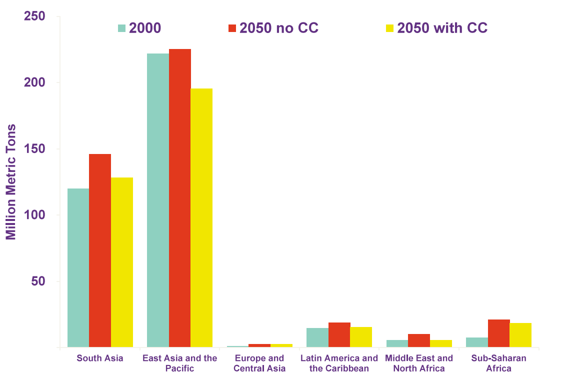
Slide 6
Food Security and Agricultural Production 3

Global Context for Food Security

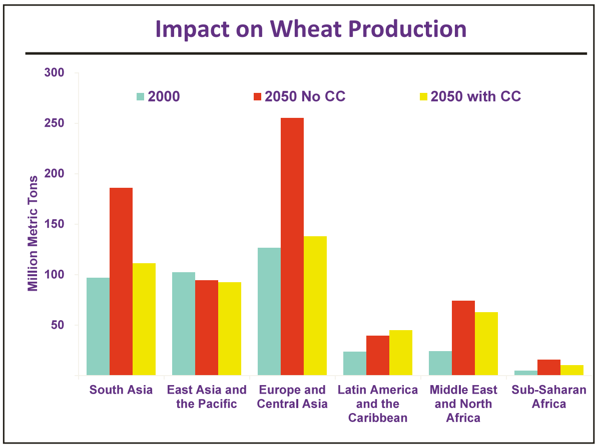
- **Less labor – disease, rural to urban migration**
- **Less water – competition from other sectors**
- **Less arable land – competition from energy crops**
- **High energy prices**
- **Distorted trade policies – OECD subsidies**
- **Land policy conflicts**
- **Loss of biodiversity: genetic, species and ecosystem**
- **Increasing levels of air and water pollution**
- **A changing climate**

Slide 6
Food Security and Agricultural Production 4

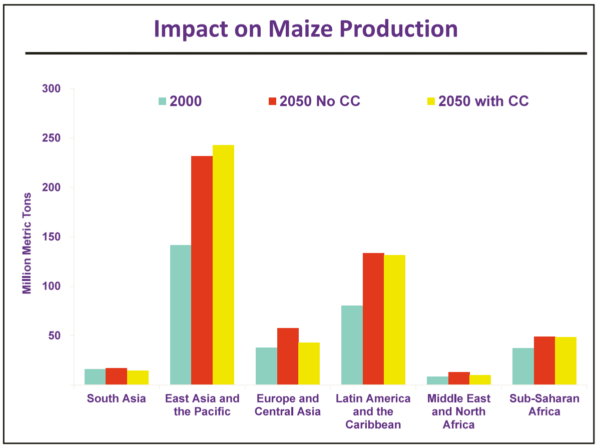
Impact on Rice Production



Slide 6
Food Security and Agricultural Production 5



Slide 6
Food Security and Agricultural Production 6



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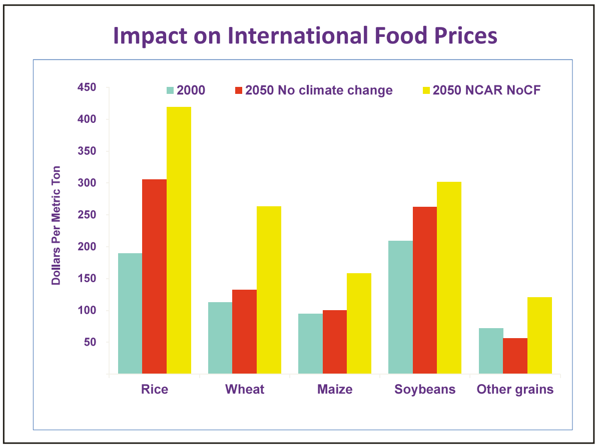
Food Security and Agricultural Production 7



Slide 6

Food Security and Agricultural Production 8

Agricultural S&T Challenges

- to produce, by region, the diversified array of crops, livestock, fish, forests, biomass (for energy) and commodities needed over the next 50 years in an environmentally and socially sustainable manner:
  - address water deficit problems, e.g., through improved drought tolerant crops, irrigation technologies, etc
  - improve the temperature tolerance of crops
  - combat new or emerging agricultural pests or diseases
  - address soil fertility, salinzation of soils and improve nutrient cycling
  - reduce external and energy-intensive inputs
  - reduce GHG emissions while maintaining productivity
  - improve the nutritional quality of food
  - reduce post harvest losses
  - improve food safety

Slide 6

Food Security and Agricultural Production 9a

Food Security: Options for Action

- **Most of today's hunger problems can be addressed with appropriate use of current technologies, emphasizing agro-ecological practices (e.g., no/low till, IPM and INRM), coupled with decreased post-harvest losses**
- **Advanced biotechnologies may be needed to address future demands for increased productivity and emerging issues such as climate change and new plant and animal pests – but the risks and benefits must be fully understood**
- **Place the farmer in the middle – understand their needs and integrate as appropriate their local and traditional knowledge with formal AKSTD – innovation involving all relevant stakeholders along the complete food chain**

Slide 6

Food Security and Agricultural Production 9b

Food Security: Options for Action

- **Recognize the critical role of women and empower them (e.g., education, property rights, access to financing)**
- **Reform international trade, e.g., eliminate OECD production subsidies, eliminate tariff escalation on processed products, recognize the special needs of the least developed countries through non-reciprocal market access**
- **Provide payments to the farmer for maintaining and enhancing ecosystem services**
- **Increase public and private sector investment in research and development, extension services, and weather and market information**

We can feed the world with affordable food, while providing a viable income for the farmer, but business-as-usual will not work

Slide 7
Water Security 1

The Global Water Crisis

- Water scarcity is growing - by 2025 more than half of the world's population is projected to live under conditions of severe water stress
- Water quality is declining in many parts of the world
- 70% of all freshwater is used for irrigation - 15 - 35% of irrigation withdrawals exceed supply rates and are therefore unsustainable
- 50-60% of wetlands have been lost
- Water has the lowest rate of cost recovery among all infrastructure sectors (about 20%)
- Human-induced climate change is projected to decrease water quality and availability in many arid- and semi-arid regions, and increase the threats posed by floods and droughts in most parts of the world

Slide 7
Water Security 2

Options for Action

- **Implementation of the Dublin Principles**
  - **Ecological Principle: River basin management (often transnational); multi-sectoral management, (agriculture, industry, households); land and water must be managed together**
  - **Institutional Principle: All stakeholders, state, private sector and civil society, especially women, must be involved in the management – principle of subsidiarity – action at the lowest level**
  - **Instrument Principle: Incentives and economic principles to improve allocation and enhance quality - pricing policies**

Slide 8
Conclusion

In Conclusion

- There is no dichotomy between environmental protection and economic growth
- Get the economics right – eliminate perverse subsidies – value ecosystem services – internalize externalities – recognize the wealth of a nation is dependent on built, human, natural and social capital
- There are cost-effective and equitable solutions to address issues such as climate change and biodiversity loss, but political will and moral leadership is needed, and the changes in policies, practices and technologies required are substantial and not currently underway
- Public and private sector decision-makers need to take a longer-term perspective
- Advances in science and technology are required – investments are needed now to address these issues cost-effectively

Major Publications

Sir Bob Watson

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