# 2010

# Blue Planet Prize

## Dr. James Hansen (USA)

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

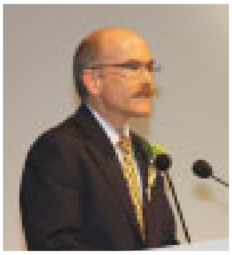
Tetsuji Tanaka, Chairman of the Foundation delivers the opening address

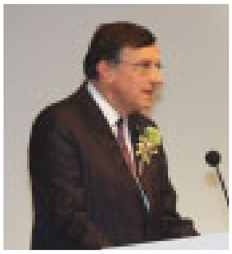
The prizewinners receive their trophies from Chairman Tanaka

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**

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| 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/t$CO_2$ (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/t$CO_2$ 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 Understood (scientists)
   - What is Known (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

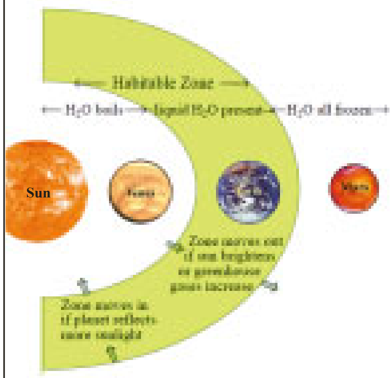
**Slide 3**
First Grandchild, Sophie — at Age Almost Two Years

## Slide 4
### Goldilocks Planets


| | Mars | Earth | Venus |
|---|---|---|---|
| Temperature | -50°C | +15°C | +450°C |
| Greenhouse Effect | a few degrees | ~30°C | ~470°C |

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

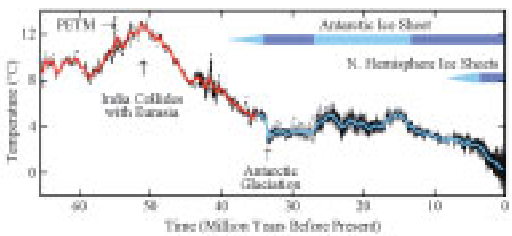
### Why be concerned about human-made climate change?

**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



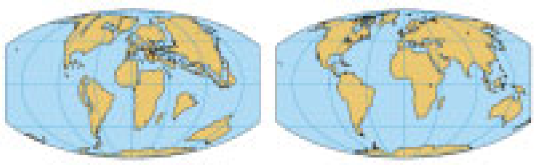

**50 million years ago (50 MYA) Earth was ice-free.**

**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

<u>Global Climate Forcings</u>

External (solar irradiance): +1 W/m$^2$

Surface (continent locations): ~1 W/m$^2$

Atmosphere ($CO_2$ changes): > 10 W/m$^2$

## Slide 10
### Summary: Cenozoic Era

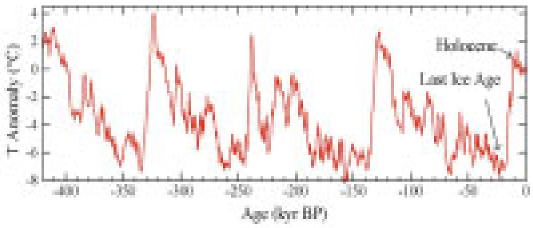
1. **Dominant Forcing: Natural $\Delta CO_2$**
   - Rate ~100 ppm/My (0.0001 ppm/year)
   - Human-made rate today: ~2 ppm/year

**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"**

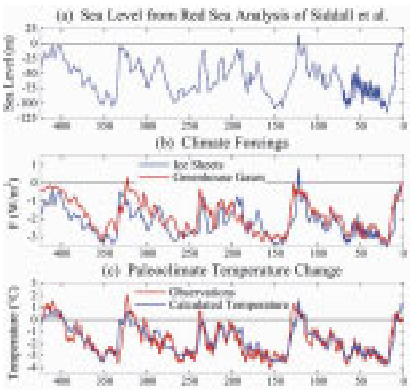
## Slide 11
### Antarctic (Vostok) Temperature




Earth's history provides important information on global warming.

Recorded human history occurs within the Holocene warm period.

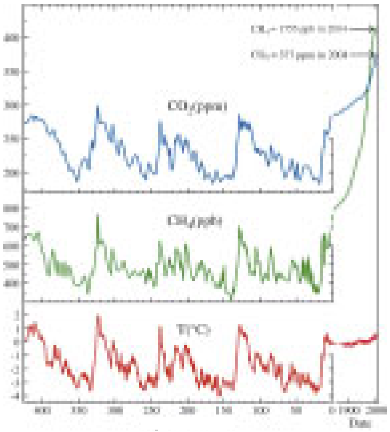
## Slide 12
### Kyr Before Present



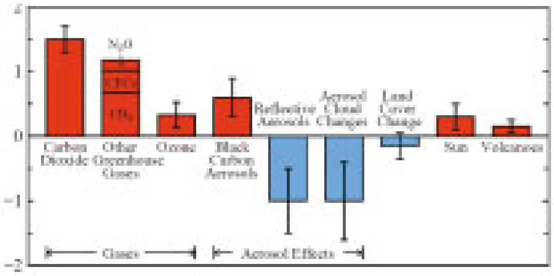
## Slide 13
### Kyr Before 1850

$CO_2$,$CH_4$ 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/m² 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/m² Forcing."

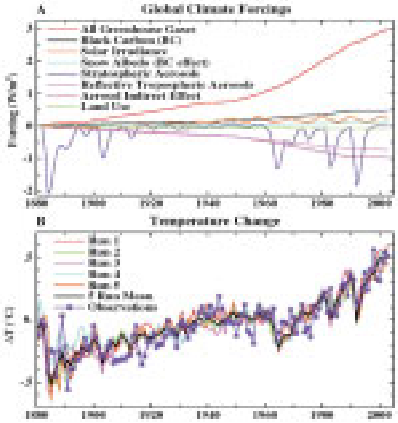
Connor only counts 1 Watt

## Slide 16
## Global Climate Forcings and Temperature Change

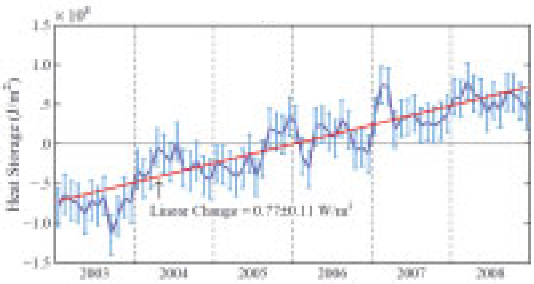
(A) Forcings used to drive climate simulations.

(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.**

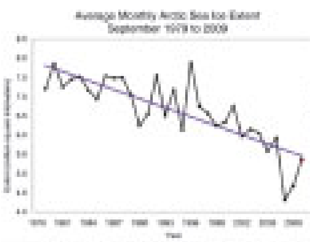
**Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens.**

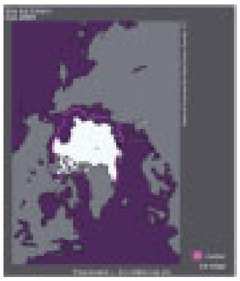
**Data must be averaged over a decade because of El Nino/La Nina and solar variability.**

**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

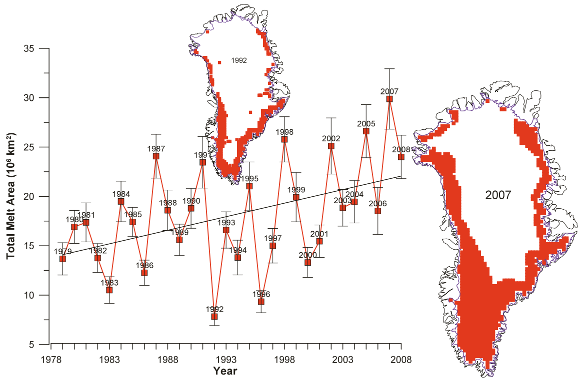


**September sea ice extent based on satellite microwave observations.**

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.

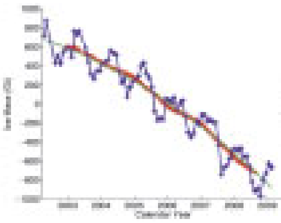
*Source: Roger Braithwaite, University of Manchester (UK)*

## Slide 21
### Jakobshavn Ice Stream in Greenland

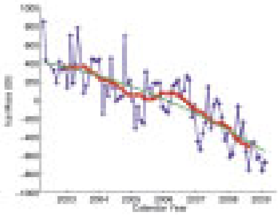
Discharge from major Greenland ice streams is accelerating markedly.

*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.

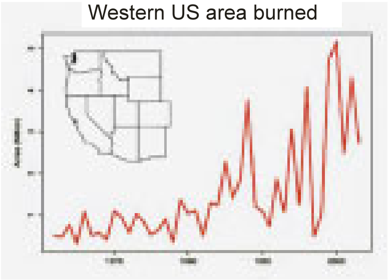
## Slide 23
### Pier on Lake Mead

**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.



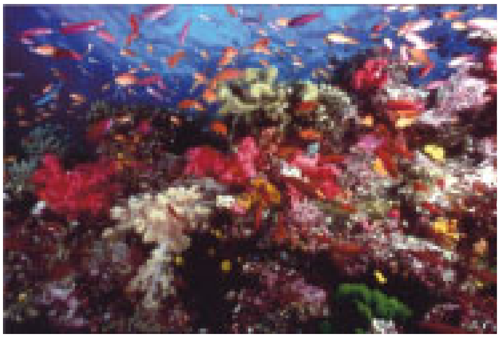


Source: Westerling et al. 2006

## 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.

## Slide 26
### Stresses on Coral Reefs



**Coral Reef off Fiji**
(Photo credit: Kevin Roland)

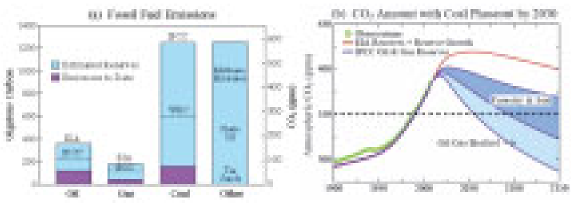
## Slide 27
### Assessment of Target $CO_2$

| 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

## Slide 28

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.

## Slide 29

<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

## Slide 30

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

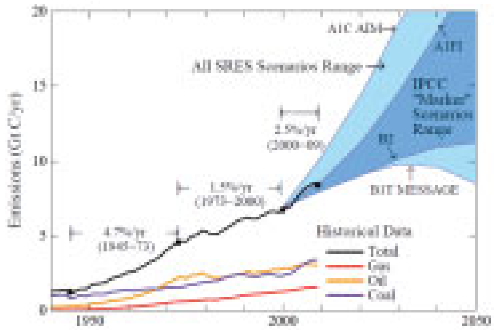
**Slide 31**

**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

**Slide 34**

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

**Slide 35**

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

**Slide 36**

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

**Slide 37**

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

**Slide 38**

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

**Slide 39**

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)

**Slide 40**

**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:**


Hansen, J., M. Sato: Paleoclimate Implications for Human-Made Climate Change. *arXiv:1105.0968v1*.

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