A Brief Life of Cape Cod

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The Cape is a place of great charm, where the manners and values of a prior age, now lost in the cities, still prevail. People are friendly, they are courteous, they are educated, they are civilized. The breezes are soft and caressing. The Cape is a place to treasure, and it is natural to ask how long it will remain with us.

To answer that question about the future, it is necessary to understand the past. I learned that Cape Cod is an infant, born only 15,000 years ago. It was created by glaciers that came into Massachusetts from Canada, pushing and dragging rubble and sand, picked up in Canada and in Maine, and depositing it to form Cape Cod, Nantucket, Martha's Vineyard, and Long Island.

The glaciers then withdrew as the Earth began to warm up. Over the next several thousand years, the Earth warmed considerably, the glaciers melted, and the seas rose by 400 feet. The rising seas added Provincetown to the North and Monomoy to the South, and have been eating into the Atlantic beaches at the rate of approximately 3 feet per century.

On current form, the Cape will lose Provincetown and Truro - they will become an island - in another few hundred years. Once the break happens, the future erosion of the Cape is impossible to predict. But is that the only possible future for the Cape? No, there are two other possible outcomes.

In one, global warming will cause ice caps to melt and the oceans to rise catastrophically. In another couple of hundred years, the oceans could rise by tens of feet, in which case, Cape Cod would be pretty well drowned.

In the other outcome, we will enter into another ice age. In this case, in another few thousand years, the glaciers would come back to New England, the oceans would have dropped by a few hundred feet, and Cape Cod would be many miles wider in every direction than it is today. Instead of being an ocean resort, it would be a ski paradise!

We thus have three starkly different possible futures for Cape Cod: it might vanish in 200 years or so; or it might break in half in a few hundred years, and then, who knows? Or it might first erode and then begin to expand over the next few thousand years until it stretches twenty miles or more to the edge of the continental shelf.

Is it possible to tell which of these futures will be realized?

As I wrestled with this question, it became clear that I would have to try to understand theories of climate change, and of global warming in particular. Perhaps my journey of discovery will be helpful to you in deciding what your position will be on global warming.

To begin, it is useful to map the terrain. 'Global Warming' refers not to the warming of the globe, but of the atmosphere and, perhaps, the oceans. The word 'global' refers to a worldwide effect, as dis-

tinct from one that might be concentrated, say, over Boston. Global warming, by itself, is neither good nor bad. But it can cause climate change, which may be good or bad. Climate change includes Boston's climate becoming like Atlanta's; ice caps melting and oceans rising, resulting in the drowning of lowlands; tropical storms becoming more frequent and more widespread; likewise for tropical diseases; rain and snow levels changing; and agriculture being transformed in unpredictable ways.

As a second step, it may be useful if I were to lay out a basic factual framework that will help you to navigate this maze.

1. Earth's climate has fluctuated tremendously over the last couple of billion years. There are times in the past when the average temperature of the atmosphere was 100F, as compared with 60F now. On the other hand, there have been times when the atmosphere cooled to the point where glaciers covered much of the world, and the oceans sank by as much as 400 feet or more compared to the present.

2. The atmosphere is getting warmer. In the 20th century, the average temperature of the atmosphere went up by 0.8C, or 1.5F. In contrast, the trend for the last millennium was a gradual decline, but with fluctuations.

3. The oceans are rising. The best estimate of the rate is 8 inches per century, about ten times what it was during the previous millennium.

4. There has been a great scientific effort over the last two hundred years to explain why these things are happening. What now seems to be known is that several forces are at play. Principal among these are the following.

    - The amount of solar energy that falls on the earth. This varies because the distance of the earth from the sun varies by as much as 10%, over a 100,000-year cycle (a surprise to most people).
    - Continental drift. The continents are not stationary. Some 600 million years ago, Africa was at the South Pole. What matters for climate is whether there is a landmass at the poles, so that an ice cap can form on it. Ice caps apparently do not like to form in the oceans, because the oceans can bring energy from the tropics and melt the ice.
    - The oceans. They transport energy from one part of the globe to another, through currents such as the Gulf Stream in the Atlantic and the complex currents in the Pacific that give rise to El Niño. A particularly interesting example is one theory of what led to the creation of the Antarctic ice cap. Some millions of years ago, both Australia and South America were joined to Antarctica. Eventually, they separated and drifted off, making Antarctica into an island. This allowed a circum-Antarctic ocean current to develop. This current had the effect of isolating Antarctica from other currents, such as the Gulf Stream, that would have brought energy to Antarctica from the tropics, and thus, allowed the Antarctic ice cap to develop.
    - Clouds and ice. They matter because they determine how much solar energy is reflected.
    - Finally, and most importantly in the short run, the atmosphere. The key players here are the green-house gases: water vapor, carbon dioxide, methane, and nitrous oxide. Without them, the earth would freeze. With too much of them, things can get very hot.

5. Collectively, the people of the earth put roughly 15 billion tons of carbon dioxide into the atmosphere each year: two-and-a-half tons for every child, woman, and man.

6. The amount of carbon dioxide in the atmosphere went up by roughly 25% in the 20th century, and,

unless we do something about it, will go up by 100% in the 21st century, the highest level in millions of years.

What I have said so far is well understood and uncontroversial. The difficulty starts when one start asking questions such as these:

- How much of the temperature rise of the 20th century was caused by mankind?
- How much will mankind's activities drive temperature up in the 21st century?
- How much will the oceans rise as a consequence?
- What will the economic impact be of the rise in the oceans?
- What are the costs of mitigation?

The only way to answer these questions is by building and testing models. These are massively complex computer programs that incorporate a lot of mathematics that attempts to represent how the oceans, clouds, atmosphere, and ice caps behave. There are also quite complex models that attempt to predict what the economic and ecological consequences could be of global warming. These models are pieced together by many scientists with different areas of expertise. The models are then fed both current and historical data from all over the planet, and used to 'predict the past', as it were. They are then suitably modified, and used to predict the future.

Projects of such complexity are best handled by multi-lateral agencies, and the task has fallen to the United Nations. It is interesting to review the UN's organization of these efforts before we come to the models and their predictions.

In 1988, at the request of Malta, the UN created the Intergovernmental Panel on Climate Change, or IPCC, under the World Meteorological Organization. In 1990, the IPCC presented its first report, the work of 170 scientists, saying that substantial reductions are needed in the emissions of greenhouse gases in order to stabilize their concentrations at sustainable levels. In 1992, at the Earth Summit in Rio de Janeiro, 142 nations signed the UN Framework Convention on Climate Change, committing to a voluntary stabilization of greenhouse gas emissions at 1990 levels. Among the nations was the USA, led by President George Bush. The U. S. Senate quickly ratified the treaty, and it became US law. In 1995, the IPCC issued its second report, saying that mankind's effect on climate was discernible. This was viewed as a far-reaching statement, comparable to the Surgeon General of the United States saying that smoking causes cancer. In 1997, the Kyoto Protocol to the UN Framework Convention on Climate Change was created, calling for binding - not voluntary - reductions in the emissions of greenhouse gases. In 2000, the IPCC issued its third report, an intimidating set of massive documents representing the work of 2000 scientists. That year, the world's governments failed in an effort to create rules for implementing the Kyoto protocol. In 2001, after many rounds of wheeling and dealing, most of the wealthy countries in the world agreed on what these rules should be. But not the USA, led now by a different President Bush. The aim was to have all the participants ratify the Kyoto Protocol and begin to enforce it by September 2002, the tenth anniversary of the Rio Earth Summit.

Why has President Bush made the USA the lone holdout among the rich countries? The charitable view takes his statement at face value when he says that the science underlying the Kyoto Protocol is incomplete and that, therefore, the causal analysis is faulty, and that nothing should be done until the science is good, and we understand what actions will be effective. He has also said that the required actions are unfair, because they do not call on developing countries such as China and India to do anything. Furthermore, being a conservative Republican, he has an intense dislike for

being told what to do by others, especially the UN.

The uncharitable view is that he was bought by the energy industry--coal and oil--and, being an honest man, he stayed bought.

You will have read the recently issued policy of the Bush administration, committing to voluntary reductions of carbon dioxide intensity of 18% over the next decade. The key word is intensity, which means the amount of carbon dioxide emitted per unit of Gross Domestic Product. That intensity has been falling in the USA, by 18% over the last decade, as the share of heavy manufacturing in GDP has declined, power-generating plants have become more efficient, old industrial plants have been replaced by new ones, and people have worked hard on conservation. Thus, the US policy proposed by President Bush is to stay the course. Since the US economy is expected to grow by significantly more than 18% over the next decade, the output of carbon dioxide from the US will actually increase. This is the way the situation will look in 2012: the rest of the developed world will have reduced carbon dioxide emissions by 5% to 7% below 1990 levels, while the USA will have increased emissions by 35% over 1990 levels. According to the IPCC, the sustainable level is 60% below the 1990 levels.

Let us examine the first of President Bush's assertions, that the science behind global warming is not right. There are, indeed, two sides to the scientific debate. On one side is the IPCC and its 2000 scientists, many of whom are prominent academics at leading universities around the world. On the other side, there is a very small set of skeptics, of whom the most influential are a faculty member at MIT, Professor Lindzen, and a faculty member at Aarhus University in Denmark, Professor Lomborg. Lomborg has recently issued a book, The Skeptical Environmentalist, which has received wide publicity. Supporting the environmentalists are magazines such as Scientific American and Nature. Supporting the skeptics are The Economist and The Wall Street Journal. You may begin to see the outline of an ideological line-up here, but let me focus for a moment on the scientific debate.

The IPCC's models do the following:

- They predict what the greenhouse gas emissions will be over the next 100 years in a 'do-nothing' scenario, in which, nevertheless, significant improvements are made in energy efficiency.
- With that as input, they predict that the atmospheric temperature will rise by between 3F and 11F, with a most likely value of around 5F. The range is wide, reflecting uncertainties in many aspects of the models.
- With that as input, they predict that the oceans will rise by between 4 and 36 inches.
- With a set of assumptions about what the rich countries will do to help those threatened by the rising oceans, they predict that if the ocean rises 16 inches, the number of people at risk from storm surges will rise from 23 million now to somewhere between 75 million and 200 million.
- They estimate that the cost of implementing the Kyoto protocol--the USA included--in the year 2010 will be between $75 billion and $350 Billion, or between 0.2% and 1% of global GDP. This will rise to perhaps 2% of GDP by the year 2050, as reductions become more difficult.

By the way, just to give you a feeling for what the effects might be of a 10F rise in average temperature, consider Boston, where the annual average temperature is about 50F. We have about 13 days a year when the temperature rises above 90F. If the mean temperature rose to 60F, this number would rise to 32 days. Our summers would be hot!

What is the skeptic's position on all of this?

- The science is wrong. It does not take into account various feedback processes that stabilize the temperature of the atmosphere. I will return to feedback processes later.
- Significantly better technologies for reducing the use of fossil fuels will develop over time, reducing carbon dioxide emissions without a crash program such as the Kyoto Protocol calls for.
- The likely increase in temperature is more like 1F to 2F. The IPCC developed its range using faulty scenarios of the future. Therefore, sea level rise will be minimal.
- The costs of implementing the Kyoto Protocol are many times the costs of dealing with the consequences of global warming.

There are, of course rebuttals to these charges from the IPCC and its supporters. Reviews of Lomborg's book, The Skeptical Environmentalist, in Scientific American and by The Union of Concerned Scientists have the following to say:

- He makes selective use of data to justify his conclusions.
- His work is not peer-reviewed, while that of the IPCC is.
- He misquotes people and their work because of sloppy scholarship.
- Where it suits his conclusions, he makes wildly optimistic assumptions about the future, especially as regards the development of technology.
- He misrepresents what the UN Framework Convention on Climate Change and the Kyoto Protocol are all about and what they can be expected to accomplish in the future.

As you might expect, there are rebuttals to the rebuttals. The fur has started flying, and we are now in the phase of ad hominem attacks. The scene reminds one of what happened when the book, The Bell Curve was published a few years ago.

What about President Bush’s second concern, that the Kyoto Protocol is not fair because it does not expect China and India (among others) to do anything?

It is not an obviously unreasonable position, until one examines a few basic facts:

- The USA puts 13.7 tons of carbon dioxide per person into the sky every year. China puts out 2.6 tons per person, India, 0.7.
- At Purchasing Power Parity, the GDP per capita is as follows: USA, $30,600; China, $4,100; India, $2,100. The argument from India and China is, 'You, the West, filled up the sky with carbon as you were getting rich. Rights to put more carbon out there should belong disproportionately to the poor countries so they can catch up. In any case, you can afford the necessary capital investments, we cannot.'
- The USA puts out one-third of the world’s carbon dioxide, and a third of that comes from vehicles. From 1975 to 1988, the fuel economy of U. S. passenger cars and trucks improved 73%. From 1988 to 2001, it declined 8%.

The supporters of the Kyoto Protocol make a further argument, as follows. ‘We will need to act on this (and on other global environmental issues) sooner or later. It will take multilateral cooperation to do what is necessary. It takes years to build the institutions that enable such action. We have made the investment and built a global coalition, and we should not undermine it. Even if the Kyoto Protocol is flawed, we should go ahead, because we can fix it in the future, including bringing China and India under

its sway.'

The fact of the matter is, the rest of the world is going ahead without the USA.

What should an intelligent layman make of all of this? I will suggest several levels at which we can examine the issues.

1. The **Climate science** level. There are two large scientific issues we should be aware of.

One is feedback loops. A feedback loop occurs when a perturbation of a system creates a response that either makes the perturbation die down (this is called a negative feedback loop) or makes the perturbation grow (this is called a positive feedback loop). Suppose that for some reason, say a solar energy burst, the atmosphere warms a little bit. This could cause more water to evaporate than normally. Since water vapor is a greenhouse gas, this would cause further warming of the atmosphere, and a continuing chain reaction. This is a positive feedback loop. On the other hand, it is possible that the increased water vapor will cause more clouds to form of the kind that reflect solar energy, thus cooling the atmosphere. This is a negative feedback loop. These feedback loops make all the difference to what happens as we pump more greenhouse gases into the sky, and they are not yet well understood.

The other is nonlinearities. This is a scientist's way of saying that what you learn about a system by applying small perturbations to it cannot always be extrapolated to predict how the system will behave when you apply large perturbations to it.

There is a familiar nonlinear behavior that occurs in the ponds around us in springtime. As the temperature warms, the ice slowly melts (if there is any!). Once all the ice has melted, the cold water on top sinks to the bottom, and the warm water from the bottom, full of the gases from decomposing vegetation, rises to the top and creates a stink. This is the spring inversion, unpredictable if you observe only what happens while the ice is getting thinner but is still there.

There is increasing evidence from research into past climate changes in Greenland and Antarctica that our climate is a nonlinear system and, therefore, that its behavior is unpredictable when the perturbations we apply to it grow large enough. For example, warming air can cause the Greenland ice cap to start melting. That could cause a major change to the Gulf Stream, causing it to sink, stop, and turn away from Europe. That could cause an ice age to start in Europe. In other words, there is the possibility that our climate will change suddenly when we push the system far enough.

2. The **impact** level. Let us assume that global temperatures are going to rise significantly: 5F to 10F. What will the physical and economic impacts be? Again, the nonlinearities come into play. If Bangladesh is submerged, the effects on India and other neighboring countries will be impossible to predict; there will be 100 million refugees, playing havoc with economic, political, and social systems. None of this is modeled by anybody. In the skeptical literature, there is a sanguine assumption that the rich countries will help the residents of Bangladesh. Like they are doing now?

It is worth remarking that many of the worst effects of global warming – if they happen – will be felt most by the poor countries. The residents of the island of Tuvalu in the South Pacific have already asked to emigrate to New Zealand as their home is getting submerged.

3. The **policy** level. What should we do? First, let us consider what we could do to reduce greenhouse gas emissions from the USA.

We could hugely improve the fuel economy of our vehicles. We could double it. We could reduce the waste of energy-intensive products such as paper, plastics, metals, glass, and rubber. We could stop air-conditioning the bejeezuz out of our buildings. We could stop leaving lights on everywhere, all the time. We could make our power-generating plants more efficient. We could energize research into alternative energy sources such as wind and solar. There are many practical things we could do, and it is not at all clear that they would lead to a reduction in our standard of living, although they might lead to a reduction in our level of consumption. In fact, the creative challenge of achieving a reduction in consumption without a concomitant reduction in living standards would, I feel, tickle the fancy of American entrepreneurs, and bring forth a surge of creativity and innovation.

Given that a wide range of solutions is available, there are some major policy issues to discuss. The one that is at the center of the debate is, 'Do we do something now to reduce emissions, as the Kyoto Protocol calls for, or do we wait until the effects of global warming show up, and then deal with them?' This is posed as an economic problem, but it has a vast human dimension as well, as I noted earlier. Equally interesting, most of the discussion of the two options, Do it now and Wait, is based on the notion that the outcomes will not be catastrophic. But, as we have seen in our discussion of nonlinearity, we cannot really be sure of that. I find it fascinating that there is nowhere in the literature on global warming a discussion of risk analysis and risk management. In designing a nuclear power plant, for example, or a Liquefied Natural Gas Storage facility, or the transport by train of hazardous chemicals, one invariably calculates a risk profile, which describes the likelihood that in a given year, an accident could happen that would exceed a given level of severity. As in, the probability of an accident with one fatality is 0.1, or one every ten years; the probability of an accident with ten fatalities is 0.005, or one every 200 years; the probability of an accident with 10,000 fatalities is one in a million, or one every million years. With this in hand, one can ask, which parts of this risk profile do we want to mitigate? The answer depends on the risk aversion of individuals which, in turn, is driven by their personal experience. But most people want to mitigate the catastrophic accidents that have a very low probability first, rather than the mundane accidents that are more likely to happen.

A second is, who pays? The developing policy is called cap-and-trade: put a cap on the total amount of emissions allowed, then ration this out among various polluters, and then allow them to trade the right to pollute. Peter Barnes has developed a variation on this theme, in a book titled, Who Owns the Sky?, that I found impossible to put down. He believes in cap-and-trade, but believes that the revenue from selling the initial permits should go not to the governments of the world, for they will squander the money, but to a Sky Trust owned by all the people, to whom the trust will pay dividends.

4. The **political** level. But before we do anything, we have to get our people and our government on board. Why is the USA the lone holdout among the wealthy nations? A cynical argument, presented by unilateralist thinkers, is that the reason the others have signed on is because they know that the Kyoto Protocol places the USA at a disadvantage, for the very reason that makes us the worst polluter: we are more heavily dependent on Carbon than most other countries. In this view, the Kyoto Protocol is a competitive weapon aimed at the USA. A different point of view says that the Bush administration's position is not that of the US people. A small margin of difference in Florida would have put Al Gore in the presidency, and the US would be leading the pack rather than being a holdout. Perhaps our leaders should be shaped by public opinion rather than by corporate interests. (I should like to ask Ralph Nader whether he still believes that

there is no difference between Al Gore and George Bush.)

Before I end, I should re-visit the issue I started with, What will happen to Cape Cod? In my lifetime, and that of my kids, it will be a great place. In the lifetime of my grandchildren, it may begin to feel a bit like Bangladesh; severely threatened by the sea. If it survives the next few hundred years, over the long term, it will grow again as another ice age comes upon us. However, it is possible that in the few thousand years before that happens, we will have really learned how to control Earth's climate.