Address by

Michael Oppenheimer

Princeton University

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Thank you. I appreciate your invitation to speak at the Forum today. I went to graduate school in Chicago, and have very fond memories of this part of the country. My first wilderness experience was a week-long trip in the Boundary Waters Canoe Area, up north. Ultimately, it was that trip, and my subsequent wilderness adventures out West and in Alaska, that led me to focus my professional life on learning about, and protecting, the environment. I made that career choice partly out of intellectual curiosity and partly for ethical reasons. I have long believed that scientists, whose education and research are often supported by public resources, have an obligation to use their knowledge wisely, and to give back something to society, in the form of the best judgment they can muster about societal problems, based on their scientific explorations. My focus on environment is one way I can give something back, in return, for the opportunities that I have been afforded.

Not coincidentally, I note that the informing theme of this lecture series is "Key Issues in Ethical Perspective". I believe that ultimately, the ethical perspective must under gird any successful attempt to grapple with the global warming problem. Scientists like me, or economists, or other experts, can provide you with reams of numbers and figures, such as the latest reports from the Intergovernmental Panel on Climate Change. Such information provides a critical basis of support for the recent groundswell of attention to the global warming problem and the sudden rise in interest in seeing that the problem is solved. But ultimately, getting the job done, and marshalling the political will to do so, depends on how people respond, at a more fundamental level, to these questions: If greenhouse gas emissions continue, how will the resulting warming reshape our planet, and what sort of place will we be leaving to future generations?

Nevertheless, given all those years of training, it is inevitable that I approach such problems, in the first instance as a scientist, so let me describe how I came to decide that climate change was so important. I first heard about the greenhouse effect and global warming in the late 1960s at about the same time that I heard about two other human interventions in the climate: warming due to escaping thermal heat from power-plants and cooling due to reflection of sunlight from particulate matter that, like the global warming gases, arises from fossil fuel combustion and deforestation. My first reaction, like that of many people, was one of astonishment: did humans really hold the power to alter the <u>world as a whole</u>, all at once?

As it turns out, improved scientific knowledge allowed us to dispense with concern over heat from thermal power plants (except in rivers where it affects fish). It also turned out that the role of particulate, while not negligible, is not large enough to counteract global warming. And particulates are likely to decrease worldwide, as they have in the US, because they are a threat to human health; so governments are acting to sharply reduce their levels, which may actually cause earth to warm faster in the future than it would otherwise.

Recall that this was a time before the discovery of the ozone hole, before the identification of widespread tropical deforestation, and before the appreciation of the global collapse of key fisheries that is continuing even as I speak. There was no "global environment" yet: The construct didn't exist, certainly not in popular imagination; and only a relative handful of scientists paid attention to any aspect of what would soon become a widely recognized, globalized set of problems.

Yet I believed from early on that global warming was a serious problem because the physics behind it was sound: Certain gases that exist naturally in the atmosphere act like the glass of a greenhouse: they are transparent to sunlight, which warms earth's surface; but these same gases trap heat radiating from the surface that would otherwise escape into space. This Greenhouse Effect is a good thing because without it, earth would be 60 degrees Fahrenheit cooler, a frozen desert, and human life would never have evolved.

Under natural conditions, emissions of these gases come from natural forest fires, they leak from certain parts of the oceans, and they percolate from the bottoms of swamps. Over millennia, nature maintained a very fine balance: for every ton of carbon dioxide arising from burning trees, about an equal amount was pulled out of the atmosphere elsewhere during photosynthesis, as somewhere else, new trees grew; or, carbon dioxide would dissolve in one area of the ocean surface even as about the same quantity emerged from another area. I'll return later to the evidence for this balance when I talk about ice cores from Greenland and Antarctica, evidence that allows me to state that we are now <u>sure</u> that for almost the entire history of civilization, ten thousand years, the balance was nearly perfect.

Then something new happened: industrialization, with the widespread use of fossil fuels, and the cutting and burning of forests for agriculture which still

is widespread in the tropics. The balance was upended, greenhouse gas levels began to increase, and a new phenomenon presented itself: The Greenhouse Gas or Global Warming Problem.

The problem is this: The atmospheric levels of several important greenhouse gases, particularly carbon dioxide, have been increasing in the atmosphere for about 200 years, primarily due to the main drivers of industrialization: a growing population, burning more and more coal, oil, and natural gas, to provide energy. Burning these fossil fuels converts them to carbon dioxide and water vapor. There is so much water already in the atmosphere that this further addition is without effect, despite that fact that water vapor itself is a potent greenhouse gas. But the increase in carbon dioxide is important: its level has grown by 30% since the industrial revolution. We know this with absolute certainty.

In fact, this much was predicted in 1896 by a Swedish chemist, Svante Arrhenius, who ultimately won the Nobel Prize for a different discovery. The greenhouse theory lay more or less dormant for about half a century, until the carbon dioxide increase was actually measured in the atmosphere, and modern computers began to allow scientists to make increasingly reliable projections of future climate.

During the 1980s, analysis of samples of air trapped in ice retrieved by drilling cores from deep beneath the surface of the Antarctic and Greenland ice sheets showed that over time, as carbon dioxide levels shifted up and down in response to natural shifts in sunlight patterns on Earth's surface, driven by changes in Earth's orbit, the climate oscillated between ice ages and warm periods like the one we are in now. The amount of warming and cooling over thousands of years can be largely explained by the changes in the amount of carbon dioxide and other greenhouse gases in the atmosphere, as well as changes in reflection of sunlight from Earth's ice sheets, over the same periods of time. Nature had done an experiment confirming the greenhouse hypothesis, many times over. It took modern humans a long, long time to find the evidence.

It was also clear from these same ice cores that greenhouse gas levels, and earth's average temperature, had been very steady for almost the entire history of civilization, again, reaching back almost ten thousand years.

Soon after, analysis of thermometer data established that earth was already warming, and less than a decade later, that humans were the likely cause.

How do we know humans are to blame? Early on, some argued that the warming was merely the result of the urban heat island effect, wherein cities retain heat, particularly at night, and remain warmer than the surrounding countryside. But there were no cities in the middle of the ocean, yet the warming was just as notable there.

In addition, my colleagues analyzed the geographic and temporal pattern of warming across earth's surface: it was characteristic of the greenhouse gases and could not be reproduced by other natural factors that cause climate to vary. For instance, some claimed that variations in the sun caused the warming. Variations in the sun do cause climate changes, but we have had satellites accurately determining the sun's intensity for nearly 30 years, and as the earth has warmed over that period, the sun's intensity has been rock steady.

Others suggested that the ever present vale of volcanic dust which reflects sunlight had diminished, leading to a warming. But we measure that, too, and in fact, the dust vale has increased, not diminished, and a very slight cooling would have resulted were it not for the greenhouse warming.

In the past decade scientists have made these findings more precise, and developed a picture, of the potential consequences, of unrestrained greenhouse gas emissions, providing a discouraging view of the future. But this discouragement is contingent, dependent on the continued growth of emissions, an outcome that, I believe, is not inevitable.

We have two ways to figure an answer to how warm earth might become, and these two approaches give about the same result. First, our computer simulations of the climate forecast a warming of 2 to 11 degrees F over this century. Two degrees would be a manageable warming, harmful to some countries, destructive of many ecosystems, but not disastrous for most people on earth, and even arguably beneficial to some (think warmer winters). I also would like to point out that inland areas, and higher latitudes such as here in Minneapolis, are projected to warm more and become wetter over the course of a typical year. But an 11–degree warming is likely to be an out-and-out catastrophe. And we have no way to determine, as of today, which extreme, or where in between, we are headed, mostly because we do

not know what the future emission level of the greenhouse gases will be, but also because our understanding of the sensitivity of climate to these emissions is still evolving.

The other way of approaching the problem is not encouraging either. Carbon dioxide has now reached levels not seen in 20 million years, a time when earth was considerably warmer, and if emissions are not restrained, carbon dioxide will reach levels during this century not seen in about 50 million years, a time when earth had no ice caps and was at least semi-tropical, everywhere. All that change could be telescoped into a few centuries, which would be unprecedented. Given both the certainties and the uncertainties, it would make sense to slow down the pace of emissions while we learn more, a point I shall return to later.

What effects would all that warming bring along? As the science has evolved, three consequences of climate change have particularly troubled me: First are the potential effects on water and agriculture, especially in the developing world. For years now, as the projections of future climate change have become more finely honed, certain predictions have remained robust, including the expected reduction in precipitation and runoff in developing countries in semi-arid regions, such as those in sub-Sahara Africa, where malnutrition is endemic even today.

This situation can only worsen in the greenhouse world. So here we have a fundamental ethical question: Don't the countries that emit large amounts of greenhouse gases, including the US and China, have an obligation to countries that currently (and for the foreseeable future) have negligible emissions, like those of southern Africa?

Second and third, come the effects of sea level rise along the coast and the threats to ecosystems and species everywhere. Again, in both cases, there is one salient factor; the disparity between the relative ability of rich countries, like ours, to deal with the problem, although still to a limited degree, even as they pumped out growing amounts of greenhouse gases, and the slender capacity of those in many developing nations, like Bangladesh, to do so, even as they contribute little to it. But as hurricane Katrina showed, there are vulnerable populations everywhere.

But from a very personal point of view, from some deep corner of my own psyche, arises a different concern, one that at the end of the day may be why

I devote so much time to the issue. And that is the idea of ***loss:*** the loss of place, the loss of species, and the loss of people. Everyone frames problems differently. For me, as an average human being rather than as a scientist, the *impending losses*, ultimately, are what grab my attention.

I do not intend to give you a complete list: it's to depressing and too paralyzing. Instead, I would like to present a couple of examples.

As I do so, keep in mind that the story of human progress is forever one of loss and renewal: to some extent we shed cultures and languages, and particularly in the US, homes, home towns, jobs, and even each other as we move from place to place. What is unique about the losses associated with global warming is that they will be **worldwide, largely irreversible, affecting every aspect of life simultaneously, and for most people, involuntarily.**

With respect to vulnerability along the coast, some of these losses will be immediate: think of New Orleans, devastated by Hurricane Katrina perhaps never to return as a great city: Half an American city wiped out in peacetime, and inconceivable event.

Katrina was not caused by global warming, and we will never know whether, or how much, the greenhouse gases contributed to its intensity. But we do know that hurricanes have become more intense on average and that further intensification is predicted as the greenhouse gases accumulate in the atmosphere.

Other losses along the coast will occur gradually: We also know that sea level has been rising due to the warming of the ocean, and the melting of glaciers, and that this rise, already accelerating, is expected to accelerate more as the century progress. A higher sea level means we should expect to be fighting a losing battle along the coast, with increasing effort needed to protect infrastructure, beaches and wetlands, and ultimately, the need to abandon many places due to the cost of doing so. But in combination with stronger hurricanes, the consequences of a higher sea level would be devastating in many places.

Of course, there was another loss in New Orleans, hopefully temporary: our trust in the ability of government at all levels to foresee, anticipate, and plan for disaster, as well as provide rescue, comfort and recovery during and after

a disaster. This loss should weigh on everyone's mind as we think about the changing climate.

Some of coastal losses are expected to occur over very long times, particularly those resulting from a monumental sea level rise due to the potential disintegration of the Greenland ice sheet, and part of the Antarctic ice sheet. The time over which the latter losses could occur is at least centuries and perhaps more than a millennium.

Some people dismiss such phenomena as irrelevant. But consider: A 20 to more than 40 foot sea level rise, which is what is at stake if the ice sheets begin to disintegrate, would be necessitate large scale withdrawal from the coast all over although certain high-value areas would probably be protected at huge expense, for example, Manhattan. But we can't protect the 1/3 of Florida that a 20-foot sea level rise would drown, or the sweep of the Gulf Coast inland almost to Houston that a 40 foot sea level rise would submerge.

But leaving this land loss aside, think of the cultural loss: entire island nations in the Pacific drowned, their cultures lost, forever.

And think of what lies near sea level that cannot be moved: The Cathedral San Marco in Venice, the temples of Mahabalipurim in India, the monuments along the Mall in Washington, DC, to provide only three examples. Aren't those worth protecting for at least a millennium?

As astonishing as the scope of loss may be, keep this in mind: despite the long timescales over which disintegration of ice sheet may play out, these outcomes could begin and be irreversibly determined, by greenhouse gas emissions occurring ***over the first half of this century.*** We know this from consideration of the polar ice extent in earlier times: when the poles were about as warm as they could become due to emissions occurring within the first half of this century, given middle-of-the-road assumptions on emissions, polar ice sheets were likely smaller and sea level higher by 13-20 feet! Only a decade or so more of ignoring the problem may make this outcome inevitable, because emissions cannot be reduced overnight.

The third category of loss that particularly concerns me is that of ecosystems and species, and the overall scope of this projected loss is staggering: 30% of all species become vulnerable to *extinction* for a warming of up to 5 degree F, and perhaps as much as 70% for a few more degrees of warming.

Here again I will rely on one particular example. The Galapagos, Darwin's touchstone, exists in a precarious climatological balance: a mild current from the north, the cold Humboldt Current from the south, and the episodic dowsing during El Ninos that bring warm water from the west. Typical of this strange mix: penguins at the equator (due to the Humboldt Current).

But even a small shift in climate may throw this system out of whack, destroy the synchronicity of climatic factors, and eliminate the special conditions that allow this unique niche to thrive.

There are many other such examples: the rich cloud forests of Central America and Africa; coral reefs worldwide that are vulnerable to bleaching and mortality, for very modest warming. What are the ethics of initiating such massive losses, all in the course of a century?

But it doesn't have to happen; we still retain control over most of the outcome. The recent report from the Intergovernmental Panel on Climate Change, makes clear, that there will be additional warming, but we have the option to assure that it is modest in size: small enough for most people to adapt, even in poor countries, slow enough for most ecosystems and species to adjust. Most important, the technologies to begin to fix the problem already exist, and the cost of implementing them is not large.
The obstacles are largely political, not technical and not economic.
The good news is that the public opinion polls, our leaders at the state level, the Congress, and even the Supreme Court, are giving strong signals that the country is getting ready to get the job done.

Concern has been raised that China, and other large developing countries, will never agree to limit their emissions. But China has a terrible air pollution problem due to fossil fuels, very large exposure to the effects of global warming, particularly along the coast, an incipient but vibrant local environmental movement, and increasing recognition, and even concern about global warming, in official circles. When I was a child, I, along with my friends, thought there was a strong chance that we would see nuclear annihilation in our time. It hasn't happened because, despite all the obstacles, countries with apparently divergent interests found a way to come together. It can happen again.

In the meantime, change your light bulbs to compact fluorescent lamps. Make sure your new car gets the highest fuel economy in its size class. Look

for the EPA Energy Star stickers when you buy appliances. Plant trees of course. *And write your Congressional representatives and other political leaders right up to the President.* Tell them you want action on this problem, now.

Let me close by taking the long view. Once emitted into the atmosphere, greenhouse gases persist for decades, centuries, even millennia. The carbon dioxide increase from the first Model-T is coursing through your lungs, right now. But at the same time, consider the revolutionary changes over that period in the way we live: At that time, transport was horse-drawn and the US had just emerged from a wood-fueled economy; despite the Wright Brothers' adventures, air travel was to remain a curiosity, unavailable to the average American for 50 years; laptop computers were unimaginable.

The context of life changed with lightning speed, and our world can be expected to experience change at least as sweeping in this century: new energy sources, new modes of transportation, and new modes of communication. While these transitions are occurring anyway, let's use change as an opportunity to reduce the threat of global warming, rather than making it even more intolerable, and gambling away this wondrous planet, before future generations have the opportunity to enjoy it.

Thank you.