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Excerpt
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Introduction

Our planet's atmosphere has been the dumping ground for all sorts of gases for as long as human history. When those using it as a dump were few, its capacity was large, and there was no problem. There are now more than six billion of us, and we have now reached the point where human activities have overloaded the atmospheric dump and the climate has begun to change. Our collective decision is what to do about it. Do we do nothing and leave the problem to our grandchildren who will suffer the consequences of our inaction, or do we begin to deal with it? It is much easier to do things now rather than later, but it will cost us something.

To me the answer is clear: we should start to deal with it. This book describes the problem and the alternatives that exist to make a start on limiting the damage. This is not an academic book, even though I am a physics professor. It is written for the general public. True, it does contain some scientific details for those interested in them, but they are in technical notes at the ends of chapters; you can skip them if you like.

The title of the book, *Beyond Smoke and Mirrors*, can be taken two ways. One is what future energy sources might replace coal and today's versions of solar power. The other is the real story behind the collection of sensible, senseless, and self-serving arguments that are being pushed by scientists, environmentalists, corporate executives, politicians, and world leaders. I mean the title both ways, and the book looks at the technical and policy options and what is really hiding behind the obscuring rhetorical smoke and mirrors. There are many ways to proceed and, unfortunately, there are more senseless arguments than sensible ones, and still more that are self-serving.

I divide those doing the most talking into the anti-greens, sometimes called the deniers; the greens; and the ultra-greens, sometimes called the exaggerators. As you might guess, I consider the greens to be the good guys. I classify myself among them.

There is a rapidly declining number of those denying that human activities are increasing the global temperature, but the species is not yet extinct and perhaps will never be. These are the anti-greens. Even they agree that the greenhouse effect is real, and that greenhouse gases in the atmosphere are the main element that controls the average temperature of the planet. Why they do not agree that changing the greenhouse gas concentration changes the temperature is beyond me.

The ultra-greens have declared an immediate planet-wide emergency where money is no object and where only solutions that match their programs are acceptable. They seem to have forgotten that the object is to cut greenhouse gas emission, not just to run the world on windmills and solar cells, which alone are insufficient to deal with the problem. By rejecting options that do not match their prejudices they make the problem more difficult and more expensive to address.

According to the anthropologists our first humanoid ancestor appeared about four million years ago. During the very long time from then until now the world has been both hotter and colder; the Arctic oceans have been ice-free before, and at other times ice has covered large parts of the world. What makes climate change a major problem today is the speed of the changes combined with the fact that there will be about nine billion of us by the middle of this century. We were able to adapt to change in the past as the climate moved back and forth from hot to cold, but there were tens of thousands of years to each swing compared with only hundreds of years for the earth to heat up this time. The slow pace of change gave the relatively small population back then time to move, and that is just what it did during the many temperature swings of the past, including the ice ages. The population now is too big to move *en masse*, so we had better do our best to limit the damage that we are causing.

Though there is now world agreement that there is a problem, there is no agreement on how to deal with it or even on what we should be trying to achieve. The European Union (EU), a collection of the richer countries, has a big program aimed at cutting greenhouse gas emissions. The richest country, the United States, has only recently acknowledged that human activity is the main cause of global warming, but has done very little so far to do anything about it. Russia thinks warming is good for it and has done nothing. The developing countries have said it is the rich countries that caused the problem so they should fix it, and poor countries should not be asked to slow their economic development. However, they are growing so fast that according to projections, the developing world will add as much greenhouse gas to the atmosphere in this century as the industrialized nations will have contributed in the 300 years from 1800 to 2100. We all live on the same globe, the actions of one affect all, and this problem cannot be solved without all working together.

There are three parts to this book. Part I is on climate change itself and explains what we know, what we don't know, what the uncertainties are in predictions of the future, and how urgent is the need for action. The section discusses what can be learned from the past, how the future is predicted, the many models that are used, and what they predict. The models are not yet good enough to converge on a single number for the expected temperature increase because the science is not that perfect. Uncertainty is used by some as an excuse for inaction, but it should not be, because by continuing "business as usual" the predictions for the end of the century range from terrible at the high end of the predicted increase (about 12 °F or 6 °C) to merely very bad at the low end (about 4 °F or 2 °C).

Part II begins with what we need to do in controlling greenhouse gas emissions to limit the ultimate temperature rise. It is too late in this century to return the atmosphere to what it was like before the start of the industrial age. I include my estimate of the allowable upper limit on greenhouse gases, the amount beyond which the risk of sudden climate instability greatly increases.

Next is a review of what the economists say about the best way financially of controlling emissions. There are no economists that I know who are saying do nothing now. The argument is over how fast to go. The natural removal time for the major greenhouse gases is measured in centuries, so if we wait until things get bad we will have to live with the consequences for a long time, no matter how hard we try to fix things. The issue is the problem that we will leave to our grandchildren.

Part II goes on to look at the sources of anthropogenic (human-caused) greenhouse gas emissions and what we might do about them. Two broad categories dominate: the energy we use to power our civilization; and agriculture and land use changes that have accompanied the increase in world population. I focus on energy use, which is responsible for 70% of greenhouse gas emissions. Agriculture and land-use changes contribute the other 30% of emissions, but their coupling to food production and the economies of the poor countries are not well understood. I leave this to others, except for biofuels which are part of the energy system.

I review what kinds of energy we use in the world economy and what each contributes to greenhouse gas emissions. The conclusion is the obvious one: fossil fuels are the culprit, and the only way to reduce their use while economic growth continues is by some combination of increased efficiency and a switch to sources of energy that do not emit greenhouse gases either by their nature or by our technology. In truth, we can continue our old ways of using fossil fuels for about another 50 years if we don't care about our grandchildren. Even with business as usual there are unlikely to be supply problems until the second half of the century, though there may be price problems.

There is no single technology that will solve all of our problems. We will have to proceed on many fronts simultaneously, starting with what we have in our technology arsenal now. All the options are reviewed, including capturing and storing away emissions from fossil fuels; efficiency; nuclear power; and all of those energy systems called the Renewables. Some are ready for the big time now, others need further development. All revolutionary technologies start in the laboratory, and we are also not investing enough in the development of the technologies of the future.

Energy supply is the area where one finds most of the senseless and self-serving calls to action. For example, it is not within the bounds of reality to eliminate all the fossil fuels from our electricity supply in the next 10 years. This one is senseless. Further, increasing the amount of corn-based ethanol in our gasoline does almost nothing to decrease emissions when emissions in ethanol production are included. This one is self-serving.

Part II concludes with an admittedly opinionated summary of the promise and the problems of various technologies (there are lots of both), as well as my personal scorecard showing winners, losers, and options for which the verdict is not yet in.

Part III concerns policy options. There are two dimensions that need discussion: what to do on a national or regional scale, and what to do on a world scale. I believe the best policies in market economies are those that allow the private sector to make the most profits by doing the right things rather than the wrong things. There is always a huge amount of brain power devoted to making money and it can and should be tapped. I call this "tilting the playing field" so that things move in a desired direction. Of course, regulations are required too. The US auto industry, for example, has resisted efficiency improvements until regulations required them to act. I know this area well, having spent six years in the 1980s on the General Motors Science and Technology Advisory Board. I think the industry has finally understood what is needed and I hope it survives the current economic downturn.

The global problem is harder to deal with. It is particularly tough because while emissions have to be tackled on a global basis, the world has countries that range from rich to poor. Most emissions are coupled to energy use, and energy use is coupled to economic development: the poor want to get rich, the rich want to get richer, and the benefits coming from actions now are going to be seen only in the future. The very poorest use so little energy that even as they begin to climb the development ladder and use more, they will still make only a tiny contribution to emissions, and the world program can leave them alone until they have climbed several steps.

But the developing countries in the rapid-growth phase – China and India, for instance – cannot be entirely left out of the action agenda as they were in the Kyoto Protocol of 1997. China has already passed the United States as the largest emitter of greenhouse gases, and the developing nations collectively are expected to surpass the industrialized ones in 15 to 20 years. There can be no effective program for the long term without all nations coming under a greenhouse control umbrella once they reach some emission threshold. It will no longer do for the developing nations to ask the industrialized nations alone to fix the problem, because they can't. In business-as-usual projections (continuing with the same mix of fuels as the world economy grows), the developing nations as a whole will emit nearly as much greenhouse gas from 2000 to 2100 as the industrialized nations will have done in the three centuries between 1800 and 2100. There is no solution to the global warming problem without the participation of the developing world. Policies have to reflect reality, and the richer counties will have to take the lead. There is no excuse for the United States to stand aside as it has done since 1997. The first Kyoto Protocol expires in 2012, and the new one now being worked on had better include some graduated way to include all but the very poorest nations.

In 1968 Garrett Hardin, then a professor of ecology at the University of California, Santa Barbara, published an enormously influential article, "The Tragedy of the Commons" [1]. The metaphor of the title referred to how overgrazing occurred on common pasture land in medieval England. It did no good for only one person to limit his sheep grazing because his contribution was so small. Only if all worked together to limit grazing could the common pasture be preserved. Hardin's "Commons" today is the Earth's atmosphere.

We can preserve our atmospheric commons. What we know, how we know it, what the uncertainties are, and what we should be doing are the subjects of this book.

Part I Climate

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Greenhouse Earth

If this were a science fiction story, I would tell of the underground cities on Mars that get their heat from the still-warm core of the planet. I would tell of the underground cities on Venus too, and their struggle to insulate themselves from the killing heat of the surface. In the story I would sympathize with the Martians because through no fault of their own, they lived on a planet that was too small to keep its atmosphere and with it the greenhouse effect that kept it warm enough for liquid water to flow. As for the Venusians, I would write with sadness of their blindness to the dangers of global warming and the runaway greenhouse effect that forced them underground.

There is no question about the reality of the greenhouse effect, even from those who still deny that human activities have anything to do with global warming. This chapter and the next three tell the story of how we can be so sure there is an effect, why almost everyone has finally concluded that our planet is getting warmer and that we are primarily responsible for it, and what the future holds if we continue on our present course.

To understand the issues, we can call on information about other planets in our Solar System as well as on what we can measure on our own. We and our nearest neighbors, Venus, closer to the Sun, and Mars, further out, are very much alike in composition, but very different in surface temperatures because of the greenhouse effect. Venus is too hot to support life, and Mars is too cold. Yet all were formed about 4.5 billion years ago, and all are made from the same stuff. The difference lies in their greenhouse effects: too much for Venus, too little for Mars, and just right for us.

The climate greenhouse effect is different in detail, but not in principle, from that which allows tomatoes to be grown in winter under a transparent roof. In the plant greenhouse, the transparent double-paned roof lets in sunlight and traps the heat that would otherwise escape. In the atmospheric greenhouse, greenhouse gases trap heat that would otherwise be radiated out into space. This is not complicated in principle, though it is complicated to calculate the surface temperature in the real world with precision (something that will be discussed later). Human activity that changes the greenhouse effect and traps more heat drives the concern about global warming. Even among the anti-green lobby there is no argument about the reality of the greenhouse effect, only about how human activity is changing it.

Our planet's average temperature is determined by a balance that is struck between the energy coming from the Sun and the energy radiated back out into space. What comes in depends on the temperature of the Sun, and what goes out depends on the Earth's surface temperature and on what things in the atmosphere block parts of the radiation. Think of it this way – what comes in from the Sun is almost all in the form of ordinary visible light. What goes out is mostly in the form of infrared radiation which we can't see but can certainly feel. If you have ever stood in front of an old-fashioned hot stove, you can feel the radiation coming from it though you cannot see it. This radiation is what is partially blocked by greenhouse gases and the temperature has to go up to let enough heat out through that part of the radiation window that remains open to balance what comes in from the Sun.

Carbon dioxide (CO_2) is the gas most discussed. It is the main man-made (anthropogenic) contributor, but it is not the only one (more about the others in Chapter 3). What is a surprise to most people is that none of the man-made gases contributes as much to keeping our planet warm as ordinary water vapor. (See Technical Note 2.1 if you are interested in more of the science of the greenhouse effect.)

Although the Earth has a core of molten iron, in our planetary greenhouse over 99.99% of the energy reaching the surface of our planet is sunlight. Rock is a very good insulator and a relatively small amount of heat from the interior reaches the surface. Glowing rivers of molten rock do come from volcanoes, but they cover a tiny fraction of the surface of our world and so contribute very little to the surface heat. What comes in is sunlight; what leaves is radiated heat called infrared radiation. We can ignore all the rest.

The total power incoming from the Sun dwarfs everything made by humans. The energy that comes in on the sunlit side of the Earth in one hour equals the total of all forms of energy used by mankind in one year. Sun power totals about 100 million gigawatts (1 GW equals 1 billion watts), equivalent to the energy output of 100 million large electricity generating plants. All the electrical power used in the

United States by everyone for everything totals only about 500 GW at the daytime peak in usage on a hot summer day.

It is simple to calculate roughly our planet's surface temperature if there were no greenhouse effect at all, though it is complicated to calculate what happens in the real world. With no greenhouse effect, none of the energy radiated would be blocked and only the surface temperature would determine the energy outflow needed to balance the energy from the Sun. If the system became out of balance, the temperature would change to bring it back. Too much heat leaving would cool the surface; too little would allow it to heat.

Assuming the entire surface of the Earth is the same, ignoring the difference between the day and night sides, ignoring the cold poles compared with the rest and assuming that nothing blocks the outgoing heat, the average temperature required to radiate enough to balance the incoming solar energy is –4 °F (–20 °C). A fancier calculation taking into account the things ignored in this simple calculation, but continuing with the assumption that nothing in the atmosphere blocks any of the radiated heat, gives a number only a few degrees higher.

The average temperature of the Earth is actually +60 °F (+15 °C). The difference of about 65 °F is entirely caused by the greenhouse effect, which traps part of the energy that would be radiated from the surface in its absence. The surface temperature has to increase so that the part of the radiated energy that can get through will carry enough energy to keep the system in balance. Without the greenhouse effect the Earth would be a frozen ball of slush. With it we have, on average, a comfortable world, capable of supporting diverse life forms.

Over the history of the Earth, the average temperature has varied considerably as the amount of greenhouse gases in the atmosphere has changed and as the output of the Sun has changed. Today, the concern about global warming focuses on human activity that causes an increase in some greenhouse gases. The logic is simple: greenhouse gases are known to increase the temperature, and if we add more of what increases the temperature, we will increase the temperature more. How much more is the question that thousands of scientists are trying to answer.

Looking again at our two nearest neighbors in the Solar System, Venus and Mars, tells what happens when the greenhouse effect goes very wrong. I began this chapter with what a science fiction story might be like. Here is the real story. Both planets have been extensively studied from Earth by telescopes and radar, observed by orbiting