ALL ABOUT CLEAN ENERGY

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*This book is dedicated to teenagers around the world,
for better or worse, the future stewards of planet Earth.*

FOREWORD

Let us begin with the question: “What is Clean Energy?”

The answer that comes up, after examining the many sides of the issue, is: “Doing the best possible to lower greenhouse gas emissions, while considering the following:

[1] The remarkable ability of humans to create, innovate, invent, manufacture, build, and to travel on the ground, on the seas, in the air, and even into space.

[2] Rapidly growing energy needs to support a chosen way of life.

[3] A strong desire by the peoples of underprivileged nations to catch up with the more advanced ones.

[4] An underlying mandate, a responsibility, to be stewards of Planet Earth and all its resources.

[5] A steady drumbeat of warnings by scientists that all is not well with Planet Earth - that human activities can alter it for the worse - forever.

A few definitions are needed, as the terms clean energy, renewable energy, and alternative energy tend to be used interchangeably.

Alternative energy means energy that doesn’t originate from the combustion of fossil fuels - coal, peat, natural gas, and oil. Alternative energy doesn’t necessarily mean clean energy. In some cases it can be worse for the environment.

Renewable energy means energy that is produced directly or indirectly from the source that originally created all the sequestered fossil fuels on the planet - the sun. This includes living plants, solar electric and solar thermal, wind, hydro, tides and currents. Also considered renewable, because of their near infinite supply, are geothermal and nuclear sources.

Clean energy means energy that ideally causes zero emission of greenhouse gases to the atmosphere, with the upper limit being carbon neutral. Carbon neutral requires that no more greenhouse gas is released to the environment than was originally taken from it to produce the fuel.

Consumption of fossil fuels is a reversal of the original sequestering process. The rapidity with which change in the environment is occurring, unless major efforts are adopted to curtail consumption of fossil fuels, is underscored by news that in 2007 carbon dioxide content in the atmosphere rose by 0.6%, an unprecedented rate, amounting to eighteen billion tons. Consumption of fossil fuels can’t be stopped. Fossil fuels are needed for vast segments of industry, such as feedstock for chemical plants, processing iron ore into steel, making cement, manufacturing plastics and glass, and a limited powering of large moving vehicles like trucks, airplanes, buses, trains and ships. As such, they are resources that should serve humanity’s needs for thousands of years, rather than being rapidly consumed in a century or two to produce energy.

It comes down to using fossil fuels more efficiently and sparingly, and finding other ways to produce energy. In the coming years, if wisdom prevails, humans will recognize the imperatives that mandate conversion to solar, geothermal and nuclear energy on a much broader scale than now exists, and to use energy more efficiently. If nothing else, good stewardship of planet Earth demands it.

CHAPTER 1

Why Clean Energy?

1-1 How we got here

Inventions during the eighteenth and nineteenth centuries changed the course of history. Until then, humanity consisted largely of agrarians, hunter/gatherers, artisans and warriors. Mechanical power for operating an assortment of mills was mostly limited to water wheels, which meant that the first industrial ventures had to be located beside rivers. At the turn of the eighteenth century world population was less than a billion people.

The big change began with the invention of the steam engine. Interest in steam power actually goes far back in history. In 130 B.C. Hero of Alexandria described the aeolipile, a rotating sphere that received its driving force from steam that was ejected from tangential tubes. It was not until the eighteenth century that a few inventors attempted to create useful steam powered devices, mainly for pumping water. Piston and cylinder designs appeared, conceived by such inventors as Edward Somerset, Marquis of Somerset, Thomas Savery, and Denis Papin. The main requirement during those years was to pump water out of mines.

A major step forward was achieved by Thomas Newcomen of England in 1705, when he created a single stroke piston that was powered by steam from an external boiler. It was still a slow, awkward device, wasteful of energy, but it served the mining interests, powering water pumps, for the next sixty years. Then Scottish engineer James Watt made a huge step forward with his invention of a steam engine with an external condenser. Other inventors rapidly moved into the scene. By the early 1800's steam engines were powering factories and ships. Steam powered locomotives were on the drawing boards. Emerging ability to machine and forge metals at high rates introduced the Industrial Revolution.

Everything that occurred from then until the present, supplying the needs of growing populations, required more and more energy. To everyone's satisfaction, forests, coal, gas, and oil deposits were plentiful and easily transported to consumption points. Smoke stacks and air pollution were a nasty inconvenience, but it was not until the second half of the twentieth century that what was occurring came under scientific scrutiny. Scientists made public the alarming news that the planet is warming, due to a rise in carbon dioxide concentration in the atmosphere.

On a macro scale, consumption of fossil fuels reverses what took place on planet Earth eons ago. In those times, plant life proliferated beyond anything imaginable. The end result was assimilation of the carbon dioxide then present in the atmosphere into plant life. Earth crust movement buried most of it, where it turned it into coal, gas and oil. For a long time, the burning of fossil fuels had little effect. The oceans and plant life had enough capacity to absorb the carbon dioxide that was generated. However, this changed as consumption of fossil fuels zoomed upward, a result of population growth that now exceeds six billion people.

Figure 1-1 illustrates the rapid rise of fossil fuel consumption. It shows no sign of levelling off. Rather, it will continue its steep rise in accordance with population growth - or until deposits run out. Figure 1-2 shows coal consumption projections out to the year 2030.

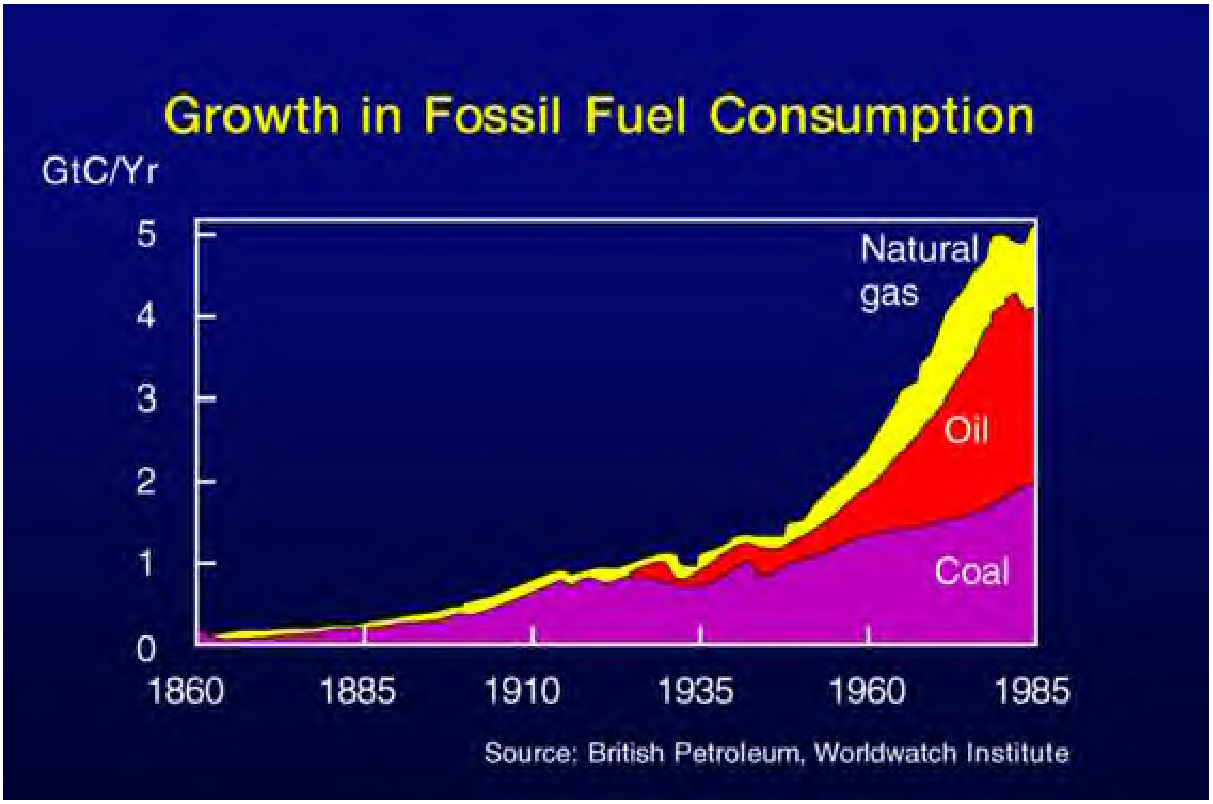
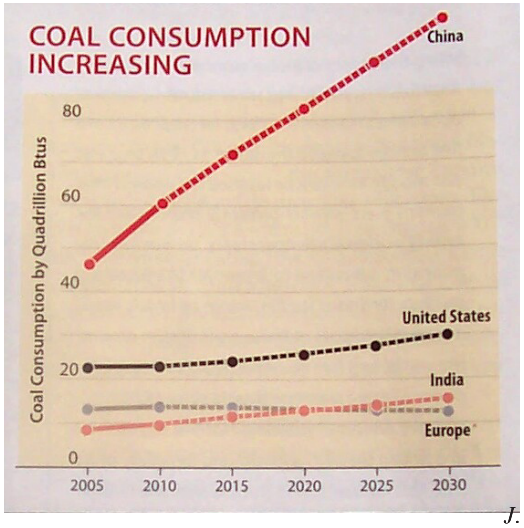


Figure 1-1 Population growth has dramatically accelerated demand for fossil fuels.



J. Hansen/Sierra Club

Figure 1-2, Projections show no slowing of demand for fossil fuels.

Scientists have made a convincing connection between observed rise in global temperature and the burning of fossil fuels. Increases in concentration of carbon dioxide in the atmosphere create what is called the greenhouse effect. Earth radiation into space is diminished until the temperature rises to new equilibrium with incoming solar radiation. A small temperature rise, only one or two degrees Centigrade can result in profound changes in the environment. Glaciers retreat, coral reefs die off, Arctic ice sheets melt away, and the ocean level rises.

Measurements of the rise in carbon dioxide concentration in the atmosphere were first undertaken in 1958 at Mauna Loa Observatory by C. David Keeling of the Scripps Institution of Oceanography in La Jolla, Ca. They continued every year until 1974 when the National Oceanic and Atmospheric Administration (NOAA) started its own measurements.

Figure 1-3 shows an unrelenting and slightly accelerating annual rise in concentration to the present. The Scripps data are in blue and the NOAA data are in red. The saw-tooth nature of the data, through which a mean is drawn in black, represent seasonal changes caused by plant growth and die-off.

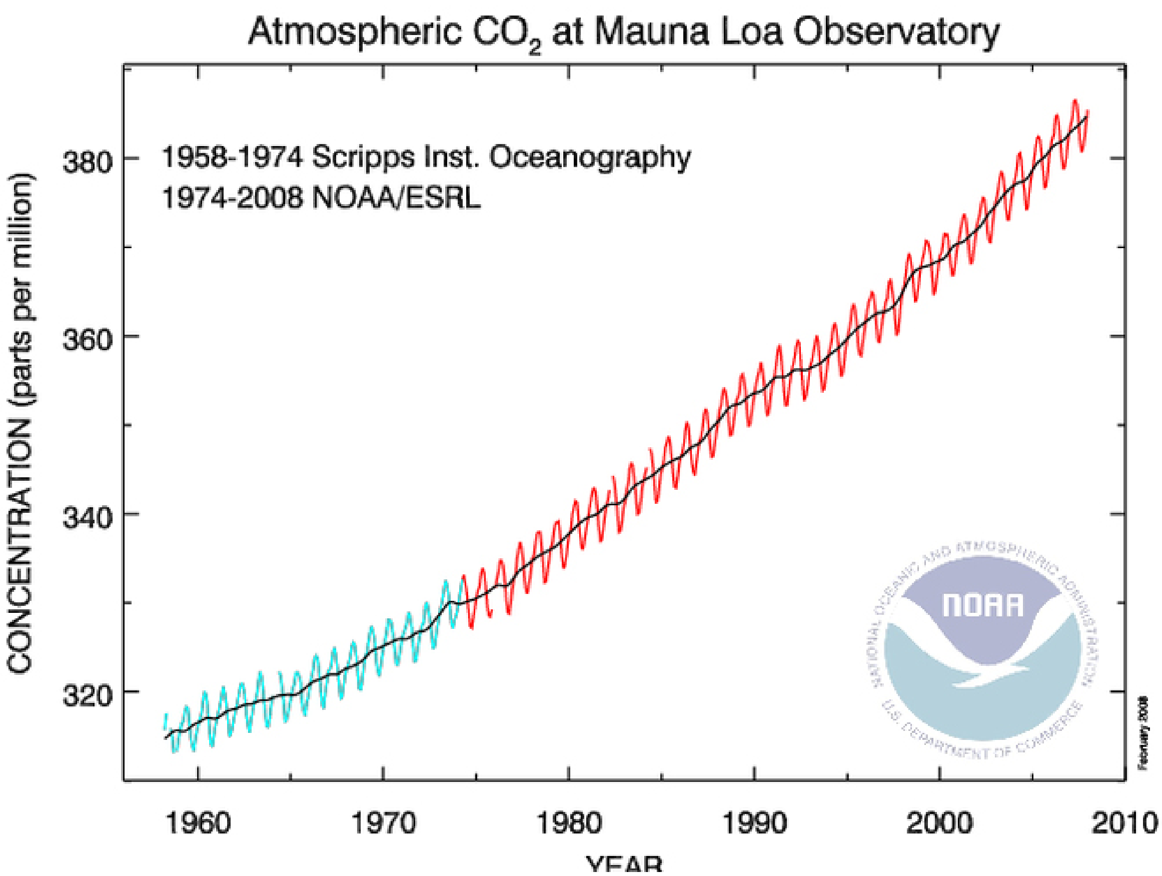


Figure 1-3 The longest record of direct measurements of carbon dioxide in Earth's atmosphere.

Carbon dioxide levels in the atmosphere have risen to the highest levels in 650,000 years, as determined by analyses of ice cores drawn from deep in the Antarctic ice (Figure 1-4). Present levels, around 380 parts per million, could reach 450-500 parts per million by 2050 if fossil fuel consumption continues along trends shown in Figure 1-1, according to the Intergovernmental Panel on Climate Change (IPCC).

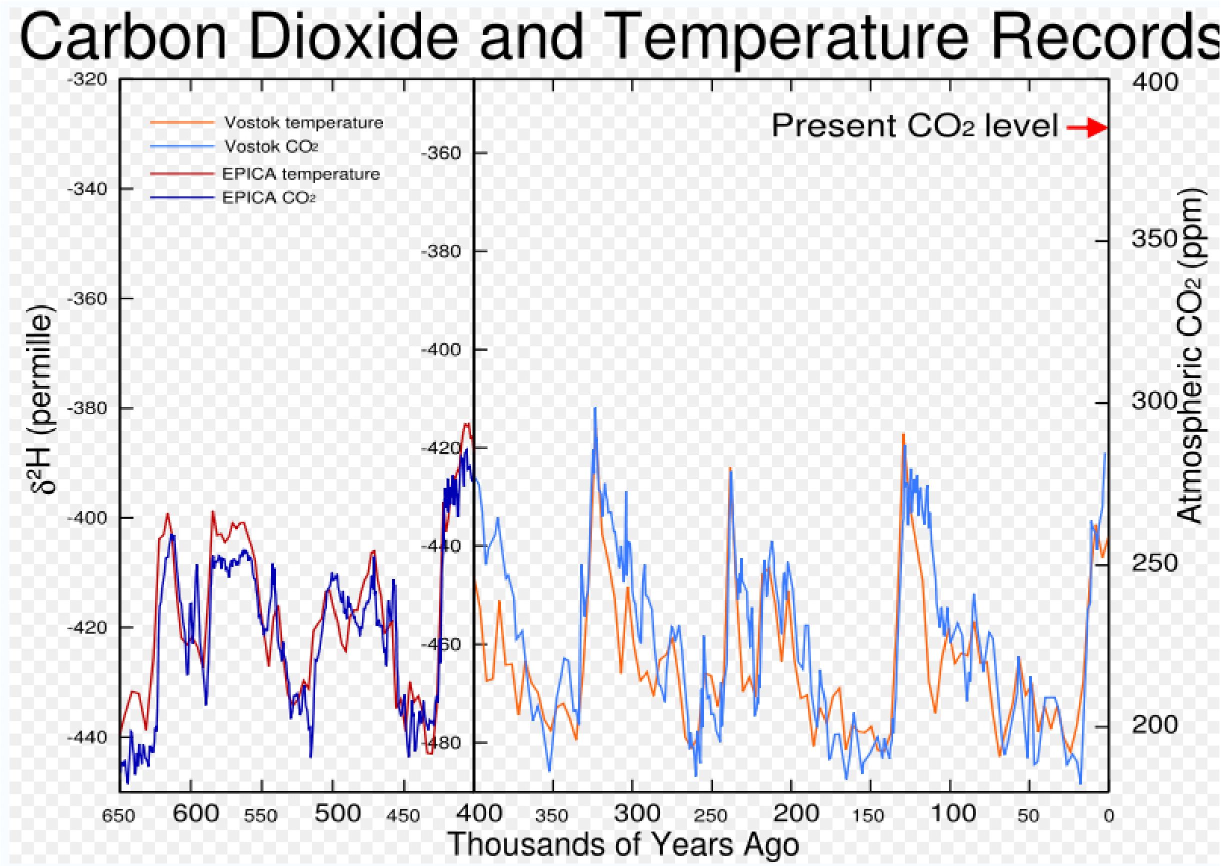


Figure 1-4 Records of carbon dioxide concentration over past 600,000 years.

The left axis plots the delta deuterium levels on two different scales that represent data from both Vostok and Antarctic samplings of ice cores. Delta deuterium is what is called a proxy temperature, which is a measurement from which a temperature can be calculated or inferred. Tree rings are an example of how proxy temperatures are useful. Varying thicknesses of tree rings can, among other influences, be used to estimate temperatures over certain time periods. In this case, levels of deuterium, which constitutes a minuscule percentage of ordinary water, can be correlated with the ocean temperatures and vapor phases that ultimately resulted in varying quantities of deuterium in the core ice.

Summing up, scientific opinion based on hard data exhumed from strata dating hunderds of thousands of years back seems to confirm that something out of the ordinary is occurring, signalled by a high carbon dioxide concentration in the atmosphere during a period when it shouldn't be present. But it's fair to present other views. What happens on Planet Earth is admittedly very complicated.

1-2 Is there really a problem?

There are doubters, though few now disbelieve that carbon dioxide is a greenhouse gas and that global warming could result from high concentrations in the atmosphere. Some people believe that global warming may be a good thing. They argue that Earth is heading into the next ice age and higher concentrations of carbon dioxide in the atmosphere could mitigate the problems. This argument falls flat upon realizing the current rate of temperature rise is out of phase with something that is tens of thousands of years in the future They argue also that Earth is far too large and complicated for humans to possibly have a measurable effect on the climate. It is true that many factors enter into how the environment behaves.

Not fully understood are the combined effects of the various cycles which affect the climate as Earth spins its way in the solar system. There are long duration cycles and there are cycles within cycles. There are the influences of tectonic movement, changes in the way ocean currents flow, volcanic action and ice field dynamics.

A principal explanation of long term climate change rests on what is called the Malinkovitch theory. Milutin Malinkovitch, a Serbian scientist, published a paper in 1938 that proved mathematically the previous work of J.A. Adhemar and James Kroll, explaining how cyclic variations in Earth's orbit around the sun cause climate change.

The Malinkovitch theory explains that solar energy reaching Earth varies with the periodic change in the eccentricity of Earth's orbit around the sun, variation of the tilt of Earth's orbit with respect to the orbital plane, called obliquity, and change in the orientation and wobbling of Earth's rotational axis, called precession.

Eccentricity describes the shape of Earth's orbit around the sun. It varies from almost perfectly circular to slightly elliptical and back, over a period of approximately 100 thousand years. The amount of solar energy reaching Earth is least when the orbit is eccentric. That appears to correspond with the recorded 100,000 year intervals of glaciation.

Obliquity, or tilt of Earth's axis of rotation, varies between 22.1 degrees and 24.5 degrees, in a cycle that approximates 40,000 years. More tilt corresponds to warmer summers and colder winters.

Precession is change in the orientation of Earth's rotational axis on a cycle that varies between 19,000 years and 23,000 years. Its effect is to increase the seasonal contrast in one hemisphere with a concurrent diminishing of the contrast in the other hemisphere.

Malinkovitch took on the formidable challenge of formulating a mathematical model that correlated the orbital variations with differences in solar energy reaching Earth latitudes, and resulting surface temperatures over a 600,000 year period. The Malinkovitch theory has shortcomings , but those are explained as due to influences of concurrent events like carbon dioxide emission and ice sheet dynamics. Figure 1-5 summarizes the Malinkovitch analyses over a million year span.

Figure 1-5 shows ice ages occurring at intervals of about every 100,000 years. The high levels of carbon dioxide during the cold periods are due to natural processes like volcanoes and Earth movements, and reflect an inability to absorb it due to low temperatures.

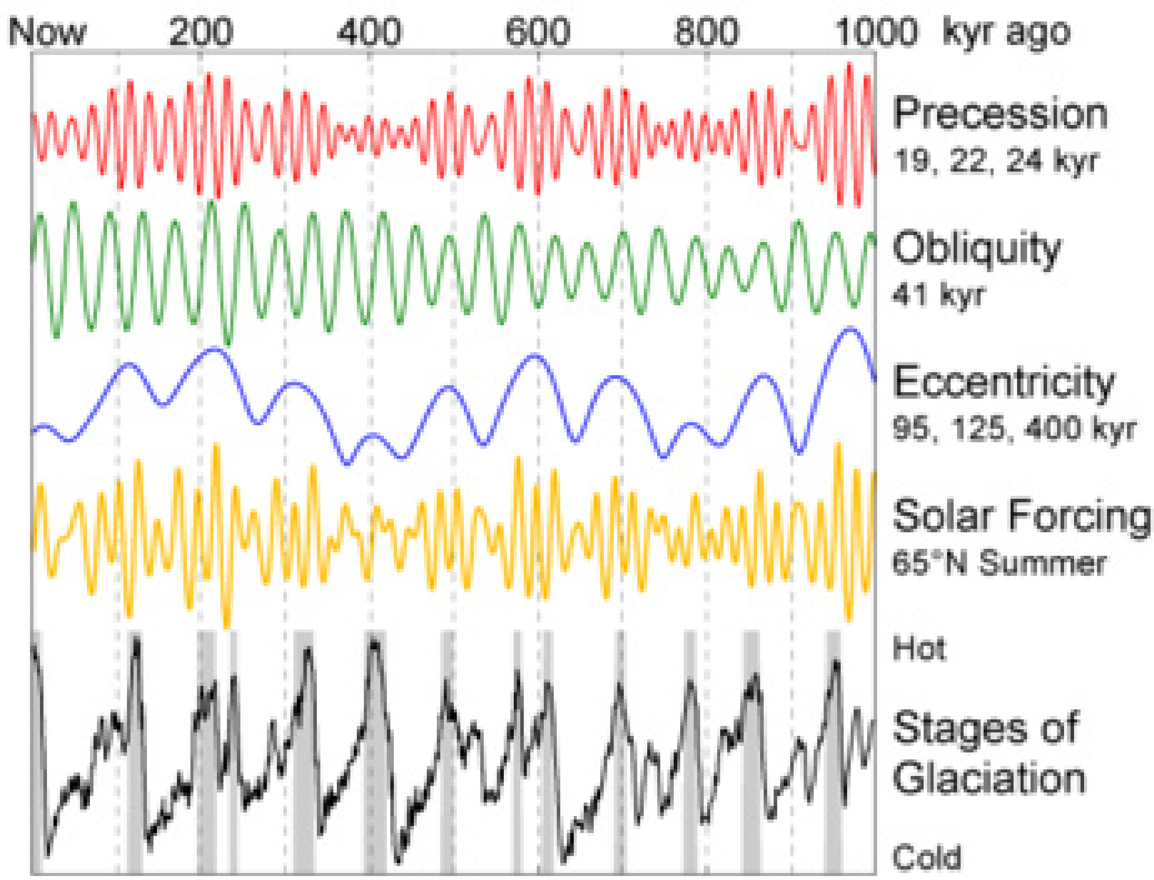


Figure 1-5 A summary of the Malinkovitch cycles.

Then there are cycles within cycles, which compound the search for clear answers. There is the climate event that appears to correspond to a 1500 year cycle, going back as far as 12,200 BC, known as the Older Dryas, a cold period in Eurasia, named after a plant species of that era. The last event, know as the Little Ice Age, had its onset around 1300 AD. It is historically deemed to be the cause of the Great Famine of 1315-1317 and the spread of the Black Plague throughout Europe.

Though data are weak at some periods, there appears to be similar little ice ages at 3200 BC, 4700 BC, 6200 BC and 10,700 BC.

Other climate influences include solar variations, volcanism and plate tectonics.

Plate tectonics influences take place over long time scales. They move continents, change the shape and extent of oceans, build and tear down mountains, and generally set the conditions for the climate above that can exist. For instance, the colliding of the North and South American continents closed off the mixing of the Atlantic and Pacific oceans across what is now the Isthmus of Panama.

The sun is where all the energy is. Solar heating and variations in solar radiation is basically what shapes Earth's climate. Over its long history, the sun is getting brighter, but the slowness of this transition is hardly measurable in the time frame of human history. There are other variations, including an eleven year sunspot cycle, as well as longer term cycles. There is no clear evidence that the eleven year cycle has much influence on Earth's climate. There is some thought that longer term variations may be the trigger for the 1500 year little ice ages.

A massive volcanic eruption of the type that occurs several times over a hundred years can cause climate cooling that can last for several years. They emit huge quantities of dust that circle Earth and block solar radiation. The 1991 eruption of Mount Pinatubo caused measurable changes in the climate. The effects of volcanic eruptions last for only a few years as the dust rapidly settles out from the atmosphere.

The arguments continue, but the fact of human influences on climate change appear to be taking center stage. The burning of fossil fuels, cement manufacture, agriculture, deforestation, and livestock combine to accelerate the rise in atmospheric carbon dioxide concentration, and mechanisms to abate it have yet to be adopted.

1-3 The Human Imperative

We now know that nothing in Earth's history has been discovered that resembles the coincidence of rapidly rising fossil fuel consumption, rapidly rising carbon dioxide concentration in the atmosphere, and observed rise in Earth temperature. There are no indications that these trends will level off. Rather, the probability exists that things will get worse faster, due to the nature of positive feedback, i.e. ice fields recede due to a temperature rise. Reflection of solar energy into space is thus reduced. Earth then becomes warmer and ice fields recede still faster.

The consequences can't be accurately predicted, but for the most part they are not good. Human history is strewn with incidents of recklessness in stewardship of the natural environment. At one time the Middle East was lush with fine forests. With no thought of reseeding, they were all cut down to build ships and temples for Greek and Roman empires. The fabled Cedars of Lebanon now exist in only a few acres of bug infested stands.

Today we know better. Stewardship, not plundering, underlies the biblical gift of dominion over the earth and all its living things. We now know that good stewardship is critical to human existence. We also know that our energy needs can be filled by tapping the limitless sources of heat from the sun and from Earth's interior. We know too, how to accomplish it.

That's what this book is about. Past generations can be forgiven for pursuing a track that utilizes energy stored in fossil fuels. They really weren't aware of the consequences. Now we know. The readers of this book will hopefully see how it is possible to stop global warming, sense the compelling need to make it happen, and take on the important task of ensuring a liveable planet for many millenia into the future.

Meanwhile, the trend toward rising concentrations of greenhouse gases shows no sign of abatement, and in fact is growing worse. In its annual index of greenhouse gas emissions, the National Oceanic and Atmospheric Administration found that carbon dioxide, the primary driver of global climate change, rose by 0.6 percent in 2007, or nineteen billion tons.