

PART I

A TRILOGY OF POPULAR MISCONCEPTIONS

One of the essential steps for uncovering the truth is to first challenge the assumptions that underlie our decision-making process. Here, we examine several key assumptions as a precursor to a more rational assessment of our energy options. Energy technology is driven primarily by thermodynamics, but many people who “get religious” about alternative energy do not understand anything about energy fundamentals and therefore substitute wishful thinking for educated pragmatism. This popular ignorance has resulted in an increasingly pervasive faith-based approach to energy technology that is fundamentally irrational and leads to many misguided choices and wrong conclusions that we see daily in the press.

Our use of the term “rational” also suggests a framework for our analysis within the context of factual decision making. We propose a framework consisting of five simple guiding principles. These are, in effect, long-term energy realities that represent guidelines for evaluating our options:

Thermodynamic factuality—some of the most vocal environmentalists do not take the time to understand immutable Laws of Thermodynamics. These laws do not adapt to wishful thinking, environmental convictions, or political interpretation.

Sustainability—the degree to which any energy resource or technology is sustainable over a long period of time.

Scalability—the degree to which any resource or technology can be scaled to serve a global population.

Efficiency—options that yield efficient energy conversion for useful work are preferred over wasteful conversions; this is a measure of cost both to the producer and the consumer of energy.

Impact—as measured in human and environmental terms. Permanent impacts are differentiated from reversible or transient impacts.

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GLOBAL WARMING

Perhaps no other aspect of the energy debate has attracted so much emotional discourse and questionable science as the topic of Global Warming (GW). GW is defined as the observed gradual increase in average global temperatures attributed to greenhouse gases that started in about 1850, coinciding with the industrial revolution. In addition to the measured temperature rise, the widely observed thinning of the polar icecaps, the worldwide erosion of glaciers, and the measurable rise in average land and ocean temperatures are strong supporting evidence of GW.

Two firmly opposed camps are emerging on the matter of global warming. One view is typified by CNN's Martin O'Brien's assertion that "the scientific debate is over. . . something must be done."¹ This is the "Al Gore camp" claiming that man's activities are dramatically and irreparably changing the Earth's climate. Its members vigorously support the principles of the Kyoto Treaty.

The other view holds that we are primarily experiencing the variability of the Earth's natural cycles. The tenor of the debate has reached such a feverish pitch that opposing camps hardly take time to understand the data presented by the other side. We are engaged in a global debate involving the highest political brinkmanship on an issue that should be rationally and objectively debated. **One of the main goals of this book is to put forward a third path— the path leading to rational choices for energizing our future.**

¹Available at <http://www.businessandmedia.org/news/2005/news20050328.asp>.

There are two important issues central to this debate: the first is to what extent man's (anthropogenic) contributions dominate the real and observed increase in global temperature. As we have seen with the popular press, the increasingly common view is that man is largely responsible and that we are irreversibly changing the Earth's atmosphere with dire environmental consequences.

The second issue concerns the extent to which this contribution is reversible through further human intervention and environmental remediation. This question is particularly intriguing as we consider that man's pervasive use of petroleum-derived energy sources will be substantially curtailed since such resources will exhaust by the end of this century. The relative size of the anthropogenic contribution to the total GW process obviously determines our ability to intervene to slow, stop or reverse the process. Thus, we need to answer the key question: "Is mankind dominating the observed global warming process, or are we merely exacerbating a natural variation of the Earth's median temperature?"

CONVENTIONAL WISDOM

It seems to have become apparent to scientists sometime during the 1960s that the Earth was experiencing a gradual warming. The phenomenon may have been missed previously because satellite and other tools were not sufficiently geographically distributed, precise, or numerous to track the change, which has been averaging about 0.01°C annually, worldwide. This long-term trend is very small relative to the "noise" in the measurement. Despite this, many observers have chosen to correlate this temperature increase with the observed increases in greenhouse gases and specifically the carbon dioxide content of the atmosphere. The increase in CO_2 levels is usually attributed primarily to industrial activity in the years before 1950–1970 and the rapid increase in the use of transportation fuels since then.

There is no doubt that atmospheric CO_2 has increased and that an apparent approximate correlation exists between the global temperature increase and GW within a narrow time period. Although there is increasing certainty of the reality of global warming, the claimed correlation between the two has always been subject to misinterpretation by the environmental lobby and the media.

For Example, in his popularized movie *An Inconvenient Truth*, Al Gore uses Antarctic ice core records of CO_2 and temperature from oxygen isotope inferences to illustrate the correlation between the two. But a more thoughtful analysis reveals that there are a number of other climate forcings besides CO_2 that contribute to the change in Antarctic temperature. Gore's simplistic extrapolation of this apparent correlation forward in time puts the temperature in 2100 A.D. at about 10°C warmer than the present, representing an exceedingly calamitous outcome. Regrettably, his type of alarmist presentation gets sensational press coverage around the globe.

Throughout the entire period between the mid-1800s and the mid-1900s, the temperature rise seems to *lead* the increase of CO_2 in the atmosphere,

suggesting to some that global warming appears to have been a cause, rather than a result, of the increase in atmospheric CO₂. This is a very important observation, assuming that additional data support it. The increase in atmospheric CO₂ has been relatively monotonic but slight, and shows no relationship with the temporarily slowed *rate* of global warming that was recorded during 1940–1970 and is now attributed to a larger than normal presence of sulfate and other aerosols related to volcanic eruptions.

Consider the example of recent low-level ozone reports in the polar regions. Beginning about 6 years ago, Dr. Drew Shindell of NASA's Goddard Institute for Space Studies garnered increasing media attention with claims that it was the low-level ozone, not CO₂, that was responsible for spring and summer warming detected in the Arctic. To quote Dr. Shindell: "Instead of being this tiny player, (ozone) can be more like 30 or 40 or even 50% of the cause of warming that we're seeing in the Arctic now. It's very dramatic." In 2004, Dr. Shindell was widely acclaimed when he was given the "Top 50 Scientists Award" by *Scientific American* magazine.

A few years later, a very comprehensive 2007 study of surface ozone in polar regions came to a much more benign conclusion, "Given the complexity of these dependencies, the sign and magnitude of the feedback of global climate change on the ozone budget over snow and at high latitudes cannot be conclusively assessed with our current knowledge of these interactions." The study adds, "Of all atmospheric trace gases, ozone has been monitored the longest, at the most stations and with the highest temporal resolution." It concludes "Calculated long-term ozone changes are in the range of 0.02–0.26 ppbv yr⁻¹. These (statistically non-significant) increases are low to moderate compared to recently published ozone trends at lower latitudes."²

The illustration is not to single out one particular study or one scientist's view at a point in time, but rather to call into question the merit of extrapolating any finite set of localized data to a system as complex as climate. It is important to consider the number of variables that must be factored into the analysis of climate models and their ability to predict accurate results. To quote Stern (2006), "A fundamental challenge regarding climate is to determine how much of observed climate change is a response to climate forcings, as opposed to chaotic (unforced) variability. A climate forcing is an imposed perturbation of the Earth's energy balance with space. Forcings arise naturally, as with aerosols injected by volcanic eruptions, and from human activities, as with increasing greenhouse gases."³

²Helmig Detlev, Samuel J. Oltmans, Daniel Carlson, Jean-Francois Lamarque, Anna Jones, Casper Labuschagne, Kurt Anlauf, Katherine Hayden. A Review of Surface Ozone in the Polar Regions. *Atmospheric Environment* 2007;41:5138–5161.

³Hansen J., M. Sato, L. Nazarenko, R. Ruedy, A. Lacis, D. Koch, I. Tegen, T. Hall, D. Shindell, B. Santer, P. Stone, T. Novakov, L. Thomason, R. Wang, Y. Wang, D. Jacob, S. Hollandsworth, L. Bishop, J. Logan, A. Thompson, R. Stolarski, J. Lean, R. Willson, S. Levitus, J. Antonov, N. Rayner, D. Parker, J. Christy. Climate Forcings in GISS SI2000 Simulations.

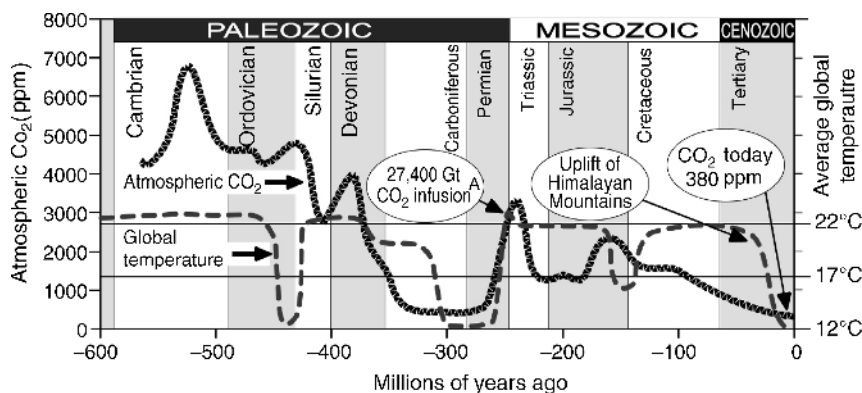


FIGURE 1.1 The recent geologic history of atmospheric CO₂. *Source:* Temperature from C. R. Scotese (<http://www.scotese.com/climate>), CO₂ from R. A. Berner 2001 (Geocarb III)

Given the qualification's that climatologists use to bracket their own conclusions, it is helpful to gain some perspective by examining a longer history of Earth's climate as currently constructed from the geologic record.

Figure 1.1 shows estimated temperature and CO₂ levels over the last 550 million years, or roughly the last 12% of Earth's existence. The time period covers significant geological events including substantial drifting of tectonic plates, five mass extinctions, the impact of large meteors, and periods of widespread glaciation.

We can see some interesting trends from this depiction. One is the clear cooling trend that characterizes the most recent 50 million years. The Late Carboniferous and Early Permian time (315–270 mya) is the only time period in the last 600 million years where both atmospheric CO₂ and temperature were as low as they are today (Quaternary Period). There does not appear to be a strong correlation between temperature and CO₂, but we might expect to see a temperature rebound to the nominal temperature of roughly 17°C over the last 300 million years. We can also see the rather dramatic range of CO₂ levels that have supported the Earth's evolution, from a high of nearly 7000 ppm in the Cambrian Period to a recent low of 275 PPM in about 900AD.

Also, note the CO₂ infusion at 250mya as a result of a very large venting of greenhouse gases that occurred during the Early Jurassic Period. It is estimated that a total of 27,400 Gigatons of CO₂ may have been transported to the surface through breccias pipes formed from tectonic collisions. The global warming that resulted from this incursion raised global temperature by 6°C and, combined with other climatic factors, resulted in Earth's most serious mass extinction event.⁴ We might find some comfort here as this episode was

⁴Svensen Henrik, Sverre Planke, Luc Chevallier, Anders Malthe-Sørenssena, Fernando Corfu and Bjørn Jamtveit. Hydrothermal venting of greenhouse gases triggering Early Jurassic global warming. *Earth and Planetary Science Letters* 2007;256(3–4):554–566.

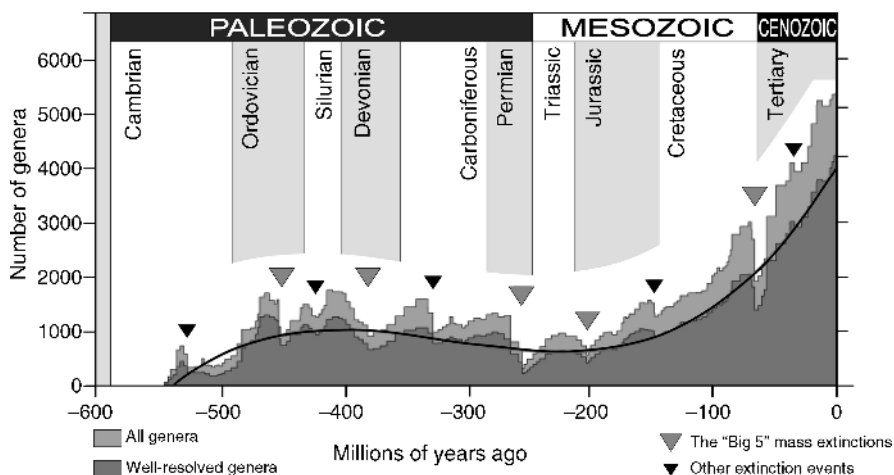


FIGURE 1.2 Biodiversity. *Source:* Wikimedia: Phanerozoic Biodiversity

many orders of magnitude larger than the event that might be triggered by releasing all the CO₂ from our fossil fuel reserves, as the recoverable supply of world coal is about 500 Gt.⁵

One of the frequent and more alarming claims made by proponents of the Kyoto Treaty is the impending mass extinction that will accompany our current path toward GW. Headlines such as “Global warming over the next century could trigger a catastrophe to rival the worst mass extinction in the history of the planet, scientists have warned”⁶ and “By 2050 Warming to Doom Million Species, Study Says”⁷

Listening to Al Gore, we get the impression that we are already on the brink of extinction with all flora and fauna. Again, some historical perspective is helpful in the context of this shrill activism. Figure 1.2 shows that Earth has recovered quite nicely from the last mass extinction event and has responded with deeper and broader biodiversity. While it is true we live on a fragile planet, more diversity improves rather than hinders the prospects for a thriving ecosystem ahead.

CO₂ AND THE CARBON CYCLE

With this historical context, let us look more closely at the carbon cycle underlying the current debate. It is widely accepted that atmospheric CO₂ and global temperature are related, but many scientists hold firm to the view that

⁵Available at <http://en.wikipedia.org/wiki/Coal>.

⁶Chris Thomas, a conservation biologist at the University of Leeds in the United Kingdom. Available at <http://www.msnbc.msn.com/id/3897120/>

⁷Available at http://news.nationalgeographic.com/news/2004/01/0107_040107_extinction.html.

CO₂ is a trailing indicator, not a forcing agent or leading indicator of climate change. Within the scientific camp holding the view that CO₂ is a leading indicator, there is further debate on the impact of man's relative contribution. This semantic positioning on all sides obfuscates the role of other factors implicated in the Earth's thermal exchanges and detracts from the need for a more complete understanding of the relative role of forcing agents and the Earth's carbon cycle.

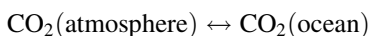
We can all agree that there is a lot of carbon in the equation and that it moves quite readily between systems over geologic time. Carbon is the fourth most abundant element in the Universe by mass. The carbon that cycles through the Earth's geological, oceanographic, and atmospheric systems was present at the birth of the Solar System 4.54 billion years ago. Since that time, a complex system of CO₂ exchange between various storage systems has evolved. Roughly 2.7 billion years ago, the first indications of life emerged in the form of cyanobacteria, and life on Earth has been supported in the margins of this carbon exchange ever since. The overall carbon exchange can be represented by a short-term cycle of interactions with the atmosphere where carbon residence times range from days to years; intermediate-term cycles with residence times of 100–1000 years and the long-term geosphere cycle of plate tectonics with residence times of millions or hundreds of millions of years.

Today, there is about 810 gigatons of carbon in the atmosphere, 1900 gigatons in the biosphere (living things) and an additional 36,000 gigatons in the world's oceans.⁸ By far the largest store of carbon is found in the Lithosphere where an additional 66,000,000–100,000,000 gigatons are sequestered. Much of this Lithospheric carbon is in the form of sedimentary rock deposits such as limestone, chalk, and dolomite, but approximately 0.00005%, or 4000 gigatons, is in the form of fossil fuels.⁹

In 1898, Svante Arrhenius first theorized that changes in carbon dioxide levels in atmosphere could substantially alter the surface temperature through the greenhouse effect. Various models of the carbon cycle have emerged since then to represent net carbon exchanges among carbon storage pools or reservoirs in the atmosphere, plants, soils, freshwater systems, ocean and geological sediments. There are three principal exchange methods that account for the majority of carbon transfers on our planet.

1. Diffusion of atmospheric CO₂ into water to form carbonate ions. This process removes CO₂ from the atmosphere, increases the acidity of the ocean, and allows further CO₂ diffusion into the ocean.

Diffusion:



⁸Available at en.wikipedia.org

⁹Dr. Charles W. Rice, Kansas State University. Available at http://www.oznet.ksu.edu/ctec/Outreach/science_ed2.htm.

Acid formation:

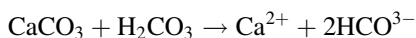


Carbonate ion formation:

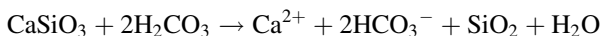


2. CO₂ in atmosphere is slowly converted into carbonic acid. The reaction is kinetically slow and conversion equilibrium is reached when about 0.2% is in the strong acid form. As this acidic water falls to the ground, it dissolves carbonate and silicate bearing rock according to the equations:

Carbonate weathering

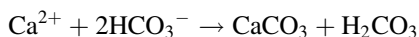


Silicate weathering



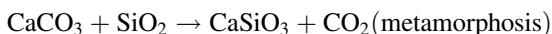
The resultant Ca²⁺, SiO₂, and HCO₃ are then returned to the ocean via streams and rivers; calcium carbonate precipitates in the ocean and is used by organisms that make shells and skeletal structure:

Carbonate mineral deposition



Here, the limestone (CaCO₃) will meet one of the three different fates: (1) limestones deposited in very shallow water can be exposed to the atmosphere (e.g. the White Cliffs of Dover) and thus undergo chemical weathering; (2) limestones deposited along a continental margin can be buried and then metamorphosed by tectonic action; or (3) limestones deposited on the deep ocean floor may be subducted and subsequently melted. The first outcome has no effect on the carbon cycle, and if not for the last two processes, atmospheric CO₂ would be eliminated from the atmosphere in about a million years. However, the these two processes release carbon dioxide into the atmosphere, sometimes in vast quantities. The metamorphic reaction involved here occurs when the calcite in limestone is intimately mixed with quartz:

Carbonate–silicate cycle



It is important to note that there are significant local imbalances in the ocean–atmosphere flux owing to variations in organic productivity and ocean upwelling. In warm waters, plants actively take up CO_2 ; ocean uptake may dominate through photosynthesis. In the open ocean, some planktons make shells simultaneously with photosynthesis. For every CO_2 molecule they produce by precipitation, they take up four by photosynthesis. Deep ocean water contains a lot of CO_2 , and when currents bring old water to the surface, CO_2 release to the atmosphere may dominate.

3. The longer term inorganic cycle is completed as sedimentary rocks are uplifted to the surface in the form of rock outcroppings or through volcanism of sedimentary tectonic plates. In both cases, the exposed rock is once again weathered eventually retuning to the ocean where the cycle repeats.



Seasonal cycles in atmospheric CO_2 concentration are the result of gas pressure equilibrium and photosynthesis variations.

A simplified model of the carbon cycle is shown in Fig. 1.3, representing both land and ocean carbon-exchange mechanisms.

THE GREENHOUSE EFFECT

The greenhouse effect is the rise in temperature the Earth experiences because certain gases in the atmosphere (water vapor, carbon dioxide, nitrous oxide, ozone, methane, and others) trap energy in the Earth's atmosphere. Without these gases, heat would escape back into space and Earth's average temperature would be about 60°F colder and unable to support much of the planet's life. Because most of this heat energy is directly comes from the Sun, they are referred to as greenhouse gases. Sources of heat energy that impact greenhouse gases-include solar energy, latent heat delivered to the Earth's surface by convection from the Earth's core,¹⁰ plate tectonics that transport heat to and from the lithosphere, the Earth's magnetic field, and cosmic rays.¹¹ Each of these energy inputs has shown to be variable and cyclic over time involving very complex mechanisms all of which are poorly understood and crudely estimated.

¹⁰Hantel Michael, Ferenc Acs. Physical aspects of the weather generator. *Journal of Hydrology* 1998:212–213.

¹¹Courtillot Vincent, Yves Gallet, Jean-Louis Le Mouél, Frédéric Fluteau, Agnès Genevey. *Earth and Planetary Science Letters* 2007;253:328–339.

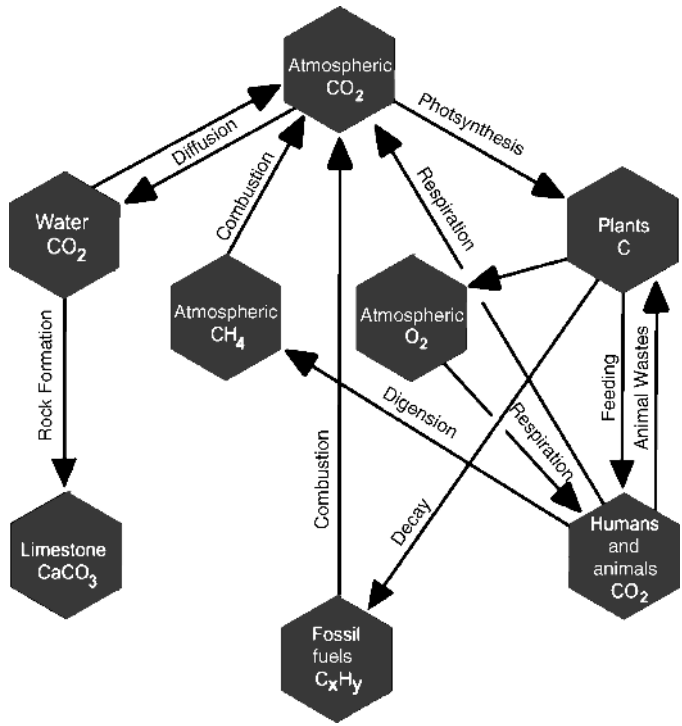


FIGURE 1.3 Carbon cycle on Earth. *Source:* Adapted from US DOE

RECENT CLIMATE CHANGES

With this added perspective on Earth’s history and the complex dynamics that impacts our atmosphere’s temperature and carbon content, let us consider the very recent changes in climate. Although few scientists now debate the fact of recent global warming, the exact *sources and mechanisms* of global warming remain unclear and unproven.

Many publications on the subject, especially those written since the first (1996) IPCC report,¹² mistakenly assume the connection between global warming and carbon dioxide is incontrovertible and start unquestioningly from that point. This serious “rush to judgment” by a small group of scientists has presumptively blamed anthropogenic carbon dioxide, methane and a few other gases as the source of global warming.¹³ This linkage is erroneous as it is

¹²Henrik Svensen, Sverre Planke, Luc Chevallier, Anders Malthe-Sørenssen, Fernando Corfu, Bjørn Jamtveit. Hydrothermal venting of greenhouse gases triggering Early Jurassic global warming. *Earth and Planetary Science Letters* 2007;256(3–4):554–566.

¹³Carbon Cycle. Available at http://en.wikipedia.org/wiki/Carbon_cycle.

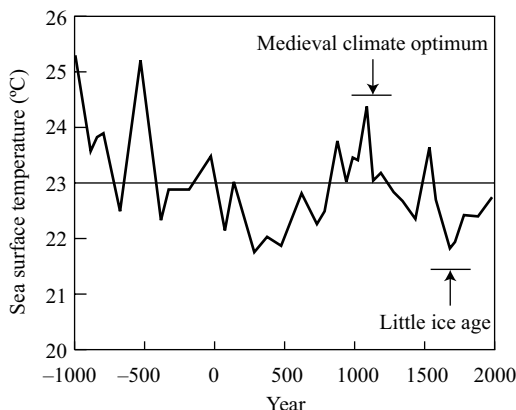


FIGURE 1.4 Marine surface temperatures as determined by isotope ratios of Sargasso Sea organism remains. *Source:* Oregon Institute of Science and Medicine <http://www.oism.org/pproject/>

becoming clear that the IPCC assumptions, and therefore conclusions, were, at best, incomplete.

Figure 1.4 shows the temperature changes around the period of the Little Ice Age (approximately 1550–1800), proposed by some to be responsible for much of the global warming we see today.^{14,15} To many scientists the current warming phase appears to be a repetition of a natural event that has occurred many times before in geologic time. Such suggestions are generally dismissed by those already committed to the CO₂ model of global warming as they have fixated on the radiative aspect of this gas as the primary cause of the increase.

Superimposed on these natural changes is the much-debated impact of CO₂ generated by anthropogenic activity. This has clearly increased since 1950, especially since about 1970, and has, of course, resulted in additional global warming, leading to additional atmospheric water vapor and yet more warming. What we do not know is exactly how large this anthropogenic contribution is in relation to (a) other sources of CO₂ and (b) other non-CO₂ sources of GW. We therefore do not know what impact any *reduction* in CO₂ from this source would have on GW.

¹⁴Most recently by Soon, W. and S. Baliunas. Fallacy of more renewables. *Capitalism Magazine*, 2002; July 7.

¹⁵Robinson, A.B., S. Baliunas, W. Soon Z.W. Robinson. Environmental effects of increased atmospheric carbon dioxide; 1998. Available at: <http://www.oism.org/pproject/review.pdf>. This *unrefered* paper is useful primarily because of its many references to earlier works. The content is controversial and has been rejected by many whose reputations have become associated with the carbon dioxide model. For the most part, we find its arguments reasonable and persuasive.

CARBON DIOXIDE

Carbon dioxide, along with the “big industry” producers (e.g., the operators of conventional fossil-fuel power generators) and those who sell products that generate it (e.g., “big oil” or “big coal” and the auto industry), have, for at least 15 years, been the whipping boys of the environmental movement. The members of this movement seldom take responsibility using these product themselves. Sometimes, as in the case of the Valdez spill in the Gulf of Alaska, this has been justified, but the same companies are always blamed for the claimed effects of the increase in atmospheric CO₂. Innumerable publications ranging from media reports to peer-reviewed papers in learned journals have unquestioningly accepted the argument that the coincidental increases in global surface temperature and atmospheric carbon dioxide levels indicate a unique cause-and-effect relationship. However, this claim is actually disputed by a increasing number of distinguished scientists, and a recent 2007 survey of articles published by climatologists indicates that sentiment continues to shift in favor of anthropogenic global warming skeptics.¹⁶

Carbon dioxide certainly makes a contribution to global warming but it appears to be only one of the several contributors. The elimination of anthropogenic CO₂ will have only a small effect on global warming. There may, however, be reasons to reduce other combustion emissions such as particulate matter. There may also be additional reasons to reduce CO₂ production, especially since most of it appears to be absorbed in the oceans that, consequently, store vast amounts of CO₂. Recently, increases in oceanic acidity have been reported and may be attributable to CO₂.¹⁷ The same may be happening to fresh water lakes and wetlands.

On the positive side of the CO₂ equation, reliable evidence from an extensive literature shows that carbon dioxide, which is required for all plant growth, also stimulates the growth of plants¹⁸ and especially trees¹⁹ when present at levels above normal. The results are quite marked in that a doubling of atmospheric CO₂ from current levels can result in a growth rate increase of as much as 100%, especially in pine and citrus trees. It is important to note that the results from plant growth rate studies on established trees are always much more predictable than they are for annual farm crops that are greatly influenced by weather-related variables. Thus, the reported data are probably best applied to “greenhouse farming”.

There is no doubt that industrial and transportation activities introduce a great deal of carbon dioxide into the atmosphere. However, the manner in

¹⁶Available at http://epw.senate.gov/public/index.cfm?FuseAction=Minority.Blogs&Content-Record_id=84e9e44a-802a-23ad-493a-b35d0842fed8

¹⁷See, for example, <http://www.harvard-magazine.com/on-line/1102198.html>.

¹⁸Idso, K.E. Idso, S.B. *Ag. and Forest Meteorology* 1974;69:153–203.

¹⁹Graybill, D.A. Idso, S.B. *Global Biogeochem Cyc.* 1993;7:81–95.

which the data have been interpreted is questionable. In 1850, when atmospheric CO₂ measurements were first reported, background levels of the gas were essentially constant at 285 ppmv. Sources at that time were decaying vegetation (directly or through methane oxidation in the atmosphere), volcanic activity, forest and grass fires and fuel (mostly wood) burning. For the next 100 years, CO₂ levels rose quite steadily at 0.3 ppmv annually to 310 ppmv in 1950. The rate of increase in the concentration then accelerated over a period of about 20 years to about 1.5 ppmv annually and has remained roughly constant at that level from 1970 to the present. The level of CO₂ in the atmosphere is currently about 385 ppmv (0.037 vol%) and slowly increasing.

Since 1850, man-made contributions to atmospheric carbon dioxide have risen from a few hundred Tg annually (1 million metric tons = 1 Tg [teragram]) to several thousand Tg annually. These may seem impressive numbers, but the Earth offers a number of very effective sinks for carbon dioxide. Most growing plants absorb CO₂ as part of the carbon cycle involved in their growth. The oceans act as a very effective “buffer” for CO₂ and help maintain atmospheric CO₂ at almost constant levels (the increase in atmospheric CO₂ since 1970 may be owing *in part* to oceanic release of CO₂, e.g., from soluble bicarbonates). Certain minerals (mostly complex magnesium silicates) also act as CO₂ sinks, forming equally complex mineral carbonates. As a result, the net impact of human activity on CO₂ levels in the atmosphere has been very small although oceanic CO₂ levels have increased appreciably.

The amount of water vapor in the atmosphere has been increasing at between 0.3% and 1% of its baseline level or 90–300 ppmv per year, apparently due to ocean warming. If we assume as first approximation that the effect on infrared radiation of water vapor in air is linear with concentration,²⁰ it completely overwhelms the influence of CO₂. Carbon dioxide is simply not the dominant player in global warming. Even if it turns out to have been responsible for the increase in water vapor levels, it does not follow that a decrease in CO₂ levels or emissions will result in a corresponding decrease in atmospheric water vapor since there are many factors supporting the continued presence of water.

Therefore, all of the proposed corrective actions that assume that a reduction of anthropogenic CO₂ will result in a pro rata reduction in global warming may have little or no measurable beneficial impact, at least for many years. Most CO₂ models recognize the link between CO₂-derived warming and increases in atmospheric water vapor, but do not recognize the enormous impact of increases in the level of atmospheric water vapor attributed to other factors such as nonanthropogenic warming.

²⁰In fact, the absorption may follow an approximate square-root “diminishing returns” law with atmospheric concentration of the absorbing species, but this has not been confirmed.

OTHER GLOBAL WARMING “FORCING AGENTS”

Water Vapor

The temperature of the Earth is maintained by thermal irradiance from the Sun, and water vapor has been largely responsible for making our planet a comfortable place to live for the last several million years, since it acts both as a thermal shield and a thermal trap.

The influence of atmospheric water vapor on global warming is quite direct, as anyone who has lived or worked in a dry desert environment might intuit, and has long been recognized as the primary factor in maintaining global temperatures at a livable average level of $+15^{\circ}\text{C}$ rather than the -18°C or lower that would occur without it.

As a consequence, instead of temperatures that swing wildly from one extreme to the other, like on planets such as Mars that lack surface water and any kind of “heat buffering” atmosphere, the Earth experiences a relatively stable surface temperature.²¹ Since the Sun and the water vapor in the atmosphere are known to have these effects, it seems logical to examine these factors as potential causes of global warming.

The global average level of atmospheric water vapor is about 3% or 30,000 ppmv compared to a total of about 385 ppmv for carbon dioxide. Thus, its impact on global warming is much greater than that of CO_2 , since it is roughly as effective a warming agent as CO_2 . Historical data support an estimate that water vapor is somewhere between 50% and 300% as effective as CO_2 on a unit mass basis over a 100-year period. Others have agreed with this highly approximate estimate.^{22,8} If the global warming potential (GWP) of CO_2 is set at 1.0, the potential of water is on average about 1.75. The total relative warming effect of atmospheric water vapor at the 3% level is thus about $30,000 \times 1.75$ or 52,500 compared to 368×1.0 or 368 for CO_2 .²³

Therefore, it is the increase *above the historical or baseline atmospheric concentration* that is important in global warming, assuming that the world was in a comfortable steady state prior to the present run-up in global temperatures that began around 1850. At that time, the atmospheric CO_2 level was steady at about 285 ppmv, so the level has increased by about 100 ppmv or about 35% over the 103 years. Intuitively, this seems hardly enough to lay claim to the notably large effect. Of course, other pollutants (most notably methane) may

²¹On Mars, a “thin”, 95% CO_2 atmosphere, is obviously not effective since the average surface temperature is -65°C . Venus is too hot to sustain life (its “thick” CO_2 atmosphere has almost certainly contributed to maintaining the very high surface temperature of 460°C of that planet).

²²See footnote 1. See also K.P. Shine and A. Sinha Sensitivity of the Earth’s climate to height-dependent changes in the water vapor mixing ratio. 1991; *Nature* 354:382–384; and D. Lubin. The role of tropical super greenhouse effect in heating the ocean surface. 1994; *Science* 265:224–227.

²³Lindzen, R.S. Some coolness concerning global warming. *Bulletin of the American Meteorological Society* 1990;71:288–299; and Sun, D.G. Lindzen, R.S. Distribution of tropical tropospheric water vapor. *Journal of Atmospheric Science* 1993;50:1643–1660.

contribute, but the largest concentration increase by far in the period since 1890 is that of *water*.

The level of water vapor in the atmosphere close to the Earth's surface has been tracked at many locations at least since 1965. As recorded by Harvey,²⁴ among others, atmospheric water vapor levels have been *increasing* at most measurement stations worldwide by between 3% and 10% per *decade* (i.e., from 0.3 to 1% per year). The rate of increase diminishes as the altitude increases within the troposphere up to the tropopause (~15 km) and then remains constant at about 1% *increase* per year above that altitude.²⁵ About 30% of the increase in stratospheric water vapor levels is usually attributed to the reaction of methane and perhaps hydrogen with hydroxyl radicals (OH⁻) to form water and carbon oxides. The rest is unexplained but may simply represent the vertical movement of tropospheric water across the tropopause because of convection stirring and diffusion.

The important conclusion, on which there seems to be a reasonable consensus, is that atmospheric water vapor levels are increasing, perhaps by as much as 1% or about 300 ppmv per annum. Even at 1% per decade, the effect of this increase would far outweigh the concurrently measured rate of increase in CO₂ concentrations in the atmosphere. CO₂ levels are increasing at about 1.5 ppmv annually or 15 ppmv per decade. In one year, the incremental warming impact of water vapor is $300 \times 1.75 = 525$ while that of carbon dioxide would be $1.5 \times 1.0 = 1.5$ —a factor of 350 less!

There are several qualifying notes to this preliminary but very important conclusion:

1. Atmospheric water vapor levels vary dramatically, both temporally and geographically. Additional data is needed (CMDL and other collaborating labs internationally* are pursuing this) to confirm our rate of increase.
2. The impact of increased water vapor levels and especially the impact of increased CO₂ levels are very small compared to the background level of global warming maintained by the “normal” level of water vapor in the atmosphere that was established around 1800. The effect of CO₂ in particular is likely to be less than the “noise” in the water vapor data.
3. The models used to predict climate behavior based on the assumption that global warming is due to CO₂ appear to take into account the influence of water vapor only as a secondary factor in determining global warming. Both CO₂ and water vapor have been present for many

*NOAA Climate Monitoring and Diagnostics Lab, <http://www.esrl.noaa.gov/gmd/>

²⁴Harvey, D. *Global Warming: The Hard Science*. Upper Saddle River, NJ; Pearson Education; 1999. This is very useful information source despite being only a textbook.

²⁵See, for example, <http://www.cmdl.noaa.gov/hotitems/watervapor.html> (The U.S. Climate Monitoring and Diagnostics Lab. website).

TABLE 1.1 Overlap of Absorption Bands of Greenhouse Gases (Micrometers)

Greenhouse gases	Greenhouse gases’ absorption bands, μm
H ₂ O	0.5–2.0
H ₂ O, CO, and CO ₂	2.0–3.0
H ₂ O and CH ₄	3.0–4.0
CO and CO ₂	4.0–5.0
H ₂ O	5.0–7.0
N ₂ O and CH ₄	7.0–8.0
O ₃	8.0–10.0
CO ₂ , CH ₄ , and O ₃	13.7–14.7
CO ₂	14.7–16.5
N ₂ O	16.5–46.0

millennia; and the dominant presence of water vapor may effectively block any increase in CO₂ contribution to infrared absorption, at least in those wavelength ranges where the spectra overlap (see Table 1.1). It is likely that increases in atmospheric water vapor levels that initially resulted from global warming following the 1550–1800 Little Ice Age and accentuated by water-only feedback effects, are predominantly responsible for global warming. Therefore, *global warming is a natural cyclic event up to a point*.

4. The increase in atmospheric water vapor content is both a *cause* of global warming and a *result* of it, in the latter case as a consequence of ocean temperature increases. Of course, by the same argument, *any* agent that forces global warming, such as an increase in solar irradiance or an increase in CO₂ levels, will result in an increase in water vapor levels and hence more global warming. Which of these – or the other factors yet to be discussed – came first and initiated the current warming trend continues to be a classic scientific “chicken and egg” problem.
5. We can conclude with confidence, however, that current increases in atmospheric water vapor levels are likely the major contributor to the observed increase in global warming. The undoubted effect of anthropogenic CO₂, while important, is overlaid on the impact of water vapor and has contributed substantially to global warming in the years since 1950.

Atmospheric water vapor has been largely ignored because of the huge point-to-point variability of its concentration in the troposphere and especially near the Earth’s surface. This results in huge “noise” in the data on atmospheric water. In addition, the absorption spectra of the greenhouse gases, and especially water, are very complex. Table 1.2 shows how the absorption bands of the greenhouse gases overlap.

TABLE 1.2 Absorption Wavelengths of Greenhouse Gases

Greenhouse gas	Absorption wavelengths, μm
CO ₂	2.69; 2.76; 4.25; 14.00; 15.00
CO	2.30; 4.70
H ₂ O	0.60; 0.72; 0.82; 0.94; 1.10; 1.38; 1.87; 2.70; 3.20; 6.30
CH ₄	3.40; 7.40; 7.58; 7.87
N ₂ O	7.83; 16.98; 44.90

Of special importance is the fact that CO₂ has two absorption bands at 14.00 and 15.00 μm that do *not* overlap with the spectra of water or any other compound of potential importance.

Thus, even in the presence of water vapor, CO₂ can exert some influence on global warming but only to the extent that the infrared radiation reradiated by the Earth’s surface falls between 14.7 and 16.5 μm (see Table 1.1). In the absence of CO₂, this is an “open window” for re-radiation²⁶ (Kemp¹⁹ claims a width of 8 to 13 μm). Re-radiation in most other wavelength ranges is absorbed by water vapor.

Partly because the infrared absorption bands of various components of atmosphere overlap, *contributions from individual absorbers do not add linearly*. Ramanathan and Coakley estimated that clouds trap only 14% of the radiation with all other major absorbers present, but would trap 50% if all other absorbers were removed²⁷ (Table 1.3 and Fig. 1.4).

In this analysis, carbon dioxide contributes only 12% to total reradiation trapping, which is much less than the contribution from either water vapor or clouds. By itself, however, carbon dioxide (if present in sufficient concentration) is capable of trapping three times as much radiation as it actually does in the Earth’s nominal atmosphere.

Freidenreich and colleagues²⁸ have reported the overlap of carbon dioxide and water absorption bands in the infrared region. They determined that, given the present composition of the atmosphere, contributions to the total heating rate in the troposphere are *about 5% from carbon dioxide and 95% from water vapor*, in general agreement with the data presented earlier. In the stratosphere, the contributions are about 80% from carbon dioxide and about 20% from water vapor. It is currently believed that the impact of water vapor produced by surface sources such as fuel combustion or cooling towers on the average concentration of water vapor in the atmosphere is minimal, although whatever

²⁶Kemp, D.D. *Global Environmental Issues: A Climatological Approach*. 2nd Ed., London: Routledge, 1994; p. 224.
²⁷Ramanathan, V. J.A. Coakley, Jr. Climate modeling through radiative-convective models. *Review of Geophysics & Space Physics* 1978;16:465.
²⁸Freidenreich, S.M. V. Ramaswamy. Solar radiation absorption by carbon dioxide, overlap with water, and a parameterization for general circulation models. *J. Geophysical Research* 1993;98:7255–7264.

TABLE 1.3 Efficiency of Heat Trapping by Greenhouse Gases and Clouds

Species removed	Percentage heat trapped	Percentage heat not trapped
All ^a	0	100
H ₂ O, CO ₂ , O ₃	50	50
H ₂ O	64	36
Clouds	86	14
CO ₂	88	12
O ₃	97	3
None	100	0

CO₂ = carbon dioxide. H₂O = water vapor. O₃ = ozone.

^aIncludes clouds.

Source: V. Ramanathan and J.A. Coakley, Jr., “Climate modeling through radiative-convective models,” *Review of Geophysics & Space Physics* 1978;16:465.

contribution there is cannot be distinguished from that made by additional evaporation from the warmer global surface. It also varies very widely.

From this analysis and the one presented earlier, it should be clear that by failing to isolate the dominant effect of atmospheric water vapor on global warming the current models have vastly exaggerated the contribution from carbon dioxide and other nonwater greenhouse gases.

Ignoring any direct water vapor contribution attributes all of the observed global warming to these gases. If the water vapor contribution is recognized but assumed to be invariant in geologic time, then all of the increase in warming is again attributed to the greenhouse gases. In fact it now appears that most of it is owing to the steady increase in the water vapor contribution since the nineteenth century and that this increase, although it may have driven the increase in atmospheric CO₂ since around 1800, was certainly not the result of increases in anthropogenic CO₂ until approximately 1950. It is extraordinary that the specific contribution of water vapor to global warming has been ignored, misunderstood or misrepresented for so long— and the lack of data has only made any detailed analysis difficult.

At most, CO₂ from all sources contributes somewhere between 5% and 35% of total global warming, although other estimates by those who have attempted to take water vapor into account have varied only up to 12%. The low levels of carbon dioxide in the Earth’s atmosphere, the slow rise in its net concentration, and its low GWP discount carbon dioxide somewhat as a *direct* contributor to global warming, although perhaps not for its impact on the total ecosystem, especially the oceans.

At a temperature of 15°C, ignoring the effect of dissolved salts, a one degree increase in temperature raises the vapor pressure of pure water by 0.0177 psi or 122 N/m². This corresponds to an increase in the concentration of water in saturated air in equilibrium with the water from 10,300 to 11,080 ppmw, an increase of 780 ppmw. At 25°C, the figures are 19,480; 20,860; and 1380 ppmw. Remember that even today we have only 385 total ppmv of CO₂ in the

atmosphere, a figure that has increased by only 30% or 78 ppmv in the past 50 years. We have, on average, at least 20,000 ppmv (2 wt%) of water and values of up to 10% (including aerosols) have been reported regionally. Clearly, the quantity of water vapor, the global warming agent that we have always depended upon for our comfort, greatly overwhelms that of carbon dioxide. Water vapor has been shown to have about the same global warming impact as carbon dioxide per unit of volume.

We also note, as have others, that land and marine releases of CO₂ and CH₄ into the atmosphere are partly a consequence of global warming caused by other factors such as changes in solar irradiance and changes in atmospheric water vapor concentrations. These releases, of course, also exert a small influence on global warming, thus ratcheting it up by a mechanism often referred to as positive feedback.

The same mechanism applies on a much larger scale to water vapor. As average global surface temperatures increase, the average level of water vapor in the air at steady state also increases, thus leading to an additional global warming. As global temperatures have increased (less than 1°C, of which a little over half occurred during the period of somewhat accelerated warming since 1950), ocean surface temperatures and the temperatures of wetlands and lakes have risen in concert.

Methane

There is substantial evidence that in contrast to the current situation, the Earth's early "reducing" atmosphere contained large amounts of methane and only trace amounts of oxygen.²⁹ Since that time, our atmosphere has gradually evolved with the accretion of oxygen, now surpassing several other elements as the total atmospheric mass continues to increase. As part of this evolution, atmospheric levels of methane, after remaining constant at about 650 parts per billion by volume (ppbv) for many millennia, began to increase markedly after about 1800 and have now reached about 1750 ppbv (1.75 ppmv) an increase of 170% in about 200 years (most of it since about 1900). This is a much larger percentage increase than that for CO₂, but from a very much smaller base. Methane is a very effective global warming agent with a reported 100-year GWP of 21 (versus 1 for carbon dioxide), but it is present in such small amounts that its influence is very limited, despite this major increase.

At 1.75 ppmv, and "assuming" a linear absorption–concentration relationship, methane's total relative contribution is 21×1.75 or 36.75 compared to 52,000 for water vapor and 385 for carbon dioxide, all in relative units, but methane levels are increasing at only about 0.6% or 0.01 ppmv per decade. Its relative effect over the decade is thus increased by $21 \times 0.01 = 0.21$ – which is

²⁹Available at <http://www.astrobio.net/news/article1708.html>.

negligible compared to the relative annual increases in the global warming contribution of 525 reported for water vapor and 1.5 for carbon dioxide.

Methane in the Earth’s recent atmosphere is derived from a number of sources. Historically, prior to the nineteenth century, it was primarily sourced from anaerobic decay of rotting vegetation, natural leaks from underground deposits of coal, oil and natural gas, and wild animal digestive systems (especially ruminants such as buffalo and oxen). Animals, including human, are also CO₂ producers but the effect is minute relative to other sources, even at today’s population levels. Later, methane release rates increased, as coal was produced, transported (especially in open-pit mines) and gasified; as oil and natural gas were discovered, produced and transported; and also as man accumulated organic wastes (e.g., in landfills), cultivated livestock (along with manure management), treated wastewater and pumped crude oil. There is little measured quantitative information on its sources; although the USEPA has done an excellent job of estimating this data.³⁰

Anaerobic decay of waste in landfills is now considered the primary source of methane, followed by cows and other farm animals (a result of what is politely called “enteric fermentation,” but includes animal waste handling). Leakage from natural gas pipelines and distribution systems is also a substantial contributor. Presumably, humans, like animals, are direct and continuous contributors of both carbon dioxide and methane, but the EPA offers no data on this source (the contribution to CO₂ is surprisingly small, about 3.2% of the annual increase of 1.5 ppmv for atmospheric CO₂).

Methane is currently a minor contributor to preserving global heat and (Fig. 1.4), relative to water vapor, does not merit much attention at this stage. It is derived from very highly distributed sources, many of them natural and not controllable. If methane emissions were to increase by one or two orders of magnitude in some way, its effectiveness as a warming agent would justify some concern but, at present this is not the case.

Nitrous Oxide

Naturally produced in soils by microbial nitrification and denitrification processes, nitrous oxide is also produced in small quantities by natural grass and forest fires. Anthropogenic additions of nitrogen to soils during agricultural activities such as ammonia injection ultimately increase the amount of N₂O released to the atmosphere. Nitrous oxide can also be emitted by industrial production activities, fossil fuel production, and the combustion of solid waste.

³⁰For an excellent brief summary (8 pages), see: <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2003.html>. The full report can be found at: [http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJQ6G/\\$File/2003-final-inventory.pdf](http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJQ6G/$File/2003-final-inventory.pdf) (this full report is 600 pages in length).

On a volume-for-volume basis, nitrous oxide is about 300 times more effective than carbon dioxide as a global warming agent. However, its concentration in the atmosphere is only 10^{-3} times that of carbon dioxide and 10^{-5} times that of water vapor, so its effect is comparatively negligible, although at a level somewhat above that of methane because of its high GWP. The concentration of nitrous oxide in the atmosphere is increasing at only about 0.25% annually, so the influence of this gas is unlikely to rise to significant levels at any time in the next century. Nitrous oxide is unique in absorbing relatively long-wavelength infrared radiation.

Ozone

Ozone is a strong smelling, reactive toxic chemical gas consisting of three oxygen atoms and has a faint pale-blue tint. Ozone occurs primarily in two layers of the atmosphere and is a product of the photochemical process involving the Sun's energy.

The layer closest to the Earth's surface is the troposphere and here, ground level ozone is considered an air pollutant. Ozone is a main ingredient in urban smog and is harmful to human health in addition to being a deleterious to crops, trees, and other vegetation.

Tropospheric ozone was responsible for one-third to half of the observed warming trend in the Arctic, according to the Goddard Institute for Space Studies. Recent studies have confirmed that ozone is transported from the industrialized countries in the Northern Hemisphere to the Arctic quite efficiently during winter and spring.³¹

The troposphere generally extends to an altitude of about 30,000 feet, where it meets the second layer, the stratosphere that extends upward from about 6 to 30 miles. Here, ozone has a beneficial effect and helps protect life on Earth by blocking harmful ultraviolet radiation. It has long been reported that portions of the Earth's upper atmosphere have suffered ozone depletion in recent years due largely to man-made chemicals.

The ozone depletion process begins when CFCs (Chlorofluorocarbons) and other ozone-depleting substances are introduced into the atmosphere (see Figure 1.5). These compounds have been widely used as aerosol propellants and air-conditioning refrigerants as well as for fire extinguishers. Winds efficiently mix down and evenly distribute the CFCs, which are very stable and resistant to decomposition by water. After a period of several years, these stable CFC molecules eventually reach the stratosphere where strong UV light breaks them. As a result, CFCs, HCFCs (hydrochlorofluorocarbons), carbon tetrachloride, methyl chloroform, and other gases then release chlorine atoms; halons and methyl bromides release bromine atoms. It is these atoms that

³¹Available at http://www.nasa.gov/centers/goddard/news/topstory/2006/troposphere_ozone.html.

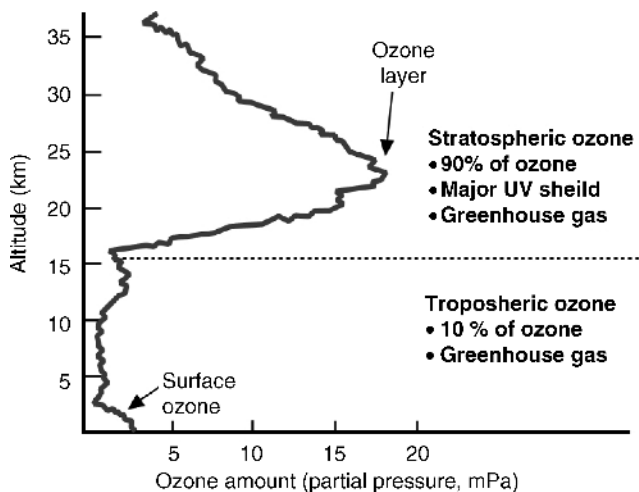


FIGURE 1.5 Atmospheric ozone production. *Source:* Australia State of the Environment Report 2001

actually destroy the ozone molecules, with one chlorine atom destroying over 100,000 ozone molecules before it is removed from the stratosphere.³²

Ozone is constantly produced and destroyed in a natural annual cycle, but the overall amount of ozone was essentially stable until the last several decades. Large increases in stratospheric chlorine and bromine are believed to have upset this fundamental balance. Ozone depletion has caused increased amounts of UV radiation to reach the Earth in the northern latitudes, and this increase is believed to lead directly to more cases of skin cancer, cataracts, and impaired immune systems. UV can also damage sensitive crops, such as soybeans, reducing crop yields. Some scientists also suggest that marine phytoplankton, which are the base of the ocean food chain, are already under stress from UV radiation.³³

In 1987, the United States, along with over 180 other countries, adopted a treaty called the Montreal Protocol which recognized the ozone depletion threat and together pledged to phase out the production of ozone-depleting substances. The EPA has also established regulations to phase out ozone-depleting chemicals in the United States. All products containing CFCs or similar substances are required to carry warning labels and nonessential uses of ozone-depleting products have been generally banned. Atmospheric releases of R-22 refrigerants commonly used in car and home air-conditioning units have been reduced by replacing them with a number of proprietary compounds.

³²Available at <http://www.ehso.com/ehshome/ozonedepletion.htm>.

³³Available at http://acdscisci.gsfc.nasa.gov/ozone/pubs/theme/marinehealth_pubs.shtml.

As ozone-depleting substances are progressively removed from the environment, we should see a return of the ozone layer to normal levels by about 2050. However, it is important to remember that many of the processes that determine climate conditions are not sufficiently understood. For example, The European Space Agency recently reported that the “Ozone Hole” over Antarctica was 30% smaller in 2007 as compared to 2006, representing a loss of 27.7 million tons of ozone as compared to 40 million tons in 2006.³⁴ This dramatic reduction in ozone depletion cannot be attributed to anthropogenic remediation alone.

Sulfur

Anthropogenic sulfur emissions play an important role in local air pollution and smog, acid rain, and global climate change. Global sulfur emissions increased fairly steadily until the end of the 1980s.³⁵ Existing global estimates for 1995 and a forecast for 2000 showed a moderate decline from 1990 to 1995.³⁶ Recent analysis by Stern for sulfur emissions which also combines previously published data, includes most countries of the world from 1850 to 2000, and new econometric estimates indicated a 22% decline in emissions over the decade of the 1990s to a level not seen since the mid-1960 (see Figure 1.6).³⁷

The decline in sulfur emissions is observed in North America, Western and Eastern Europe, and in the last several years in East Asia. Emissions per capita in developing countries are lower than historical emissions in the industrialized world and lower than in all industrialized regions apart from Western Europe today. The results by Stern support recent theoretical and empirical research that emissions are monotonic in income and that reduction in emissions are time-related rather than income-related. If this new trend is maintained, local air pollution problems may be mitigated, although global warming may be somewhat exacerbated as this trend may result in global brightening.³⁸

Other Pollutants

Three types of gaseous contaminants may at some point in the future exert very high influences on heat trapping and hence on global warming:

³⁴Ozone hole smaller than usual 2007. Available at <http://www.sciencedaily.com/releases/2007/10/071003100537.htm>.

³⁵Lefohn, A.S. J.D. Husar, R.B. Husar, Estimating historical anthropogenic global sulfur emission patterns for the period 1850–1990. *Atmospheric Environment* 1999;33:3435–3444.

³⁶Olivier, J.G.J., J.J.M. Berdowski, Global emissions sources and sinks. In: Berdowski, J., Guicherit, R., Heij, B.J. (Eds.), *The Climate System*. The Netherlands Lisse, A.A. Balkema Publishers/Swets & Zeitlinger Publishers 2001 p. 33–78.

³⁷Stern, D.I., 2006. Reversal of the trend in global anthropogenic sulfur emissions. *Global Environmental Change* Accepted for publication January, 2006.

³⁸Stern, D.I., Beyond the environmental Kuznets curve: Diffusion of sulfur-emissions-abating technology. *Journal of Environment and Development* 2005b;14(1):101–124.

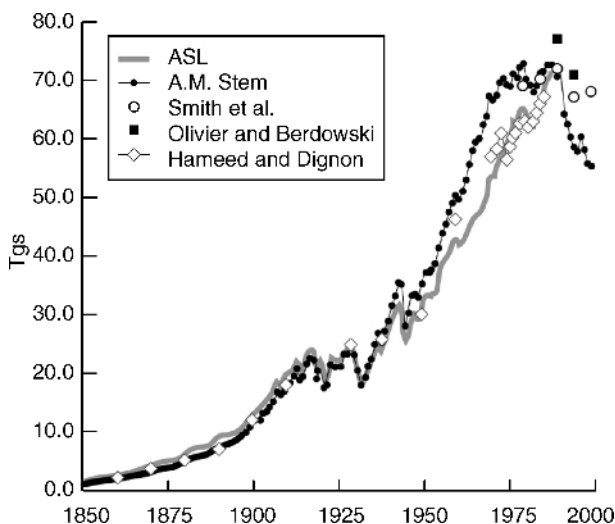


FIGURE 1.6 Estimated global anthropogenic sulfur emissions. *Source:* Adapted from D. I. Stern with permission

hydrofluorocarbons (HFCs) (GWP = 500–12,000 relative to $\text{CO}_2 = 1$ over 100 years), perfluorocarbons (PFCs), (relative GWP = 6500–9000), and sulfur hexafluoride, (SF_6), (relative GWP = 23,900). They are all present in minute quantities, but their concentration in the atmosphere is reportedly growing rapidly (25% annually in aggregate), albeit from an extremely low base (some of the reported increases may be caused by the improved sensitivity of analytical techniques). Since they are extremely stable, they may be able to accumulate in the atmosphere. Their chemical stability and a very high GWP suggest that they should be controlled, as they can contribute to future global warming.

Hansen et al. who have published many papers, some of them rather hysterical in tone, identifying CO_2 as the primary contributor to global warming,³⁹ have also proposed an alternative scenario.⁴⁰ They suggest “rapid warming in recent years has been driven mainly by non- CO_2 greenhouse gases such as chlorofluorocarbons, CH_4 and N_2O , *not by the products of fossil fuel burning, CO_2 and aerosols.*” However, non- CO_2 greenhouse gases are simply not present in sufficient concentration (notwithstanding their very high GWP parameters) to validate this view. Significantly, like so many authors, Hansen et al. make no mention at all of water vapor despite a number of entertaining explanations for global warming.

³⁹See, for example, J. Hansen. Can we defuse the global warming time bomb?; 2003 Available at http://naturescience.com/ns/articles/01-16/ns_jeh.html and many others.

⁴⁰Hansen has often been referred to as the “father of global warming” since his early work on the subject in the 1980s. In fact, he was the originator of the CO_2 theory of GW.

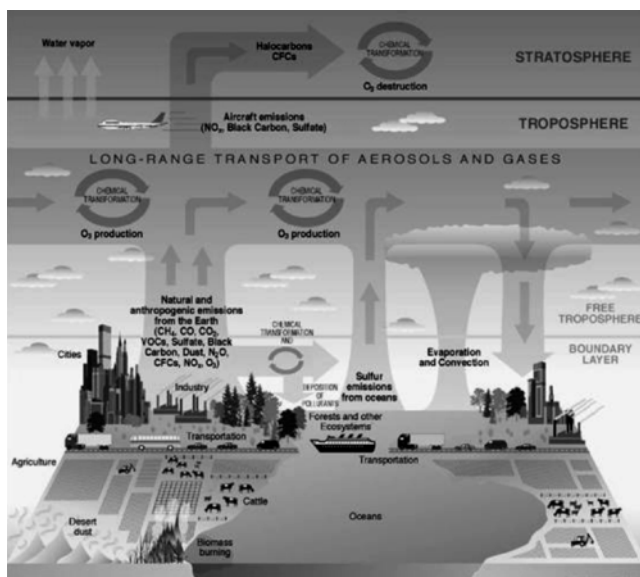


FIGURE 1.7 Representation of atmospheric energy exchanges. *Source:* www.climate-science.gov

Carbon-Based and Other Particulates

Automobiles, trucks, industrial operations, volcanoes, and forest and other fires, in addition to many other sources, emit mostly carbon or carbon-based particulate matter. Automobile gasoline engines emit a surprisingly large volume of very small, invisible particulates that unlike most diesel particulates are too light to easily settle to the ground. They remain entrained in air, and if present in sufficient quantities, (like ash particles after a volcanic eruption), they can darken the skies and exert a material effect on global temperatures by blocking inbound solar radiation, often for years.⁴¹ In smaller and more normal quantities, however, they can exert a major effect on cloud formation and hence may once again block inbound solar radiation, possibly leading to global cooling.

Solar Influences—Insolation and Irradiance

A steady but small increase in solar irradiance over the past 150–200 years,⁴² *probably* related initially to the return to median temperatures following

⁴¹The effects of the Krakatoa and Pinatubo eruptions, along with that of Mt. Saint Helens, appear to have been particularly noticeable.

⁴²See, for example, R.C. Willson, A.V. Mordvinov. Secular total solar irradiance trend during solar cycles 21–23. *Geophysical Research Letters*. 2003;30:3–1 to 3–4; also http://www.space.com/scienceastronomy/sun_output_030320.html. There are many other papers written on solar irradiance.

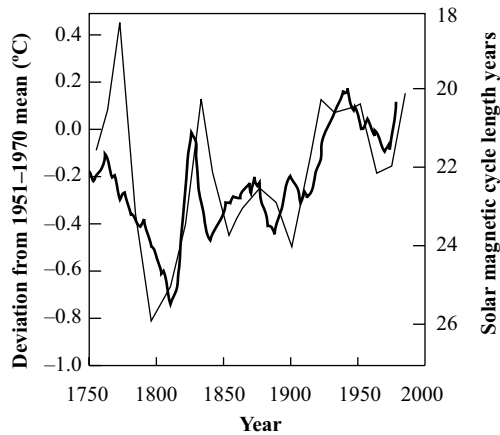


FIGURE 1.8 11-year average Northern Hemisphere temperatures. *Source* Adapted from A. H. Gordon⁴³

the Little Ice Age, has resulted in gradual but accelerating ocean warming with an accompanying increase in atmospheric water vapor and carbon dioxide levels.

Figure 1.8 shows the moving 11-year average of terrestrial Northern Hemisphere temperatures in °C deviation from the 1951–1970 mean (left axis and darker line (Ref. 1). Solar magnetic cycle lengths are shown by the right axis and the lighter line (Ref. 2).

The depiction shows that the Medieval Warming Period was much more “aggressive” than today’s global warming—all without the benefit of anthropogenic CO₂ or, indeed, increases in CO₂ regardless of origin.

Solar irradiance and therefore heating variations are related to solar magnetic cycles (Fig. 1.5 showing the dark line and the left axis show temperature variation,⁴⁴ and the thin line and right axis depicting the variation in solar magnetic field⁴⁵). The two show remarkable correlation despite the inevitable uncertainties in historical data.

This solar warming has been accentuated by the ratcheting or “feedback” acceleration of global warming and ocean heating that results from the increased level of water vapor, with the further result that there is yet more escalation of atmospheric H₂O and CO₂ levels. Water vapor is likely a more important global warming agent than carbon dioxide with a global warming potential lying somewhere between 0.5 and 3.0 (GWP_{CO₂} = 1)⁴⁶ and, more

⁴³Gordon A.H. In *Global Warming – The Continuing Debate*, R. Bate, ed. London: The European Science and Environment Forum, 1998; p. 53–61.

⁴⁴Jones, P.D., Raper, S.C.B., Bradley, R.S., Diaz, H.F., Kelly, P.M. and Wigley, T.M.L., 1986 “Northern Hemisphere surface air temperature variations: 1851–1984.” *Journal of Climate and Applied Meteorology* 25, 161–179 (R).

⁴⁵Baliunas, S. W. Soon. *Astrophysical Journal* 1995;450:896–901.

⁴⁶See for example http://www.eia.doe.gov/cneaf/pubs_html/attf94_v2/appd_d.html and related chapters and appendices, especially Note 22.

importantly, is present in far greater amounts in the atmosphere ($\sim 30,000$ ppmv versus 385 ppmv for CO_2). Incredibly, water vapor is seldom taken into account correctly in global warming discussions or projections and is assumed, implicitly or otherwise, to play a role secondary to that of CO_2 and to be a component of the impact of CO_2 . In fact, the reverse may be true.

Any discussion of the Sun's impact on Earth temperature must include a careful historical perspective. The output from the Sun, whether in the ultraviolet, visible, infrared or other wavelengths is variable, sometimes over lengthy time cycles (centuries) and sometimes over short periods (ranging from a few weeks to a decade). Periods of low energy output from the Sun are usually associated with low solar surface temperatures and these, in turn, appear to correlate with periods of low solar magnetic field strength. The most notable examples were (a) the "Medieval Warm Period" (roughly 600 to 1400 AD, when temperatures were about 1.5°C above today's averages, albeit with great regional variability) and (b) the so-called "Little Ice Age" that extended over at least 300 years between about 1500 and 1800 and peaked in its effect between approximately 1640 and 1720 (but again with very uneven effect around the globe). It also had a very long "tail" — in 1850, temperatures were still approximately 0.7°C below 1950 averages.

The Little Ice Age coincided with an extreme low in the Sun's magnetism and sunspot activity, commonly termed a "Maunder minimum," but this was of much greater length than usual. Solar magnetic field information can now be obtained from direct measurements, but historical values must be determined from ^{14}C radiocarbon measurements in tree rings or ^{10}Be measurements in ice cores. Available data confirm that Maunder minima occur every few centuries apparently coinciding with a reduced brightness of the Sun. The evidence suggests that sustained magnetic maxima also occur less frequently during these solar ebbs. There seems to be little doubt that sustained cold periods have coincided approximately with magnetic minima on numerous occasions over the past 10,000 years.⁴⁷

It is less clear that significant global warming such as the Medieval Warm Period has been associated with magnetic field and sunspot activity maxima, but this seems likely. Computer simulations⁴⁸ of the climate suggest that a change of roughly 0.4% in solar irradiance over many decades would produce a global temperature change of about $+0.5^\circ\text{C}$. Such variations do occur, but there are very few well-documented examples. Correlations are made even more difficult by the uncertainty about the exact rate of surface warming in the

⁴⁷Wigley, T.M.L. P.M. Kelly. Holocene climatic change: ^{14}C wiggles and variations in solar irradiance. *Phil. Trans. Roy. Soc. London (Series A)* 1990;330:547–60; Karlen, W., J. Kuylenstierna. On solar forcing of holocene climate: evidence from scandinavia. *Holocene* 1996;6:359–85

⁴⁸Soon, W.H., E. Posmentier, S.L. Baliunas. Inference of solar irradiance variability from terrestrial temperature changes, 1890–1993: an astrophysical application of the sun-climate connection. *Astrophysical J.*, 1996;472:891–902.

current long-term warming cycle. This is now thought to have begun in the early-to-mid nineteenth century as noted above.

The average warming rate is usually set at 0.5–1.0°C (0.9–1.8°F) per *century*, of which it is possible to conclude that solar irradiance variations account for about one-third to one-half, although there are wide local variations owing to the presence of major population centers (urban “heat islands”) and other sources of disturbance (e.g., agricultural “heat islands” such as crops or large areas of tilled land, major bodies of water, etc.) that render precise measurements and therefore global averaging difficult. Indeed, given the huge diversity of climates globally, it is difficult to attach much meaning to an average global temperature. The observed rate of increase of the average global surface temperature has been higher since about 1970. However, to underline the uncertainties involved, between approximately 1940 and 1970, there was an apparent short-term *cooling* period, with a rate of temperature change of about –0.5°C per *century*. However, between 1890 and 1940 an apparent slow *heating* period with a rate of increase in surface temperatures of about +0.5°C per *century* was observed. It is now becoming apparent that some of these relatively short-term anomalies were caused by variations in atmospheric aerosol levels, especially those involving sulfates and due to either volcanic (e.g., the Krakatoa explosion of 1883) or, perhaps, anthropogenic activity.⁴⁹ Forest fires on a massive scale can exert a similar effect (e.g., the fires in the Western United States and Canada in the Fall of 2003) and produce large amounts of CO₂ and other pollutants.

The Sun may also exert other direct and indirect influences on climate change. For example, changes in ultraviolet irradiance may affect chemical changes in the troposphere and especially the stratosphere that may, in turn, influence global warming.⁵⁰ Changes in the troposphere may influence the lower atmosphere and the sea surface.⁵¹ Furthermore, the Sun’s surface magnetism and its magnetic “wind” influence the galactic cosmic rays impinging on the global geomagnetic field and thus may influence the electrical and chemical properties of the upper atmosphere. This, in turn, may result in changes in cloud microphysics and coverage, with a resulting profound, if temporary, effect both on the amount of solar irradiance reaching the Earth’s surface and on the global warming process.⁵²

In the period since 1950 during which atmospheric CO₂ levels have increased more dramatically than ever previously, there appears to be a significant, but not dominant, “overlay” contribution from carbon dioxide through its capacity as a

⁴⁹Jones, C.D., P.M. Cox, R.L.H. Essery, D.L. Roberts, M.J. Woodage. Strong carbon cycle feedbacks in the climate model with interactive CO₂ and sulphate aerosols. *Geophys. Res. Letters* 2003;30:1479.

⁵⁰Haigh, J.D. The influence of solar variability on climate. *Science* 1996;272:981–84.

⁵¹White, W.B., J. Lean, D.R. Cayan, M.D. Dettinger. Response of global upper ocean temperature to changing solar irradiance. *J. Geophysical Research* 1997;102:3255–66.

⁵²Shaviv, N.J., Jan Veizer. Celestial driver of the phanerozoic climate? *GSA Today* 2003;13(7):4–10.

greenhouse gas (GHG). Methane, much of it coming from natural sources, may also exert a larger effect than once thought before it converts to carbon dioxide. Indeed, carbon dioxide may not have been much of a factor at all prior to about 1950 and only one of several contributing factors since then.

If correct, this new and expanded model calls into doubt an array of proposed remedies for global warming ranging from the Kyoto Treaty to numerous government and individual initiatives worldwide that are focused almost entirely on the control or elimination of carbon dioxide emissions. Although some of those emission reductions can be achieved through energy conservation and thus may result in cost savings (a number of such steps have already been taken, especially in the oil industry), many of the proposed remedies are very costly.

The shift in emphasis from CO₂ to water “vapor and solar” irradiance as the principal causes also means that we must look for additional ‘stalking horses’ to blame for global warming and also must find another set of solutions for the problem. If these new models prove more accurate, it would be very unlikely that we will be able to control global warming itself. A simple reduction in CO₂ (which in itself, as we are all beginning to realize, is a nontrivial achievement) will have little effect on global warming.

Unfortunately, resistance to change in this area is enormous. Numerous individuals, academics, environmental groups, and government departments have built their careers and reputations around assigning the blame for global warming to anthropogenic carbon dioxide, and especially to the industries such as “big oil” that are thought to be the sources of CO₂. Additionally, the worldwide media appear to have accepted, in their usual unquestioning way the notion that carbon dioxide is the guilty party and have been especially vociferous in blaming “big business.” The difficulties in communicating any changes in the commonly held myths about global warming are compounded by the complexity and uncertainty of the data, especially those relating to our distant past, and by the qualitative nature of the phenomena that must be presented and analyzed. The development and presentation of a well-founded and persuasive argument contrary to the “CO₂-only” model is a challenge indeed.

GLOBAL NET PRIMARY PRODUCTIVITY (NPP)

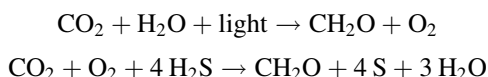
Conspicuously absent in the body of IPCC work is a more comprehensive analysis of the changes in Net Primary Productivity (NPP). Primary production is the growth of all organic compounds from atmospheric or aquatic CO₂, principally through the process of photosynthesis. Given that increased levels of CO₂ and higher concentrations of water vapor are inherent in global warming scenarios and are just what plants and animals need to thrive, the lack of NPP forecasting is seen to be a serious omission.

All oxygen-cycle life on Earth directly or indirectly relies on primary production. The organisms responsible for primary production are known as

primary producers and form the base of the food chain. In the terrestrial environment, these are mainly plants, while in aquatic environments algae and seaweed are primarily responsible. Primary production is distinguished as net after accounting for losses because of cellular respiration.

Primary production is the conversion of energy in the form of electromagnetic radiation into stored chemical energy by living organisms. The main source of this energy is the Sun, but a small fraction of primary production is driven by organisms using the chemical energy of inorganic molecules.

Regardless of the energy source, life forms synthesize complex organic molecules from simpler inorganic compounds such as carbon dioxide (CO₂) and water (H₂O). The following two equations are simplified representations of photosynthesis and chemosynthesis, respectively:



In both cases, the end point is reduced carbohydrate (CH₂O) including molecules such as glucose or other sugars. These relatively simple molecules may be then used to further synthesize more complex molecules, including proteins, complex carbohydrates, lipids, and nucleic acids. Some of this metabolic energy is respired to perform work (gross minus respired = net). Consumption of primary producers by animals transfers these organic molecules and their stored energy up the food chain, in turn fueling the Earth's all living systems.

On the land, almost all primary production is now performed by vascular plants, although a small fraction comes from algae and nonvascular plants, such as mosses and liverworts. Primary production on land is a function of many factors, principally local hydrology and temperature. While plants cover much of the Earth's surface, they are strongly curtailed in arid or polar regions as both light and liquid water are necessary for their growth.

In the oceans, the reverse is true as almost all primary production is performed by algae, with a small fraction contributed by vascular plants and other groups. Algae encompass a diverse range of organisms, ranging from single floating cells to attached seaweeds.

The biosphere is an important part of the carbon cycle, and estimating changes in CO₂ concentration at the global scale is critical to accurately model the CO₂ update.

In one of the few authoritative real-time global monitoring tools at our disposal, NASA collects satellite data on NPP continuously and distributes a complete report every 8 days, 2–3 days after data collection.⁵³ The total primary production for the Earth is currently about 105 Gt C/yr, which translates to 280 Gt of CO₂. Land mass produces about 56% of the current

⁵³Available at <http://earthobservatory.nasa.gov/Newsroom/NPP/npp.html>.

total, but experts believe that the production for a slightly enriched CO₂ atmosphere could increase substantially.⁵⁴

Phytoplankton are tiny marine plants that account for about half of the biosphere's CO₂ uptake and generate about half the planet's oxygen. Their photosynthesis highly depends on micronutrient iron historically delivered to the open sea by dust storms from arid lands. Due to modern agricultural practices and increased terrestrial plant stabilization, the supply of iron nutrients has been reduced by about 35%. Plankton are metabolizing less CO₂ today than they were 10 years ago, but this situation could be rectified quite quickly since every iron atom that we restore can catalyze the photosynthetic removal of over 100,000 molecules of atmospheric CO₂. Replenishing just a few hundred thousand tons of iron by exposing selected coastal sources to wind uptake would pull down billions of tons of CO₂ annually.

With an anthropogenic contribution of 7–8 Gt/yr, this NPP uptake is a significant factor in computer modeling. While the IPCC report does predict a large increase in global NPP, the current modeling underestimates the full production effect, as it does not fully account for nutrient cycling feedbacks. This error in the large magnitude of potential NPP uptake could potentially change the sign the CO₂ climatic feedback mechanism and represents a serious shortcoming of the report. In addition, the 2007 report fails to identify the full benefit that could be derived from relatively simple remediation efforts to restore iron supplies.⁵⁵ It strikes us as something odd that such a “fertile” source of global CO₂ rebalancing would be less than fully developed in the IPCC data.⁵⁶

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

The IPCC was established in 1988 by two United Nations organizations, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), with the purpose of evaluating the risk of climate change brought on by humans. More recently, the *Third Assessment Report: Climate Change* was issued in 2001 and in 2007 followed the *Fourth IPCC Assessment Report*. The reports prepared have focused recent global debate on melting Arctic ice, a precipitous rise in ocean levels, and other possibly calamitous events.

There is a considerable amount of political involvement in shaping the outcome of this debate due to the implicit redistribution of energy

⁵⁴Planktos Answers Grim IPCC Climate Diagnosis. Available at <http://64.233.167.104/search?q=cache:0mIOEBGyv3kJ:www.planktos.com/Newsroom/PlanktosAnswersGrimIPCCClimate-Diagnosis.html+ipcc+report+CO2+surplus&hl=en&ct=clnk&cd=5&gl=us>

⁵⁵Schimel, David Churkina, Galina, Brasswell B.H., Trenbath, James. *Remembrance of Weather Past, Ecosystem Responses to Climate Variability*. Springer Publishing.

⁵⁶Available at <http://www.pnas.org/cgi/content/full/102/50/18052?ck=nck>.

consumption patterns between rich and poor nations that would be required for meaningful remediation. In January 2005, Christopher Landsea resigned from work on the IPCC AR4, saying that he viewed the process “*as both being motivated by pre-conceived agendas and being scientifically unsound.*”⁵⁷

We take issue with the IPCC reports for several reasons. These, principally, relate to the conclusions and predictability they propose to offer, as we believe that the IPCC climate models are far too rudimentary to properly consider important energy transfer agents. Indeed, we do not think that it is technically possible with our limited understanding of global systems to predict such forward-looking findings with confidence. We concur with the following excerpt from the IPCC WGI Second Assessment Report⁵⁸ and believe that it will be applicable for some time:

“The climate system is particularly challenging since it is known that components in the system are inherently chaotic; there are feedbacks that could potentially switch sign, and there are central processes that affect the system in a complicated, non-linear manner. These complex, chaotic, non-linear dynamics are an inherent aspect of the climate system... Our knowledge about the processes, and feedback mechanisms determining them, must be significantly improved in order to extract early signs of such changes from model simulations and observations.”

Others have reported findings or opinions similar to those that we argue here, but their contributions have been systematically ignored by the popular press.^{59,60} Unfortunately, because water vapor is such a powerful conduit for energy transfer, and due to its complex atmospheric interactions of conduction, radiation, and phase change, water is substantially more difficult to model on a global scale than is carbon dioxide. Quoting a 2002 NASA report on GLI-ADEOS-II multispectral radiance data:

“Our inability to adequately model cloud processes is a major obstacle in accurate simulations of global warming scenarios. Low-level clouds and upper-level clouds play different roles in the climate system. How they change through the global warming process is, at present, not fully understood.”⁶¹

Nevertheless, the role of water vapor is not properly represented in the models used to support the IPCC conclusions. Indeed, the impact of

⁵⁷Available at http://sciencepolicy.colorado.edu/prometheus/archives/science_policy_general/000318chris_landsea_leaves.html.

⁵⁸Available at http://www.grida.no/climate/ipcc_tar/wg1/516.htm.

⁵⁹Oltmans, S. 2003. <http://www.cmdl.noaa.gov/hotitems/watervapor.html>.

⁶⁰Hieb, M. 2003. http://www.clearlight.com/~mhieb/WVFossils/greenhouse_data.html.

⁶¹Available at <http://www.google.com/search?hl=en&q=Summary+of+the+GLI+atmospheric+analysis&btnG=Google+Search>.

tropospheric water vapor is minimally represented in the analysis of Global Mean Radiative Forcings in the AR4 WG1 report published in 2007.

Such oversimplifications necessarily require huge caveats with regard to scientific methods used, and these caveats are to be found in the supplementary notations of the report that underscore the incompleteness of the models employed.⁶²

“Structural uncertainties arise from an incomplete understanding of the processes that control particular values or results, for example, when the conceptual framework or model used for analysis does not include all the relevant processes or relationships.”⁶³

IPCC REPORT CONCLUSIONS

Ironically, we find ourselves in partial agreement with the 2001 IPCC report with regard to their conclusions as stated by Work Group I: The Scientific Basis (3.7.4):

“The differences among the CO₂ concentrations projected with the various SRES scenarios considered are larger than the differences caused by inclusion or omission of climate-mediated feedbacks. The range of uptake rates projected by process-based models for any one scenario is, however, considerable, due to uncertainties about (especially) terrestrial ecosystem responses to high CO₂ concentrations, which have not yet been resolved experimentally, and uncertainties about the response of global NPP to changes in climate (Cramer et al., 1999).”

We also find ourselves in agreement with the IPCC conclusion (also 3.7.4) that the short-term variability of CO₂ levels stems from anthropogenic origins, except that we disagree fundamentally as to the effect this extra CO₂ contribution will have on overall global warming.

“In conclusion, anthropogenic CO₂ emissions are virtually certain to be the dominant factor determining CO₂ concentrations throughout the 21st century. The importance of anthropogenic emissions is underlined by the expectation that the proportion of emissions taken up by both ocean and land will decline at high atmospheric CO₂ concentrations (even if absolute uptake by the ocean continues to rise). There is considerable uncertainty in projections of future CO₂ concentration, because of uncertainty about the effects of climate change on the

⁶²Chapter 8, IPCC WG1 AR4 Report.

⁶³Intergovernmental Panel on Climate Change. Available at <http://www.google.com/search?hl=en&sa=X&oi=spell&resnum=0&ct=result&cd=1&q=ar4+wg1+report&spell=1>.

processes determining ocean and land uptake of CO₂. These uncertainties do not negate the main finding that anthropogenic emissions will be the main control.”

FOOTNOTE ON THE IPCC

In the early 1980s James Hansen and a team of scientists at Goddard reached the conclusion that carbon dioxide in the atmosphere would lead directly to global warming. They were worried that world leaders would not take their concerns seriously since many scientists during the 1970's believed we were instead embarking on a period of global cooling.⁶⁴ His testimony to the US Congress in mid 80s is credited by some as leading to the formation of the IPCC by the United Nations in 1988. Although other climatologists had already predicted that a trend would be apparent by 2020, Hansen predicted in a paper published in *Science* (Vol. 244) that the change was already occurring and that there would record high temperatures as early as 1990.

Adopted from Monckton, Hansen's graph is updated to reflect observed temperatures through the end of 2006 (Fig. 1.9). Note that the actual temperatures reported are nearly identical to the “CO₂ Stabilized” outcome. This is the same graph that principally launched the current “Global Warming” mania, but on this evidence it would be considered legitimate by some to conclude that the additional CO₂ that has been generated by anthropogenic factors since that time has had no climatic influence whatsoever.⁶⁵

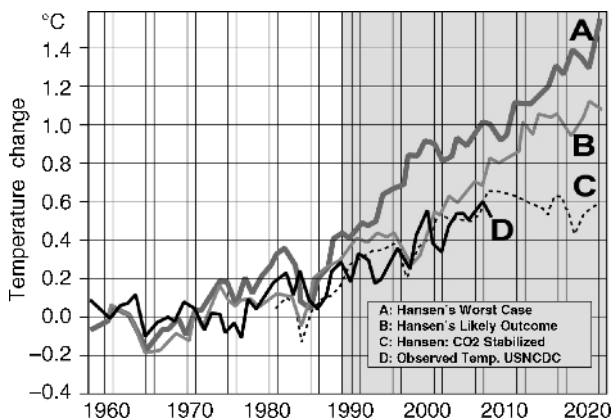


FIGURE 1.9 The uncertainty of predicting climate change: J. Hansen. *Source:* Adopted from C. Monckton: www.telegraph.co.uk/news/graphics/2006/11/05/warm-refs.pdf

⁶⁴The cooling world – global cooling newswave, April 28, 1975.

⁶⁵The Viscount Monckton of Brechley, July 2007. Available at http://en.wikipedia.org/wiki/Christopher_Monckton,_3rd_Viscount_Monckton_of_Brechley.

DEALING WITH GLOBAL WARMING

The world must determine as soon as possible whether the evidence for or against carbon dioxide as a primary causal agent of global warming is sufficient to determine if (a) we move aggressively and expensively toward a carbon-free-fuel or zero-carbon society; (b) stop halfway by emphasizing reduced-carbon fuels; (c) extensively sequester carbon dioxide generated by our use of existing fossil fuel supplies or (d) do nothing until we really understand the mechanism of, and therefore “cure(s)” for, global warming. European countries have already adopted a proactive stance in their precautionary principle approach to energy policy matters.

The stakes are high. We must scrutinize far more carefully the atmospheric models (and their input assumptions) that we hope will help us in making critical decisions about global warming. And we must set politics aside so that the conclusions reached can be based on facts and knowledge.

Accurately modeling the complexity of global weather and the energy exchanges that occur within the atmosphere is a massively complex task. Even with the enormous computing power available today, scientists can only represent a tiny fraction of the dynamic variables that must be included to create accurate predictions. Therefore, existing models are highly abstracted through elaborate simplifications and far-reaching assumptions that can be a huge impact on the results.

While scientists may be able to agree on what a particular model predicts, there remains great debate about which models to use and what assumptions must be made to derive accurate results. At the center of this scientific debate is the carbon dioxide model of global warming that has been the collective world focus for the last 15 years. While it may be true that “scientists agree” on what a given model predicts under certain assumptions, it is little short of fraudulent for the popular press to represent that “all scientists” or even “leading scientists” agree on the model itself. This is the crux of the global warming debate. A model that starts with the presumption that anthropogenic carbon dioxide is the primary cause of global warming is likely to deliver the same conclusion.

Our preferred hypothesis is focused on variations in insolation and in the concentration of atmospheric water vapor related to solar irradiance are the *primary* causes of global warming and that the so-called global warming gases, while potentially significant at much higher atmospheric concentrations, are not currently significant factors in global warming, with the possible exception of a modest contribution from man-made CO₂.

In other words, *the global warming that we are experiencing today is substantially but not totally a normal, natural event*. If this hypothesis is proved to be correct, it has major implications for ongoing and future efforts to control our environment. For example, most remedial actions, including the entire Kyoto Treaty program, are currently directed toward controlling only carbon dioxide emissions. It seems extremely unlikely that this will achieve the

desired result. Although there may be secondary benefits such as the control of particulate emissions or of the acidification of water bodies, these can be controlled at much lower cost by using alternative technologies. We should evaluate the influence of CO₂ from all sources upon the oceans where its effects may be much more serious than in the atmosphere. About one-third of CO₂ ends up in the oceans (the balance being absorbed by plants and soils) where it has reportedly resulted in a significant decrease in ocean pH levels (increase in acidity). The impact of this change is uncertain.

CAN ANYTHING BE DONE?

Realistically, little can be done to control global warming. Hoffert reached essentially the same conclusion,⁶⁶ pointing out that based on present data, immense capital expenditures on emissions-free power generating equipment would be needed before mid-twenty-first century just to limit the global temperature increase to only 1.8°C (3.6°F). The challenge of actually reversing global warming is huge, overwhelming, and probably impossible. Furthermore, it is far from clear that we have sufficient knowledge to select the most appropriate steps to achieve GW reversal. We probably have to “just get used to it” and do what we can to compensate for its effects.

It is clear, as Hoffert points out, that any reduction in CO₂ production — and thus any resulting reduction in the *rate of increase* of atmospheric CO₂ — would have little effect. Since CO₂ is not the only contributor to global warming, it is not evident that a reduction in total atmospheric CO₂ levels would help. This, of course, renders the well-intended Kyoto Treaty largely ineffective.

The best possible alternative focus of our efforts may be to develop measures that will protect us from the effects of global warming. These may include changes in energy use, changing agricultural practices in regions that will experience the effects of GW, building sea walls against anticipated rises in sea level, and developing greater protections against weather changes such as increased (or decreased) rainfall. A primary cause of global warming today is the steady increase in atmospheric water vapor, and this can be reversed (as it seems to have been in the distant past, most recently in the sixteenth and seventeenth centuries) only by a period of global cooling. There is little or nothing that humans can do about it.

We should not be surprised by this conclusion as the world has historically experienced global warming and cooling of a greater magnitude than that observed today and without the contribution of anthropogenic emissions. The mechanism of global warming then was probably much the same as it is today. The present period of warming would have occurred anyway – it is simply a

⁶⁶Hoffert, Martin I. *et al.*, *Science*, November 1, 2002, 981–987. See also an article by Kenneth Chang in *The New York Times* November 4, 2003 that reports on Dr. Hoffert’s work.

natural event – although its magnitude would undoubtedly have been less, particularly in the period since 1950–70.

We should, however, discontinue profligate energy consumption. Conservation is needed to minimize other harmful emissions and to extend the life of our energy resources. We must continue to aggressively pursue alternative “clean energy” technologies (with the exception of hydrogen energy which is not technically or economically viable for most uses). Refocusing our efforts on intelligent alternatives to current options is a worthwhile endeavor. We must also accelerate our research into understanding how plant growth and NPP can contribute to greenhouse gas reductions.

Benefits will undoubtedly accrue from global warming, but the purveyors of “gloom and doom” scenarios who relish the negative have largely ignored these. For instance, in the northern United States and Canada, the Corn Belt will move northward, perhaps permitting corn to be grown reliably as far north as Sault Ste. Marie Michigan, or in Ottawa, Canada, utilizing rich farmland. Areas of the central and northern states, like the Carolinas, may be able to produce two or even three crops of alfalfa per year, rather than one. We must also accelerate our research into understanding how plant growth and NPP can contribute to greenhouse gas reductions.

Historical precedents lend credence to positive effects. During the Medieval Warming Period, central England became a prolific region for wine grape cultivation (much to the delight of the contemporary kings of England), although it certainly is not sufficiently warm for that use today. Given the difficulty of predicting even normal weather patterns, the result of a modest additional rise in ocean temperatures is very difficult to forecast. In this period of global warming, melting polar ice will result in a rise in sea levels, just as has occurred in previous warming episodes (the last being in medieval times). The difference is that this time, people and the results of their activities, ranging from industry to vacation homes to parkland, occupy the coastal regions of most of the developed nations and inundation will result in untold damage and miseries. Similarly, the peoples of most of the less-developed nations, such as Bangladesh, will suffer extreme hardship as a result of permanent flooding. Therefore, any attempts to control atmospheric carbon dioxide seems a little like rearranging the deck chairs on the Titanic. We must, instead, focus on the iceberg.

Like many matters in science, the facts will emerge slowly from our continuously refined efforts to garner the objective truth. Because of the complexity of the global equations we are trying to solve, it is likely that a highly quantified answers that precisely rank the manifold contributors of GW will take many years, if not decades, before scientific unanimity is achieved.

THE KYOTO PROTOCOL

One of the largest failures of the Kyoto Protocol was not requiring many of the less-developed countries – among them China and India – to restrain their CO₂

emissions. This was a result of political pressure from third-world countries. China, India, Brazil, and the countries that make up the former USSR, are highly industrialized with heavy use of coal-fired equipment (which due to its high carbon content, produces more carbon dioxide per unit of energy produced and also per ton of coal burned), represent major CO₂ producers. However, the United States and, on a per-capita basis, Canada are the world's largest offenders; the United States produces about 27% of all carbon emissions and therefore uses an equally intemperate amount of the world's energy resources.⁶⁷

There are many opinions that parallel our views on Kyoto, including those by Tom DeWeese who makes the following assertions with respect to the original treaty protocol:⁶⁸

In fact the Kyoto Protocol is a legally binding international treaty through which industrial nations agree to cut back their energy emissions to 7 percent below 1990 levels. That means that all of the energy growth since 1990 would be rolled back, plus 7 percent more. Such a massive disruption in the American economy, particularly since it has nothing to do with protecting the environment, will devastate this nation.

To meet such drastically-reduced energy standards will—in the short run—cost the United States over one million jobs. Some estimate it will cost over seven million jobs in 14 years. If the treaty sends the economy into a tailspin, as many predict, it will cost even more jobs.

It will cost the average family \$1000 to \$4000 dollars per year in increased energy costs. The cost of food will skyrocket. It has been estimated that in order for the United States to meet such a goal, our gross domestic product will be reduced by \$200 billion annually.

To force down energy use, the Federal government will have to enforce a massive energy tax that will drive up the cost of heating your home by as much as 30 to 40 percent. In all likelihood there will be a tax on gasoline—as high as 60 cents per gallon. There will be consumption taxes and carbon taxes. The Department of Energy has estimated that electricity prices could rise 86 percent—and gasoline prices 53 percent.

Although the Kyoto agreement has served a useful purpose in drawing attention to the very important issue of global warming, the ill-considered and “lunatic fringe” character of its proposals has diluted its impact. Revision of the Kyoto agreement to eliminate some of its idealistic and impractical requirements while applying careful economic analysis of the remainder with visible and demonstrable results will benefit the cause. The present version of

⁶⁷U.S. Climate Change Science Program, Synthesis and Assessment Product 2.2, May 2006, Page ES-4.

⁶⁸DeWeese, Tom. December 16, 2004. <http://www.newswithviews.com/DeWeese/tom23.htm>.

the treaty is unlikely to have *any* visible impact because it targets CO₂ control only, while ignoring the many additional factors causing global warming.

Third-world countries need inexpensive clean energy technology to aid in the development of positive solutions unique to their needs. Currently, there are no fuels that are economically and technically viable with 100% emission-free results. Hydrogen may be clean burning, but it is a relatively poor industrial fuel and its manufacture is energy and pollution intensive. H₂ is acceptable (but inefficient) for combustion equipment and also for stationary fuel cells, but is not acceptable for personal transportation. It is better used for its traditional application – as a chemical feedstock and reducing agent.

Alternative fuels, low- (but not zero-) carbon fuels aiming for 50% reduction in CO₂ emissions, are plentiful. Finally, given the uncertainties regarding the true effectiveness of the Kyoto approach (even if it is formalized in a ratified treaty), it is appropriate to defer consideration of large, capital-intensive “solutions” to the CO₂ problem that may have little impact on global warming.