# CLIMATE UPHEAVAL

## Needed: A New Operating Manual for Spaceship Earth

Prepared as a talk for The Examiner Club, 19 December 2007

### *Introduction*

"This generation of mankind will be the last to experience a stable climate."

That sentence, from a book titled *With Speed and Violence*, came to mind as I considered what title I should give to my talk. Two obvious possibilities were "Global Warming" and "Climate Change". These are the two favored descriptive labels in the popular media. However, I went to a talk given a few weeks ago by John Holdren, a professor of Earth and Planetary Sciences at Harvard. The title of his talk was "Global Climate Disruption", and he started by explaining why. He said that both "Global Warming" and Climate Change" created an implicit feeling of something happening that was both gradual and relatively benign, and that this lulled us into a feeling of complacency that resulted in inaction. "Disruption", he felt, more accurately described what was going to happen. The dictionary defines disruption as follows: "the act of being broken apart, rupturing, or thrown into disorder".

As I reflected on all the talks I have listened to, all the books, articles, and media reports I have read, all the websites I have visited, all the movies, documentaries and TV broadcasts I have watched, and all the experts, skeptics, and ordinary people I have talked to, I concluded that "disruption" was also too weak a word. I searched for a word that better describes the future I believe will unfold, and settled on the word "upheaval". Here is its dictionary definition: "extreme agitation or disorder; radical change".

Some examples of upheavals are World Wars I and II, the Black Plague, what happened to the peoples of India and Pakistan during the partition of India in

1947, and the mass extinctions of species in the ancient past. The future may, indeed, hold similar things.

My sub-title, “Needed: a New Operating Manual for Spaceship Earth”, is meant to telegraph my intention to end my talk on a more hopeful note than my title alone might imply. You may recognize the imagery of “Spaceship Earth” as one created by Buckminster Fuller in the early 1960s. The image is highly appropriate to our present circumstance, although what he wrote in his Operating Manual remains as opaque to me now as it did in the 1960s. But I am getting ahead of myself.

It’s three score and ten months since I gave a talk on this identical topic to the Examiners. A great deal has changed since then. Then, there was still some contention in the public discussion around “Is it happening?” and “Is mankind responsible?” Although I should add that my Examiner audience had little doubt about the truth, and expressed the opinion that the only reason for US inaction was “politics”, which I took to mean dishonesty and greed.

Now, the scene is vastly different. Sure, there are still a few residual skeptics singing the same old song, but by-and-large the world has moved on, and the questions are, “How bad is it going to be?”, “What will happen, when, and to whom”, and “What can we do about it?”

What are the reasons for this sea change? I think the most important are these:

First, scientists have, through research, answered, one-by-one, all the questions of the skeptics.

Second, research on the past has shown that the climate is notoriously volatile and unpredictable, and that the relatively stable and quiescent climate

mankind has experienced for the last 8000 years or so could vanish if we give it a hard shove.

Third, there have been a number of reports that have quantified the costs of mitigation, and shown that they are affordable and will not cause hardship. Prime among these has been the Stern Review, prepared for the UK Government. I will come back to this later.

Fourth, research has emerged that suggests that we may not have a lot of time to act, creating a real sense of urgency that was lacking six years ago.

Fifth, Al Gore has done a wonderful job of explaining the science to ordinary people all around the world, backed by the superb summarization of the science by the United Nations Intergovernmental Panel on Climate Change.

And finally, many other people have shown leadership, ranging from scientists to university communities to towns and cities to states such as California, where Arnold Schwarzenegger decided to stop being a caricature right-wing Republican and become a real human being instead, to companies such as Canon, Wal-Mart, and Honda, to countries of the European Union.

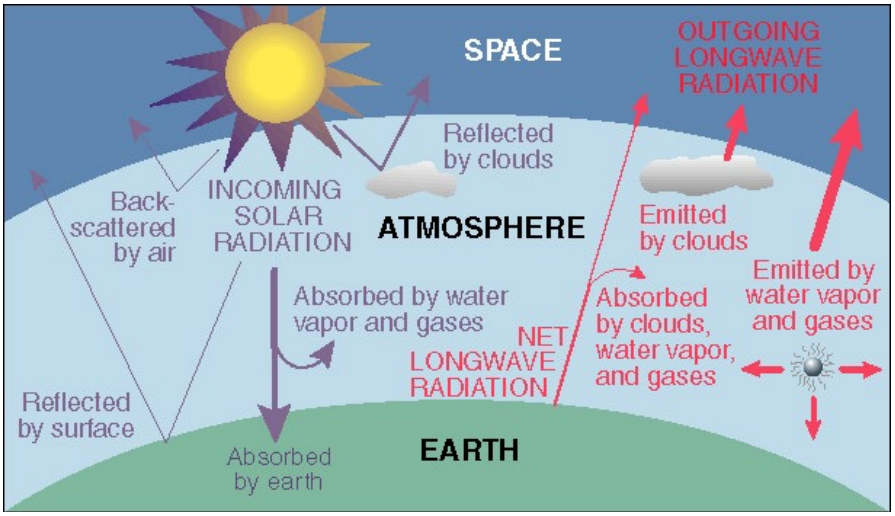
Nevertheless, the world is not different enough. Despite all I have just said, the world is, as a whole, and led by the United States, still sitting on its hands, with its head in the sand, hoping that this is all a nightmarish dream, and that we will wake up in the morning and be OK.

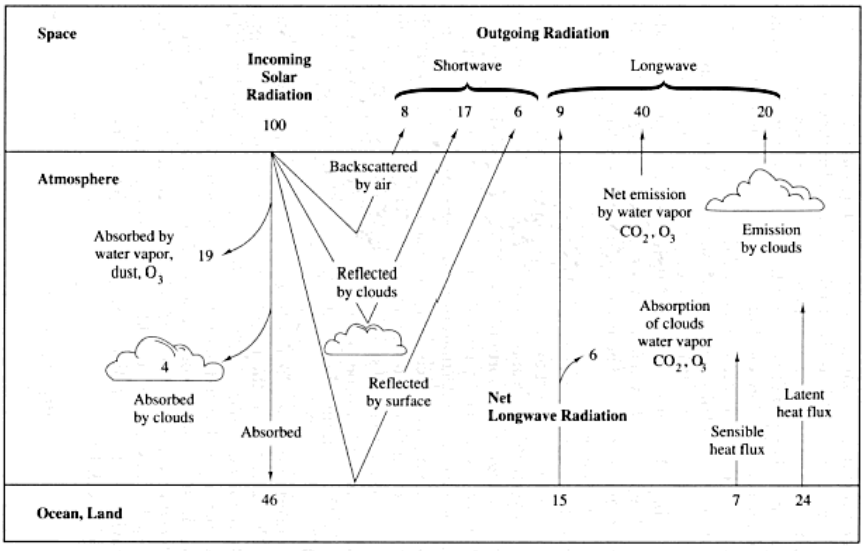
I would like to tell you about some of these things this evening.

### ***The Science***

The basic scientific understanding of what is happening is straightforward but worth summarizing. Greenhouse gases, named that by the French scientist

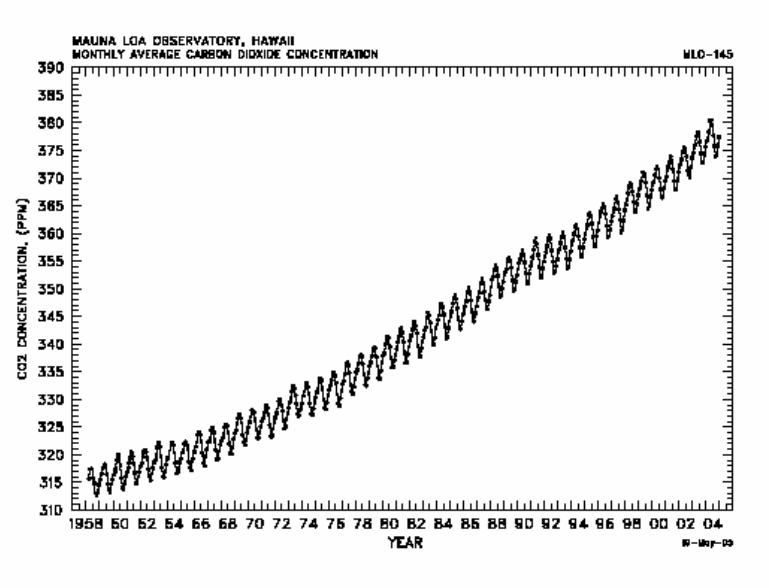
Fourier in the early 1800s, have molecular structures complex enough so that they vibrate at frequencies low enough to be excited by infrared electromagnetic radiation, also known as “heat”. Sunlight combines visible radiation with infrared, which is visible not to our eyes but to our skin. Some of the infrared and much of the visible reaches the ground, and is re-radiated as largely infrared, combined with some of the heat coming from inside the earth. This heat gets trapped by greenhouse gases, which vibrate, collide with other gases in the atmosphere, and send molecules scurrying hither and thither. Faster-moving molecules make the air warmer.



Without greenhouse gases, the average temperature of the earth would be at freezing. Thanks to the greenhouse gases, the average temperature of the earth is almost 60˚F. However, with an excess of green house gases, one of which is carbon dioxide, Earth could be like Venus, which has a carbon-rich atmosphere and an atmospheric temperature of 850˚F. For rescue from this fate, we must thank all the little creatures billions of years ago that captured carbon dioxide from the atmosphere to make food and released oxygen.

The problem is that since the start of the Industrial Revolution, fueled as it has been by the burning of fossil fuels—coal and oil--, we have increased the quantity of carbon dioxide in the atmosphere by just over a third.




*Voila!* The atmosphere is trapping slightly more heat than it used to, and the temperature of the atmosphere is going up, and will continue to do so until the hotter atmosphere again achieves an energy balance, with incoming energy from the sun equaling outgoing energy from the hotter atmosphere.

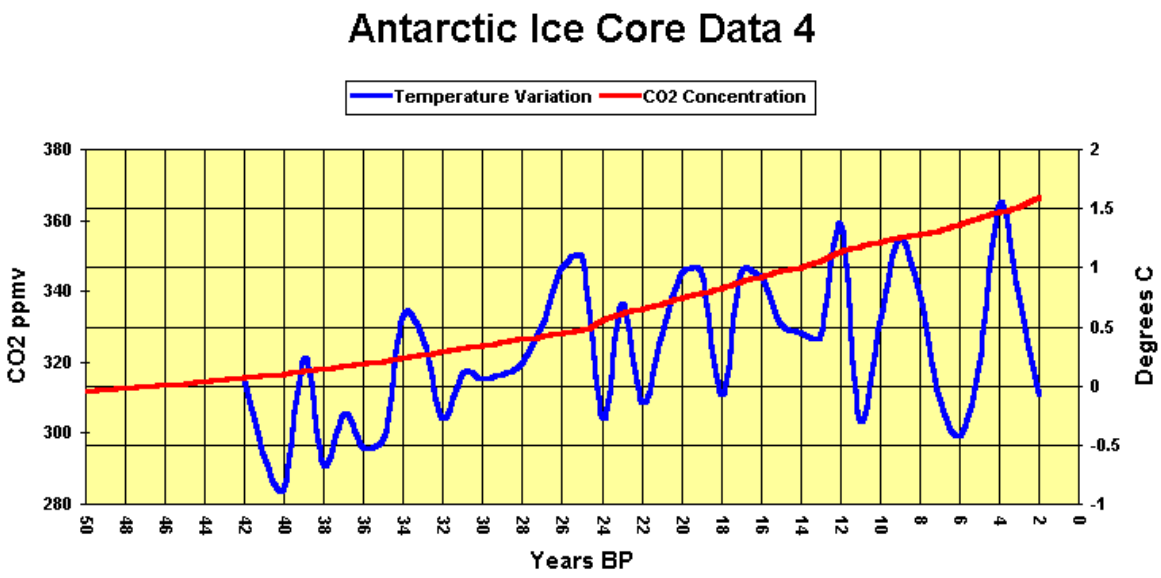
There are other greenhouse gases, among which the ones most worth mentioning as “man-made” are methane, nitrous oxide, and the chlorofluorocarbons, or CFCs. Though truth to tell, its cows that make a lot of

the methane, not man directly. And I am told that the methane issues from the front end of cows, not the back end as people had supposed. Be warned not to smoke near the front end of a cow.

Why do cows make methane? One answer that is emerging from research points the finger—as you might expect—at man. They didn't used to when their diet was rich in various grasses. Initially, grazing areas were filled with a variety of grasses and flowers that grew naturally, offering a diverse diet for cows and other ruminants. However, in order to improve the efficiency of feeding livestock, many of these pastures became reseeded with perennial ryegrass. With the aid of artificial fertilizers, perennial ryegrass grows quickly and in huge quantities. The downside is that it lacks the nutritious content of other grasses and prevents more nutritious plants from growing.

This simple diet allows many cows to be fed, but it inhibits digestion. This is where the methane comes in. The difficult-to-digest grass stays longer in the rumen, where it interacts with microbes, ferments, and produces gas. The exact details of the process are still being studied, and more information may allow scientists to reduce cows' methane output. Nowadays, the grass-fed population of cows is decreasing, and the corn-fed population is increasing. There is increasing evidence that the undiversified diet of corn-fed cattle has the same effect on the rumen of cattle as does an undiversified diet of rye grass. It produces methane.

Has the globe warmed? Yes. Is it beyond doubt that the warming is because of mankind's activities rather than other factors such as more energy from the sun? Yes, yes. How much has the globe warmed so far? About 1.5˚F during the 20$^{th}$ century.




How much warmer is it going to get? To answer that, one needs to understand how predictions are made of the global temperature. And to get there, one needs to understand what is meant by the globe's temperature.

How *do* you measure the temperature of the globe? The very concept seems absurd. What we mean, of course, is not the temperature of the globe, which is vast and mainly inaccessible, but the average temperature of the atmosphere at the surface over the land and over the oceans. Just doing this is hard enough. You have to get data from thousands of thermometers that are placed at a standard height of 2 meters and housed in white boxes with louvered sides—white so they reflect sunlight, louvered so that air can circulate—correct them for a range of reasons, weight them appropriately, add to this data taken by thousands of ships, check against satellite and weather balloon data (weather balloons are released twice a day from hundreds of sites around the world), and then publish a temperature of the globe. This is done by three independent organizations, one in the United Kingdom, and two in the USA, all using very different approaches to weighting and correction, and their estimates are pretty close to one another. There used to be discrepancies between the estimates and what was observed with

the satellites, but these have largely been resolved, and there is no longer any basis for asking, “How do we know the globe is *really* warming?” It is.

How much? As I said earlier, about 1.5˚F over the 20th century. And how much more might it warm up over the 21st century? The predicted range is somewhere between 2.5˚F and 10.5˚F, a range of 400%. This wide range is used to deride the predictions, the argument being, if you are so uncertain, then your predictions are worth nothing. What the skeptics have failed to mention is that underlying that wide range is a series of scenarios around what mankind will do by way of mitigation. In any one scenario, the range of uncertainty is around 60%, not 400%.

It’s worth spending a little time to understand how these predictions are made. They are made using massively complex computer models of the atmosphere and the oceans. The models are tested by feeding into them the measured Carbon dioxide rise observed in the 20th century, and their “predictions” for temperature rise in the 20th century are tested against the observed actual rise. The match is pretty good, so that increases our confidence that the predictions for the future make sense. But before these predictions can be made, we have to say what the levels of carbon dioxide will be in the future. If we continue Business As Usual, then carbon dioxide levels will become roughly double those of the pre-industrial era. The predicted range is then from 4˚F to 6˚F.

All of this was known 6 years ago, at least to the scientists. What is new now?

First, we understand better what the world may look like when the temperature has gone up by more than 4˚F.

Second, we now also have data that suggest that the temperature rise could be both a lot bigger and a lot more sudden than we believed 6 years ago.

And third, there is an increasing awareness that the future may unfold rapidly, in decades, rather than slowly, over centuries, as is generally believed.

To understand why, despite these revelations, the world, as I mentioned earlier, is still sitting on its hands, we need to understand why a temperature increase is an inadequate way to describe climate upheaval.

### *The problem is with the words we use*

When a person is sick, we use temperature as a quick way of telling how sick. But we don't usually stop there. We try to figure out what is wrong, what is causing the temperature to go up. Does the person just have a bad cold, or the flu, or malaria? And we try to treat the actual disease.

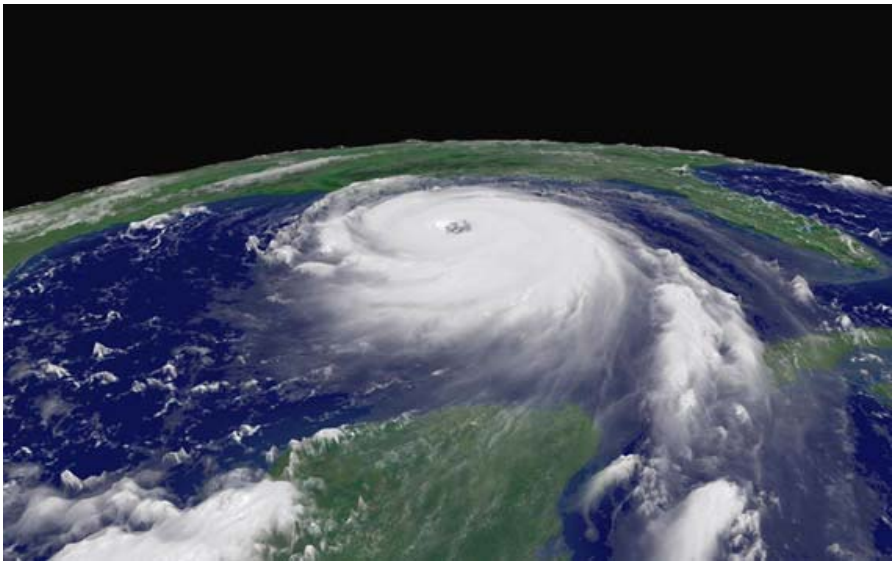
With the globe, it's similar. Temperature is still an index of what's gone wrong, but we still need to know what's gone wrong. Temperature increases are the end result of massive inputs of heat into the atmosphere that empower the atmosphere to create heat waves, extended droughts, forest fires, spread of mosquitoes, melting of glaciers, giant hurricanes, floods from endless rain, and the rise of sea levels. In other words, the climate can go wrong, and temperature is only one measure for describing climate. Other measures include heat waves, droughts, floods, and storms.

Averages have a way of lulling us into a state of false security. We all know the shortcomings of describing the economy by per capita income while ignoring the distribution of income. Here is another analogy. Imagine two people in the kitchen, one sitting at the table and eating breakfast, and the other with his head in the oven and feet in the freezer. They may both have the same average temperature of 98.6˚F, but one is alive and well, while the

other is dead, cooked, and frozen. The same is true of the globe. A 4˚F rise in the global average may go with a 12˚F rise in the arctic and the tundra in Alaska, Canada, and Siberia, and a 6˚F drop in temperature somewhere else, in Australia, South America, or the Antarctic. In a large system with a great deal of variability, talking about averages is meaningless. Moreover, just as the human body is designed to be well at 98.6˚F, human society is conditioned to be well in the climate we now have. Major changes could make us feel quite unwell, despite the claim by optimists that a warmer world would be more comfortable.

Still, people often ask, "How can a few degrees of temperature matter so much? After all, our local temperature fluctuates more than that from one day to the next." What matters is the scale on which the change happens. Your local temperature depends on changes in a relatively small mass of air. Let's consider what it takes to increase the temperature of earth's atmosphere as a whole by 4˚F. Here is a calculation. We know that the air above one square inch weighs 14.7 pounds, for that is the pressure the column of air exerts on a square inch of ground. A square foot contains 144 square inches, and when you multiply 144 by 14.7, you get roughly 2000 pounds, or a ton. Each square foot of the globe's surface has a ton of air above it. A square mile has about 30 million square feet, so it supports 30 million tons of air. The earth's surface has an area of roughly 200 million square miles. If you multiply that number by 30 million tons per square mile, you arrive at the weight of the atmosphere. The number is 6,000 trillion tons. How much is this? Let's consider an oil supertanker full of oil and weighing half a million tons, close to the largest ever built. We would need 12 billion such tankers, and, lined up side-by-side and stem to stern, they would overflow the Pacific Ocean.

The energy required to raise the temperature of this weight of air by 4˚F is 3500 trillion kWh. This is enough energy to create one Katrina every year for a thousand years.



A thousand coastal cities laid waste over the next millennium.

It is also the equivalent of 1,000 Hiroshima nuclear bombs every day for the next 350 years.

I need to make a very important parenthetical comment at this point. You might imagine from what I have just said that we are putting too much energy into the atmosphere because we consume so much energy to support our life styles. Nothing is further from the truth. The annual energy consumption of mankind is one ten-thousandth the energy falling on planet Earth from the sun in the same period. The problem is not energy consumption *per se* but *dirty* energy consumption. It's the greenhouse gases that matter. If we could consume energy without putting greenhouse gases into the atmosphere, we wouldn't have a problem. At least not this problem.

Another way to answer the question, "Why does 4˚F matter so much?' is to examine *which* 4˚F we are affecting. When ice goes from 29˚F to 33˚F, it

melts, and the surface goes from energy-reflecting to energy-absorbing. And this has a giant effect on the acceleration of global warming. This is particularly true of sea ice in the Arctic. Ice reflects 90% of the incident energy from the sun. The ocean reflects 10%. Thus, when the Arctic melts (which it is doing at a frantic pace), the energy absorption of that vast region increases nine-fold, warming the seas even faster and potentially changing the circulation patterns of the world's waters.

What this suggests is that temperature is a truly inadequate way to describe climate upheaval. We need the words to describe how we are feeding huge amounts of energy into a system that can put it to uses both benign and malignant.

However, there is another curious twist to the question of why so many people are still passive. There is a widely-held opinion that climate change proponents speak too much as though they really know what is going to happen, and that no one can know the future with such certainty, so let's discount what they tell us. "They are crying 'wolf' again", people say. In other words, there is the suggestion that we need to talk about climate change with a more harmonious cadence, with less shrillness. There is also a suggestion that people do not respond to prophecies of impending doom, but do respond to messages of hope. In this view, it is better to talk of the wonderful world we could create if we acted—the new technologies, the new jobs, the continued prosperity.

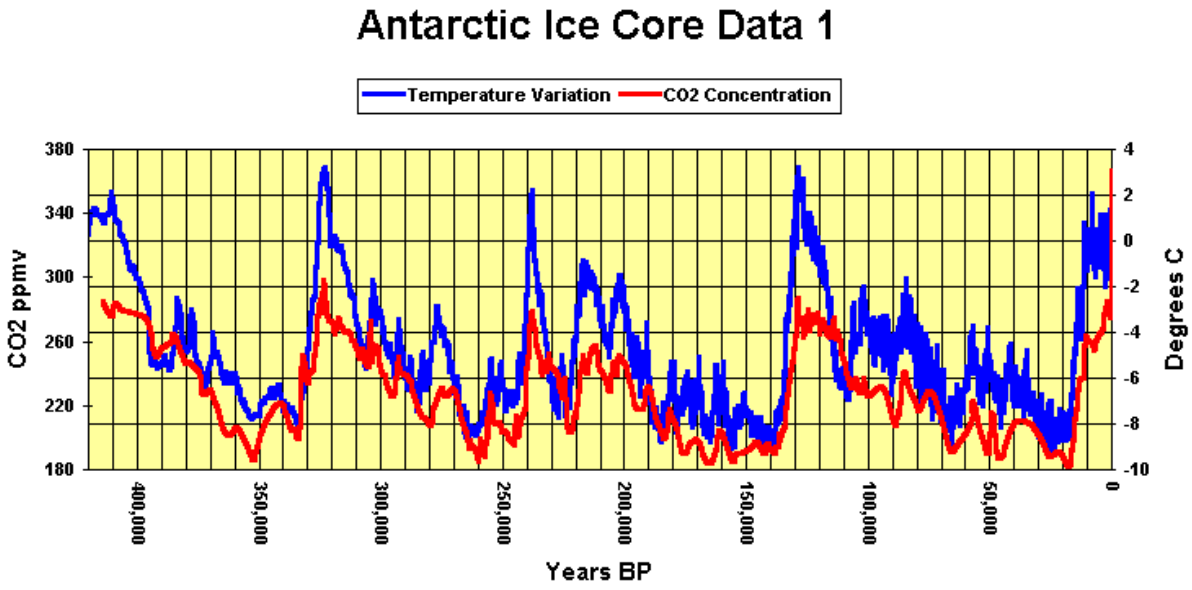
This sounds right to me, but it is a curious contrast to the experience of the last few years, when the Bush administration has been able to use fear as the prime mover to get its way. Perhaps the difference is having an experience such as 9/11. Perhaps the difference is marketing; 9/11 was used to sell the "War on terror", but no one has used Katrina and forest fires and heat waves and floods to sell climate change. Perhaps the difference is the role of the

media in moving the electorate along; they have colluded with the Bush administration in selling the war on terror, and by-and-large have stood on the sidelines in the climate change discussion.

***What we have learned from the past?***

A good way to get the words to talk about the future of climate and of our society is to examine how our climate has behaved in the past. This is admittedly difficult to do, and is not unlike detective work.

Here is a chart which tells the story. I apologize that I am back to describing the climate through temperature, but I don't have better words yet.




If we assume two things:

1. That what is deduced from these ice cores correlates to what is going on elsewhere on earth, and
2. That temperature is a proxy for climate,

then one can say this about our past climate:

Climate is a capricious beast. It is unstable, and it lurches from one end of the cage to the other. The temperature lurched from high to low and back

again repeatedly, sometimes going up 30˚F in just forty years, and then back down slowly over a few hundred years.

It used to be believed that if these things happen at all, they happen over thousands of years. What the ice cores of Greenland and Antarctica have revealed is that, instead, change happens all of a sudden.

Our climate is anything but stable, undermining the premise of the quotation that I started my talk with, “This generation of mankind will be the last to experience a stable climate.” We probably never have experienced a stable climate except in short bursts, even over the last few thousand years, something I will return to later in my talk.

What has driven this immense variability? As far as is known, there are only four external influences on the climate. One is the sun and earth’s positional relationship to it. This determines how much energy is falling on earth, and where. Another is volcanic action, sending dust into the atmosphere. By-and-large, the effects are short-lived, and volcanism has been a minor feature over the last million years. The third is plate tectonics, the movement of the continents. This is interesting. Land masses need to be near the poles for ice sheets to form, for the oceans bring heat in easily, and only if ice sheets form does a feedback loop kick in which makes a runaway cooling possible. More later on feedback loops. The last is meteors. It is a well-supported theory that meteor impacts millions of years ago sent vast clouds of dust into the atmosphere, leading to extended cooling, changes in precipitation and habitats, and mass extinctions of species.

However, none of these external influences is enough to explain the vast apparent fluctuations in our climate.

The real culprits are “feedback loops” and “instability”. Let’s examine each of these terms in turn.

Suppose you give a dynamic system, i.e., one capable of change, a little shove. Will the system respond by going along or pushing back? That depends on feedback loops. A feedback loop is a situation in which the response of the system to a shove either modulates or exacerbates the initial jolt. A modulating response is called a negative feedback loop, and an exacerbating response is called a positive feedback loop. Negative feedback loops ensure stability, while positive feedback loops create instability.

An example of a negative feedback loop is what happens to our bodies when they are exposed to excessive heat. The pores on our skin expand, we sweat, and the effect of moisture evaporation on our skins (other than making us smell) is to cool us.

An example of a positive feedback loop is what happens when an industry such as the oil industry gets rich. It buys control of the lawmakers and the legal system, and they jigger the whole legal and economic system so that the oil industry gets richer.

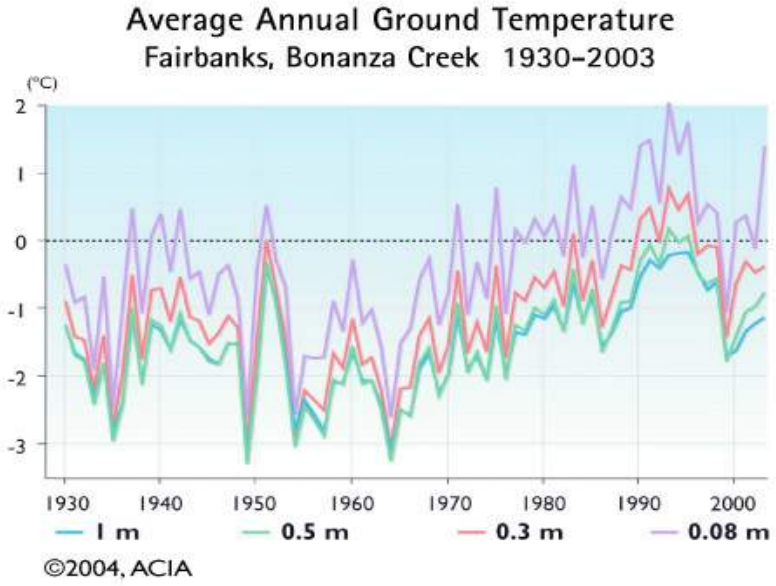
In terms of climate, there are many feedback loops. But here is an interesting point. I searched extensively, and found many examples of positive feedback loops, and few of negative feedback loops. That, of course, is consistent with the observed pattern of variability of the climate.

The most important feedback loop is the melting of ice when the atmosphere warms. There is a concept called *albedo* which it is useful to understand. It symbolizes the amount of incoming energy from the sun that a surface reflects, the rest being absorbed by the surface. Ice has an albedo of 0.9, which means it reflects 90% of the sun’s energy that falls on it. Ocean water,

on the other hand, has an albedo of 0.1; it reflects 10% of the sun's energy, and absorbs the remaining 90%, getting warmer in the process. When ocean ice melts because of an increase in solar radiation, then more energy is absorbed, and the ice melts faster, and the process goes out of kilter. Conversely, if the incoming solar radiation decreases by a small amount, ice forms, and the local area cools because of the albedo of ice, the ice continues to grow in extent, and the planet cools far more than you would have expected from the decrease in solar input.

In other words, positive feedback loops make the atmosphere and oceans into an amplifier of the variations in sunlight.

A feared positive feedback loop is when the warming atmosphere melts the tundra in Canada and Siberia and may cause the release of thousands of billions of tons of methane locked up there because of anaerobic decomposition. Methane is twenty times more potent that $CO_2$ as a greenhouse gas, and that release could trigger a runaway increase
In climate upheaval.




There is some evidence that something like this happened 50 million years ago, triggering a mass extinction of species. Scientists, with their well-known

juvenile humor, have labeled what is presumed to have happened a “methane megafart”.

The main negative feedback loop is vegetation. When $CO_2$ increases because of forest fires, and the atmosphere warms, the air gets moister and it rains more, and the combination of more water and more $CO_2$ makes the forests grow faster, combating the effects of the fires. Another important feedback loop is provided by clouds. If the atmosphere warms because of green house gases, then the oceans warm, and they put more moisture into the air. This moisture turns into clouds, and they reflect more energy from the sun, counteracting the primary effect of the green house gases.

But vegetation can also become a positive feedback loop. Lack of rain can lead to a decrease in vegetation, and, because the vegetated land absorbs more sunlight, land surface holds less moisture, fewer clouds form, and the rain decreases further.

Unfortunately for us, the positive feedback loops dominate, and the climate is unstable. Eventually, of course, every positive feedback loop is stopped by a negative feedback loop, or we would have a system that runs away to infinity. But the evidence shows that climate is, indeed, a system that tends to go to its extremes easily.

In addition to all the feedback loops, there is the concept of instability. The two are related but not synonymous. Many systems respond like this: if you push them a little bit, they respond a little bit. Push them twice as hard, and they respond twice as much, and so on. These are called *linear* systems. However, there are other systems that are non-linear. The best known example is a human being. You aggravate a person a little bit, and they respond with a little bit of irritation. Aggravate them a little bit more, and you get a little bit more irritation. But suddenly, you push them a bit more, and

they go berserk. They go to malls and shoot people. They turn into suicide bombers.

Earth's climate is also a nonlinear system. Within limits, the positive and negative feedback loops keep the system under control. But if the shove becomes large enough, then it is impossible to predict where we will land.

One thing we do know about non-linear systems is that they can have more than one stable state. Given a large enough shove, they will shift from one stable state (let's say ice age) to another (let's say Inter-Glacial warm period). My own studies of non-linear systems told me that during the transition, the system becomes unpredictable, and fluctuates violently before settling down. That may be what we are experiencing now.

One of the sources of instability in our climate is the "ocean conveyor", a vast network of globe-encircling currents that carries energy from the tropics to the higher latitudes. Near Greenland and Iceland, the warm surface water cools, sinks, and returns under the surface to the tropics. Given enough of a shove—for example, from melting ice sheets--, this conveyor can re-configure itself, possibly shifting the whole earth's climate to a new stable state. The Gulf Stream, El Nino, and La Nina are all part of this conveyor. What the new stable state could look like, no one knows.

I neglected to mention another external influence on climate, and that is life itself. We do know that without the help of early life on earth, which developed the capacity for photosynthesis and took carbon dioxide out of the atmosphere and put oxygen into it, we would have a very hot planet. Look at Venus, a planet similar to ours, where the atmosphere is 95% carbon dioxide, and the atmospheric temperature is 850˚F. Life somehow made it on earth and didn't on Venus.

And then, what about the special kind of life that mankind claims to be, intelligent life? Through most of history, we were negligible as an external influence on climate, but the scientific record clearly shows that we have become a major external influence over the last two hundred years. Whether or not our influence will over-ride that of the sun is too early to tell, and may, depend, in part, on how we act, and if we do not, whether the climate will exert an influence on us that will dampen our activities, making for one more negative feedback loop.

I may have given you the impression that the climate was unstable during the last ice age, but that mankind has enjoyed a stable climate for the last ten thousand years. We have not.

The earth started warming about 15,000 years ago. Two thousand years later, it suddenly cooled and plunged back into an ice age that lasted 1,300 years. The atmosphere then continued to warm for a few thousand years, until about 8,000 years ago, when there was another burst of cooling.

What then followed was a warming followed by a slow cooling over the last 1,000 years. That is a pretty picture, but here is the reality.

Unbearable droughts hit various parts of the planet. The Sahara turned from green and fertile to what it is today. Once, Lake Chad was an inland ocean, and the Sahara was green and fertile. Lake Chad is now almost gone, and the area around it is one of the dustiest places on planet earth.

There is increasing evidence that the Akkadian civilization in southern Mesopotamia, the Indus Valley civilization in India, the Mayan civilization in Central America, and the Anasazi civilization with its famous cliff dwellings in the southwest USA, all disappeared because of drought.

The era that laid waste to the Mayans and the Anasazi is referred to as “The Medieval Warm Period”, a phrase concocted by Europeans. Temperatures in Europe were then about what they are now, and things felt good. In Europe.

And then there was the mini Ice Age that ended in the 1850s and started about 400 years earlier. The Viking settlement on Greenland expired. Life in Europe was miserable. But here is a nice positive element. Antonio Stradivari, the famous violin maker, produced his instruments during the little ice age. It has been proposed that the colder climate caused the wood used in his violins to be denser than in warmer periods, contributing to the tone of Stradivari's instruments.

### ***What does the future hold?***

All of the preceding discussion is, of course, a prelude to a discussion of the question, “What does the future hold?” In many circumstances, the past is prelude to the future. With climate upheaval, the present is prelude to the future.

Harm is happening *now*. Here are some examples, and I will concentrate on people, even though harm is happening to other species that we depend on.

The way of life of the Inuit is coming to an end.

This is well documented in Alaska, where coastal villages are being inundated by storms that eat coastlines because there is no ice to calm the swells as oil does. Hunting for seals is no longer an onshore experience; hunters have to go 60 miles in power boats. Many people have asked for help to migrate.


In Canada, the Inuit depend on the vast Caribou migration for food.

This migration, involving herds of over 150,000 animals, has been compared to scenes from the Serengeti. In recent years, the herd has declined to the point where the Inuit themselves are in difficulty. The reason? It's because the warmer climate in Canada has increased the range of the giant Canadian mosquitoes which, I am told, are as big as hummingbirds. These mosquitoes make life so miserable for the caribou that the caribou seek higher and cooler ground where the mosquitoes do not thrive. Unfortunately, there is not enough food there, and the caribou are dying.

If you will forgive me, I will now make a little litany of things going wrong, and then I will quickly return to the question, “What can be done?”

The Tuvalu islanders have given up hope.

Their home is vanishing under the rising ocean, and they have decided to migrate to New Zealand.

The Maldive islands in the Indian Ocean will soon be under water.

Marine Drive, Male’ this morning

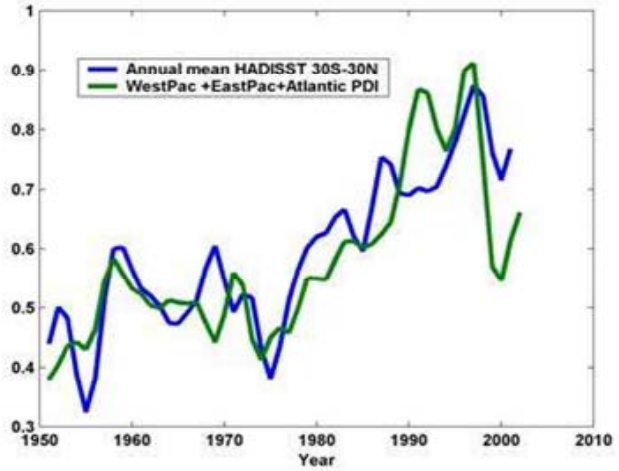
Honduras experienced it's first-ever and incredibly devastating hurricane in 1998. More than 40,000 people died in floods and mud slides.

You know what happened to New Orleans when Katrina struck.

The intensity of tropical storms is going up, as is the frequency.

## Harm is already occurring (continued)

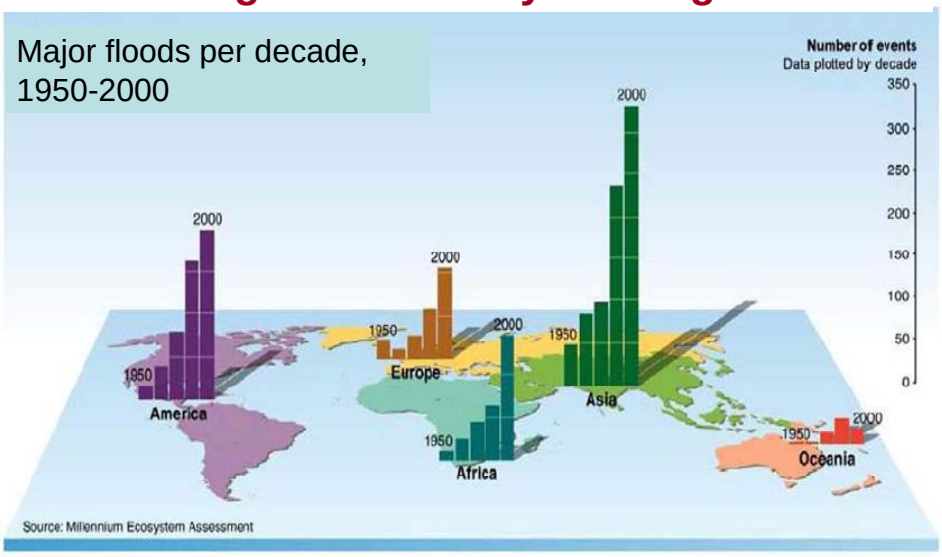
Total power released by tropical cyclones (green) has increased along with sea surface temperatures (blue).




Kerry Emanuel, MIT, 2006

Major floods have multiplied five- to ten-fold over the last fifty years.

## These changes are already causing harm

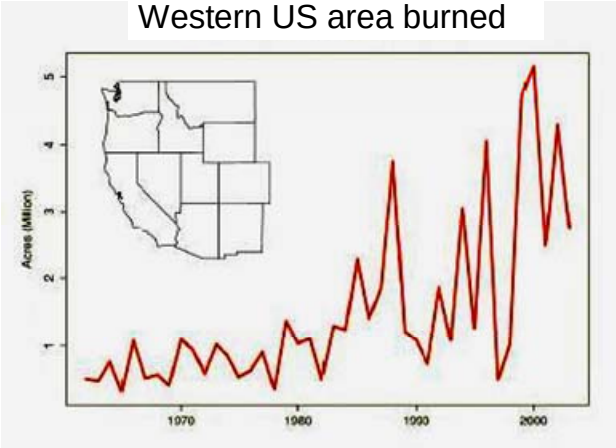



**There's a consistent 50-year upward trend in every region except Oceania.**

Wildfires in the western US have increased four-fold in the last thirty years.

## Harm is already occurring (continued)

**Wildfires in the Western USA have increased 4-fold in the last 30 years.**





Source: Westerling et al. 2006

The heat wave of 2003 in Europe killed at least 40,000 people, including 20,000 in Italy and 15,000 in Paris alone.

Most were either old or poor or both, and could afford neither air conditioning nor a vacation in the countryside.

Warm weather days in Boston are increasing in number.

In many places, wet days are getting wetter, causing more flooding.
In 2005, unprecedented rains in Mumbai in India (37 inches in 24 hours!) caused hundreds of deaths from flash floods.

One “takeaway” from this is that an instability is happening. That’s a calm way of saying, “Uh Oh!”

How bad could it get? The IPCC has tried hard because of the US Government and its allied skeptics to be “reasonable” in forecasting the future, and, in the process, may have biased their predictions to an optimistic tilt.

It’s true that predicting the future is difficult (although, as one wag noted, not as difficult as predicting the past). But it’s worth doing for, without it, we are navigating without a compass.

So, here goes.

Ocean levels could rise dramatically, anywhere from a few inches to several feet. The wild card is what will happen to the ice sheets in Greenland and Antarctica. We are learning that we know very little about how these ice sheets behave. It was long thought that they would slowly melt over hundreds of years. Then the scientists began to understand that when you model ice sheets, you need to include surface melting. It turns out that when these vast ice sheets melt, the water runs through cracks, widens them, and eventually cascades in mile-long waterfalls right down to the bottom of the ice sheet, where it lubricates the forward movement of the ice sheet towards the ocean.

If both ice sheets melted, the level of the ocean would rise 60 feet, not just a few inches. Will it happen? Who knows? If it happens, how bad will it be? Every major coastal city will have to be evacuated. Boston. New York. San Francisco. Mumbai. London. Bangladesh would have to evacuate its entire population, which would almost certainly result in war with India and other neighbors.

Short of this, rising ocean levels will mean rising storm damage along coastlines.

What is more certain is that the extremes of climate are going to get worse. Droughts and floods will increase. Hurricanes will rise in frequency and intensity, as will tornadoes.

Crop yields may get better in temperate climates such as North America and Europe, but may significantly decline in India, China, and Africa.

Weather patterns will change. For example, warmer seas may result in intensifying monsoons in India and China. This could result in more flooding in Mumbai, such as happened in 2005. In a curious twist, however, and one

not inconsistent with the concept of instability and unpredictability, monsoons could go the other way as well. That is because there is a vast cloud of soot hanging over India and the Indian Ocean, the result of a billion cooking fires. This cloud is blocking the sun and causing local cooling. It may be that this will weaken the monsoons, in which case Mumbai would be OK, but northern India would suffer a long drought.

It's a cliché to say that our society is designed for the climate we are accustomed to, but it's true. We can probably adapt to a changing climate, but it may involve vast adaptations, including whole-scale migrations, such as are being initiated by the Tuvalu Islanders and the Inuit people of coastal Alaska.

### *What can be done?*

Staying the course, also known as Business As Usual, looks fraught with risk. Shouldn't we consider what can be done? The literature on Climate has a pet description of what our choices are: Mitigation, Adaptation, and Suffering. Activists go on to say that we will be doing all three of these, that we are already suffering, and how much more we suffer depends on how smartly we move ahead with mitigation and adaptation.

To set the scene, we need to understand a bit more about greenhouse gas emissions.

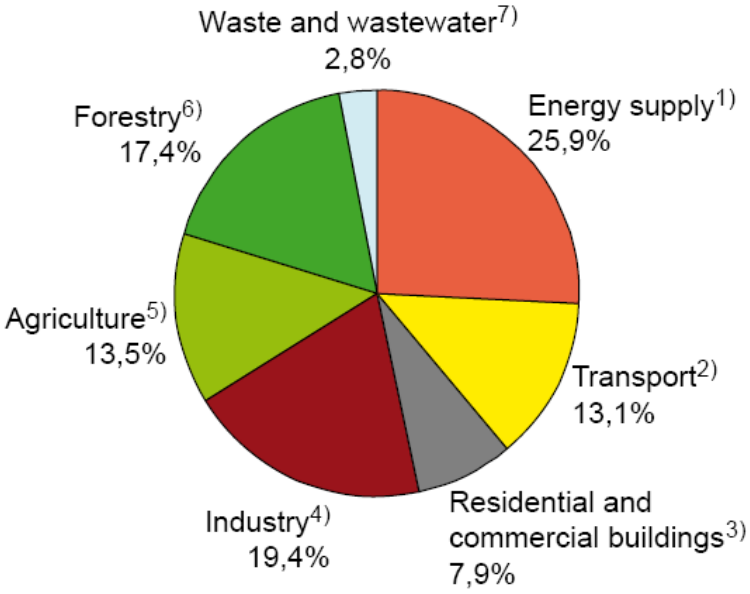
So who are the culprits? Let's focus on carbon dioxide.

We are currently emitting 26 billion tons of $CO_2$ every year. If business continues as usual, this rate of emission will double by 2050. Before the industrial revolution, the concentration of $CO_2$ in the atmosphere was about 280 parts per million (known as "ppm"). Now it is around 380 ppm, and it is forecasted to rise to 500 ppm by 2050, the highest level, as far as we can tell,

in a couple of million years. That could mean that we are entering an era in which the past is no prologue to the future, with the one exception that the climate is unpredictable and fractious.

The main sources of $CO_2$ are the burning of fossil fuels, coal and oil, and deforestation. Deforestation creates a double whammy. The forests are no longer there to absorb carbon dioxide by converting it into wood, and their burning puts $CO_2$ right up into the air.

## Mitigation leverage: The sources of GHG




Who is putting out all this stuff? The US leads the way. We account for 20% of annual emissions, with 5% of the world's population. The US also accounts for 30% of what's already out there. China is second to the USA as a current emitter, but is far behind the western countries in cumulative emissions. Americans account for 25 tons of $CO_2$ annually on a per-capita basis, the highest of any major country. Canada and Australia are not far behind. Japan, Germany, and the UK weigh in at 11 tons per capita. China is around 4, and India is around 1.3.

In these numbers lies the crux of the debate over who's doing what. George Bush's position is, "Why should we contain our emissions if China and India and Brazil are not willing to do so?" The response from those countries is, "You are the source of most of what's out there, and you have benefited economically from that. Our output is a small fraction of yours, and to accept limits based on what we now consume [a key aspect of the Kyoto protocol] would condemn us forever to be economically under-developed."

There is merit in their argument, but I should mention a point of view that is a counter-argument. After the recent Bali conference, a friend in India wrote to me as follows: Is it right for India to take the stand that it is a "developing country" and seek concessions to be allowed to continue polluting the environment for just a few years longer when it also believes that it is now a SUPER Power and needs Nuclear Power, rockets, and a show of strength befitting its supposed new status?

What the response of the US ought to be is this: "We accept the responsibilities of a leader. We will pave the way by implementing innovative mitigation policies as we have done with the ozone hole and with acid rain. We will create carbon markets that the rest of the world can participate in. We will invest in the development of innovative technologies for clean energy. This will bring down the cost of these technologies so that you can afford to implement them. We understand your aspirations for prosperity, but there is no need for you to follow the path we took, pumping greenhouse gases into the atmosphere. We will help you to create an alternative path. Brazil, we will pay you to not burn the Rainforest of the Amazon." Imagine what that would do to our standing in the world. It could become our next Manhattan Project, our next Man on the Moon Mission, our next Marshall Plan.

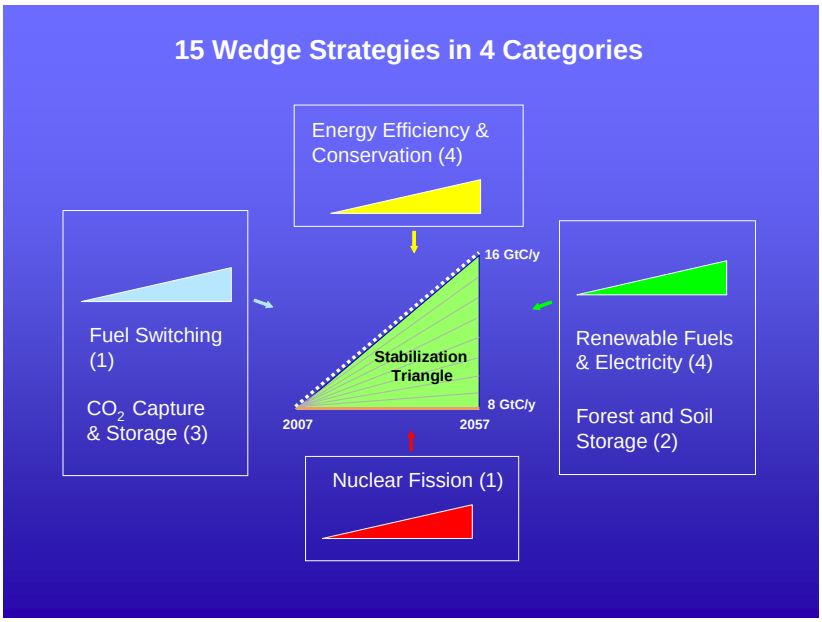
Could we do it? Yes. The technologies are there, either developed or showing great promise. What are they?

I will not have time today to go into any of these in any detail, but I will mention the most important ones. First is Carbon Capture and Sequestration, in which the $CO_2$ from coal burning is caught at source and buried in deep geological sites. There is coal gasification. Then there are all the renewable energy technologies, ranging from wind power to solar cells to wave energy to geothermal to biomass. There are an infinite number of ways to make homes, office buildings, factories, and transportation systems significantly more energy efficient. There are hybrid, electric, and diesel automobiles. There are exciting technologies that can make agriculture not only less dependent on fertilizers and insecticides but at the same time significantly more productive per acre and better at retaining water. And there is nuclear power.

Will what we need to do be easy to do? By no means. It will require not sacrifice, but a willingness to have different winners and losers than we now have. And that means tough-minded political leadership. It will be up to us as citizens to toughen the spines of our political leaders.

The scale of what we need to do is captured by first setting a target for green house gases, and then examining strategies for getting to that target. The target is to limit global temperature rise to 4˚F. That means we will need to make sure that greenhouse gas emissions in 2050 are no larger than they are now. In the Business As Usual scenario, they will double. Thus, we need approaches to reduce emissions by 25 billion tons of $CO_2$ per year. A picture of what it will take has been created by two people at Yale University, Stephen Paccala and Robert Socolow. They have identified 15 strategies, any 8 of which would accomplish the goal. Some examples: doubling vehicle fuel economy; making all residential and commercial buildings energy efficient by using compact fluorescent lights and energy-efficient appliances; improving the efficiency of coal-fired plants from 40% to 60%; increasing wind

energy 50-fold; halting deforestation; and carbon sequestration and capture. That last one alone will accomplish almost 40% of what is needed.




There will be costs, of course. Energy will cost more, but for most of us in the West, it will not make a significant dent in our lifestyles, certainly les than the doubling of gasoline costs has done. And we will have to help the poor among us who cannot afford winter heating fuel. We should be doing that anyway as a just society.

George Bush has argued that working on this problem will slow the economy down. This issue has been comprehensively examined in the Stern Review of The Economics of Climate Change, prepared for the UK Government by Nicholas Stern in 2007. The bottom line is that the GDP per capita in 2050 could be about 2% less than in Business As Usual. Given that the rate of growth of GDP is at least 2% a year, this means that with the needed investments, instead of reaching a certain state of wealth in 2050, we would get there in 2051 instead. Not too much of a wait.

And, in my opinion, these estimates by no means capture the potential windfalls that will accrue from action, ranging from whole new industries for

carbon capture, biomass conversion, and wind energy, to new methods of agriculture to jobs for millions retrofitting buildings in the USA with energy efficiency measures. Can we look back on Rachel Carson and the environmental movement she energized and say, that cost us 2% in growth and 5 million jobs? Indeed not. They did wonders for us, although with any such new idea, it has sometimes been taken to excess.

On the adaptation front, too, there are many technologies that could be developed. Water desalination plants will help areas that experience drought. A major effort is under way to protect the water supplies of Perth in Australia. Climate forecasts can help farmers pick the right crops. Land use changes (such as less paved surface and more greenery) can help reduce flash flooding in cities such as Mumbai. Better dikes and levees can help the Netherlands and New Orleans. Better surface water management can improve the drinking water situation in India and China. Better fire management policies can reduce the intensity of California forest fires.

The means are there. Is the will?

Leave Washington D. C. aside for a moment. It is absolutely amazing what is going on across the United States. There is tremendous movement at the level of individuals, university campuses, towns, states, and even businesses towards becoming “green”. Rebecca Haskell, a junior at Boston University, got upset that the University was doing no recycling. She bugged enough people often enough that the University decided to take recycling seriously.

The Boston Globe report said this:

“Last fall, on her own, she approached assistant provost Michael Field, presenting him with a 15-page set of recommendations on expanding recycling into more academic buildings. The eventual results included a document on how offices and students could use less paper - now linked from the school's "Greening the Campus" website - and the forming of a team of student volunteers who worked alongside Haskell to write up building-by-building proposals for expanding recycling.

The school's garbage and recycling contract was renegotiated this summer. And, according to [Assistant Provost] Field, "we have recycling in more buildings than last year, and that's because of her. She was able to get attention focused."

Harvard University, Mt. Holyoke and a host of Universities have green campus programs, often energized by the student body.

Arnold Schwarzenegger was persuaded by his wife’s cousin, Bobby Kennedy, to meet a remarkable individual named Terry Tamminen. He did, and his thinking was transformed. California now leads the states in deploying far-sighted policies, and Terry Tamminen, who had never served in Government, is now Arnold’s head of the California EPA.

In June 2005, Governor Schwarzenegger signed Executive Order S-3-05, establishing the most ambitious greenhouse gas emission reduction targets of any state or nation in the world. The Order directed Cal/EPA lead a multi-agency effort to meet the targets, and to report every two years on the progress toward meeting the targets.

Republican Charlie Crist became governor of Florida and immediately started implementing changes to climate-related policies. Why? Because he was concerned about Florida's fate in the face of climate upheaval.

Following the advice of St. Petersburg Mayor Rick Baker and California Gov. Arnold Schwarzenegger (right), Gov. Charlie Crist took up the issue of global warming for Florida, although he hadn't mentioned it during his election campaign or inaugural address. On July 13, Crist signed executive orders calling for cuts in greenhouse gases, more use of renewable energy and a revamp of the state's building code.

Portland, Oregon, San Francisco, and Seattle lead the 50 major US cities in implementing climate-friendly policies, but there is movement everywhere. Portland has paid major attention to making buildings energy efficient, to articulating a climate policy, and to creating a "green economy".

Wal-Mart has articulated specific policies for reducing waste and $CO_2$ emissions and is pushing the sale of compact fluorescent lights very hard.

Near Wal-Mart's headquarters in Bentonville, Arkansas, is the town of Fayetteville. Fayetteville has decided to shed the straw-chewing image of the Ozarks and become the Berkeley of the Ozarks, and is leading the way in Northwest Arkansas in creating awareness of the future of climate upheaval and the need for change.

There's evidence of leadership everywhere except in Washington, D. C. What do we do? We need to throw the bums out. The movement to do that is already gathering steam based on a whole range of other failings of this

administration, but I would like to suggest a workout for those who wish to take the climate route to regime change in the USA.

### *Getting to action*

I recommend a process for you.

1. Get informed.
2. Get bragging rights.
3. Organize.
4. Change the political system

The first thing to do is to read and discuss issues enough to be dangerous. At the end of this paper I have provided information resources that I hope will take you quite a long way.

The second thing to do is to get bragging rights. You have no right to exhort others to take action until you have taken action yourself.

The first step here is to reduce your carbon footprint. That's code for taking actions that will reduce the amount of $CO_2$ that goes into the atmosphere because of what you do and consume. There are some simple things you can do to reduce your carbon footprint. The very first step is to figure out what your carbon footprint *is.* There are various websites that will help you to do this. It's important to get moving, so do what's easy first—like changing your light bulbs; getting a more energy-efficient car or refrigerator may or may not be affordable. Do those when you can. Eventually, however, you have to do the things that really matter. In simple terms, the big items are your car, your heating and air conditioning, your lighting, your appliances, your use of hot water for bathing, washing clothes, and washing dishes, and your clothes dryer. Surprisingly, there is another lurking culprit in the modern American home: electronic devices such as TV sets that are in an "instant on" mode 24 hours a day. They seem to be turned off, but they are not. Studies show that

as much as 15% of your consumption of electricity goes to support this convenience. So, turn off devices at the wall, not at the device.

Beyond reducing your carbon-intensive energy consumption, you can also buy carbon offsets. You send money to plant a tree that will absorb $CO_2$ or to build a wind turbine. There are audited websites that will enable you to do this. The typical cost for offsetting a ton of $CO_2$ release is about $10 to $15.

How much $CO_2$ do you account for? Here are a few tips. The average for an American is 25 tons a year, but that includes all the activity in Government, industry, and the non-profit sector that you may feel you have no control over. What you consume that is within your direct control is probably half that.

A gallon of gasoline releases about 19 pounds of $CO_2$. If you drive 15,000 mile in a car that gets an average of 20 miles per gallon then you consume 750 gallons and release 7.3 tons a year. Buying offsets would cost you about $75. That is less than 4% of what you paid for the gasoline. Would you rather do that or continue to fund dictatorial regimes that control the world's oil by paying them high prices for gasoline in short supply? If you drove a Prius and got 40mpg and drove only 12,000 miles a year, your output would drop to 3 tons a year.

A bath that consumes 20 gallons of water at 120˚F releases about 17 pounds of $CO_2$. If you bathe every day, that would amount to about 3 tons a year. Almost half as much as driving a not very efficient car! A modern shower head puts out about 2.2 gallons per minute, so a 20 gallon shower would last 8 minutes. Tell your kids and grand-kids to get out of the shower fast!

A compact fluorescent light bulb (known as a CFL) consumes one-fourth the amount of energy as an incandescent for the same light output. A 100 watt incandescent that is on six hours a day would generate 550 pounds of $CO_2$ a

year.  A CFL would save three-quarters of that, or 400 pounds.  Ten such replacements would net a two-ton savings in $CO_2$ emissions.  In addition, you would save quite a lot of money on your electricity bill.

By the way, I have done the calculation, and it always makes sense to replace an incandescent light bulb with a CFL, no matter how new the incandescent is.

Heating your home in the North (and air-conditioning it in the South) can generate lots of $CO_2$.  If you use a thousand gallons of heating oil a year, the amount of $CO_2$ generated is almost 10 tons, significantly more than driving. Setting your winter thermostat a little lower can make quite a difference, and will be healthier to boot because the air will be less dry, and you will have fewer problems resulting from dried out mucous linings.

Install energy-saving appliances.

The next step after gaining bragging rights is to widen your circle of influence. Start a Climate Change Club of America. Gather a few neighbors together and trade information and "here's what I did's". Read books and blogs and teach one another. Start discussing climate-sensitive investment portfolios.

Now that you have a cohesive group, it's time to pay attention to your town as well as to any organization to which you belong. Persuade them to develop a climate action plan. They may feel awkward at first, but eventually, they will turn into enthusiasts.

You are now at the scale where you can club together with others in your state and pressure your state to change its policies. Then, it's on to a regional coalition of states, and finally the Federal Government.

What I am describing is, of course, a naïve version of political organization, but that is what we need—political organization. Because the final step is to develop a national movement that throws the bums in Washington D. C. out, and along with them, all the reactionaries in business and the courts and the media who are playing games with the future of humanity. To do this, you may to have to join and influence a political party, team up with organizations such as the Environmental Defense Fund and Natural Resources Defense Council, as well as support the route of litigation to make policy change happen.

The other thing we need is to comprehensively answer and silence the skeptics and cynics who make it so easy for those in power to drag their feet.

What do these forces of opposition have to say, and how do we answer them?

### *Answering the skeptics and cynics*

*Assertion:* There is no global warming.

*Response:* That's absurd. Even George Bush admits there is. Moreover, a comprehensive study by the National Research Council of the National Academy of Sciences has established beyond a reasonable doubt that global warming is happening.

*Assertion:* There is no global warming. The cooling trend of the last 1,000 years will soon re-assert itself, and then we will all laugh about the string of warm years. (Holman Jenkins in the *WSJ*.)

*Response:* That's absurd as well. The cooling trend is 0.7˚F in a thousand years, and the recent warming trend is 1˚F in a hundred years. That is a fourteen-to-one ratio. The long-term trend won't save us.

*Assertion:* It's not because of man.

*Response:* What else? The sun? Well, output from the sun has actually been lower than normal over the last thirty years. The oceans are warming and releasing $CO_2$? Measurements show that, instead, the oceans are absorbing $CO_2$ and becoming more acid as a consequence. This is beginning to affect sea life in many negative ways.

*Assertion:* Water vapor, not $CO_2$, is the most important green house gas. (Richard Lindzen of MIT.)

*Response:* Yes, but how does it get there? It gets there because warmer oceans evaporate more. The oceans are warmer because the air has more heat in it. The air has more heat in it because $CO_2$ and other greenhouse gases are trapping more heat in the atmosphere.

*Assertion:* The Gulf Stream does not really matter because most of the energy transport from the tropics to the higher latitudes happens through the atmosphere, with a lot of help from hurricanes. [Richard Lindzen of MIT.]

*Response*: Even if only 30% of the energy transport was done by the Gulf Stream, there would be huge effects in the UK and Europe if it stopped. Moreover, the idea that a warming climate could trigger a little ice age in Europe is the least of our worries; i.e., unless you live in Europe.

*Assertion*: Peer review makes the scientists on the Inter-Governmental Panel on Climate Change, or IPCC, like sheep. (Richard Lindzen of MIT.)
*Response*: Is there a better option for doing science? Simply accept the assertions of a Richard Lindzen? Leave unchallenged the flat-earthers? Let the "intelligent design" promoters rule? Let Lysenko tell us how evolution works?

*Assertion:* A warmer globe will be good for us.
*Response:* You're using the wrong description. Don't think warming, think climate disruption. Not balmy weather in New York, Boston, and Chicago, but heat waves, hurricanes, floods, tornadoes, mosquitoes, water shortages.

*Assertion:* The climate is unstable anyway. Why should we tighten our belts to prevent something that is going to happen anyway?
*Response:* First of all, we aren't talking about tightening our belts. We are talking about reducing waste, and making energy cleaner. Second, consider this analogy: the human body is under attack all the time by germs, viruses, and toxins. Does that mean we should stop trying to be healthy? It's the same for our planet.

*Assertion:* There are better things for mankind to spend its money on. (Bjorn Lomborg, the "skeptical environmentalist".)
*Response*: How did you do that calculation? What assumptions did you make about how bad the results of climate upheaval could be? And then, what evidence is there that we are going to spend money on all these other things? Did we do what we needed to do after Katrina? Did we intervene in

Darfur? And moreover, the money for what we need to do does not come out of a common pot labeled “for working on the world’s problems” that you can direct anywhere at will. It comes from industries that will need to invest to create new technologies, and that consumers will pay for over the decades. We can’t tell the coal industry to invest in eradicating malaria. But we could tell them to invest in assuring their own futures.

*Assertion:* We are saving the planet from descending into another ice age, which is due anyway.
*Response:* First of all, the best understanding we have of the ice ages says that another one isn’t due for thousands of years. On the other hand, efforts to shape our climate are not a bad idea. But if we want to go down that route, we should do so carefully and based on a scientific understanding of the consequences of our actions, not blunder along blindly.

### ***The end game***

Is that the end? We deal with our current crisis and then it’s over?

I think we need to re-think who we are and what we are about. I return to the image of Spaceship Earth, for that is truly what we are on. There is no other planet for us to go to if we foul up this one. There isn’t even another place on this spaceship for us to go to, as there always has been in the past, because the spaceship is full. Why not put ourselves in the shoes of the Founding Fathers of the US and act as though we are the Founding Fathers of Spaceship Earth? What would we say in the Constitution? It’s a worthwhile endeavor because the Founding Fathers articulated a vision that has shone brightly down the centuries, even if its light is a little dimmed at the moment. I believe this is what is needed in our current crisis.

It takes poets of great humanity to do the job that needs to be done, and I am not one. I am a technocrat. But if you will put up with me, I will offer a

starting point for a New Operating Manual for Spaceship Earth. Perhaps you can add some poetry to it.

The Preamble says this:

1. We have a prime mission: the indefinite survival and spiritual prosperity of the human species.
2. Within that mission, we want every human being to live a life that can be looked upon at life's end with a feeling of satisfaction.
3. Consumption of goods and services is not a useful measure of a good life. Service to the prime mission is.
4. Thus, we will measure standards of living not through economic measures that measure consumption but through psychological and spiritual measures.
5. Education and good health are birthrights, and we will ensure that everyone has access to them.
6. The health and stability of the land, the oceans, and the atmosphere are basic to our mission. So are the many other forms of life on this planet. They are not there merely for us to exploit.
7. On issues where opinion matters, we will decide through participatory democracy.

As I looked for evidence that mankind could, indeed, act for the benefit of our descendants, many friends pointed to the intentions of the people who freed this country from British tyranny and then articulated what we should be. I became aware that a strong influence on the Constitution was exerted by Benjamin Franklin, and that, in turn, a strong influence was exerted on him by the Iroquois Nation, the first truly *participatory* (not *representative)* democracy on earth, and one that has been in existence for 800 years. What the Iroquois have to say has a strong relevance to our problems. Here is an excerpt from a speech made in the early 1990s by Carol Jacobs, Cayuga Clan Bear Mother from the Iroquois Nation.

> Our prophecies tell us that life on earth is in danger of coming to an end. Our instructions tell us that we are to maintain our ceremonies, however few of us there are, and to maintain the spirit of those ceremonies, and the care of the natural world.
>
> In making any law, our chiefs must always consider three things: the effect of their decision on peace; the effect on the natural world; and the effect on seven generations in the future. We believe that all lawmakers should be required to think this way, that all constitutions should contain these rules.
>
> We call the future generations "the coming faces". We are told that we can see the faces of our children to come in the rain that is falling, and that we must tread lightly on the earth, for we are walking on the faces of our children yet to come. That attitude, too, we want to have you learn and share.

After the preamble, what rules shall we put in the New Operating Manual for Spaceship Earth? I have a small set ready. I hope you will improve them and add to them.

1. Supporting the prime mission is the number one duty of every member of the crew. The needs of the individual will be subordinated to the needs of the prime mission.
2. Helping other members of the crew who are in difficulty is the second priority. When you find someone in difficulty, help them, either personally or by reporting the situation to Central Command.
3. Looking after the commons is the number three priority of all members of the crew. If you find someone despoiling the commons, stop them.
4. There is no such thing as waste. It is too expensive to eject things from this spaceship, and the spaceship has no room for waste. There is no “elsewhere” where we can dump stuff. Everything must be recycled.
5. There will be no “them” versus “us”. For every one of us, our community is every human being as well as the ecosystems that sustain us.
6. By age 25, everyone will have lived in at least five different places on this spaceship in order to become familiar with and trustful of other people.
7. Every citizen can vote, but only after taking a full course on the ecology of the spaceship and signing on to science as the best way to understand how things work.

I now ask you to Examine what I have said.

## Information Resources

### Books

*The Rough Guide to Climate Change* by Robert Henson. Published in September 2006 by Rough Guides Ltd.
If you want to read just one book, this is it. It's balanced and comprehensive, and easy to read. You can dip into it anywhere and find interesting stuff.

*Field Notes from a Catastrophe* by Elizabeth Kolbert. Published in 2006 by Bloomsbury.
The second book to read is this one. Written by a *New Yorker* staff writer, the book is a compilation of stories that convey something that facts and figures don't. Hard to put down.

*Global Warming Survival Handbook*, by David de Rothschild. Published in 2007 by Live Earth.
Amusing, accurate, and practical. A step-by-step guide to action.

### Websites

http://www.worldchanging.com/archives/007016.html
This website will guide you to a whole host of others. See my selection below.

http://www.eia.doe.gov/ A great website for information on energy and climate, from the Energy Information Administration of the U. S. Department of Energy. Surprisingly, not politicized. Take a look particularly at the Energy Kids Page.

http://www.pewclimate.org/ A superb website for information on climate, hosted by the Pew Center on Global Climate Change. Global, pretty comprehensive, and easy to navigate.

http://cdiac.ornl.gov/ A good website for information on greenhouse gases, particularly carbon dioxide, and their effects on climate. Hosted by the Carbon Dioxide Information Analysis Center at DOE's Oak Ridge National Laboratory.

http://www.epa.gov/climatechange/emissions/ind_calculator.html Calculate your personal carbon footprint. Hosted by the U. S. Environmental Protection Agency.

http://www.climatestraegies.us/ A good website for information on state and regional initiatives on climate. Hosted by The Center for Climate Strategies.

http://www.climatechange.ca.gov/ California's climate change website.

http://www.terrytamminen.com/ Website hosted by the man who changed Arnold Schwarzenegger's mind.

http://www.sustainlane.com/us-city-rankings/ Rankings on how the 50 largest U. S. cities are doing on sustainability, along with detailed information on what they are doing.

http://presidentsclimatecommitment.org/html/commitment.php What universities should do, with many adherents among American College & University Presidents.

http://www.climatecare.org/ You can buy carbon offsets here to make yourself a zero net carbon person. Sites such as these are audited.

http://www.climateactionproject.com/ U. Colorado website on what the next US President should do.

http://dotearth.blogs.nytimes.com/ A good website for discussions of climate, hosted by the New York Times' environment reporter, Andrew Revkin.

http://www.realclimate.org/ A good discussion website, hosted by leading climate academics.