A RATIONAL LOOK AT CLIMATE CHANGE CONCERNS

AND THE IMPLICATIONS FOR U.S. POWER CONSUMERS

By Kimball Rasmussen | President and CEO, Deseret Power | November 2008, Edition 4.1

"The virtue of what you have written is that it is very clear, and should be easily understood by readers who have no previous familiarity with the arguments."

Comment on this paper by Lord Christopher Walter Monckton
3rd Viscount Monckton of Brenchley
Former Advisor to Prime Minister Margaret Thatcher

"A highly accessible and intelligent evaluation of the CO_2 global warming idea, and the relevant impacts."

Comment on this paper by Dr. Willie Soon
Solar and Stellar Physics Division of the Harvard-Smithsonian Center for Astrophysics
Astronomer at the Mount Wilson Observatory
Senior Scientist of the George Marshall Institute

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Climate Change Legislation Will Put the Nation at Risk—With Imperceptible Results

There is, perhaps, no subject that currently stands greater in importance—not to mention confusion, hype and hysteria—than the topic of climate change (formerly referred to as global warming). Regardless of man's influence on the climate, policies under active debate and consideration could entirely change the way that we produce, and consume, energy to fuel our economy and lifestyle. This issue spans the globe, impacting both developed and developing countries. Whether the planet is in peril, or whether the risk is an artifice, potential climate change legislation will come with inescapable consequences, both intended and unintended; yet, the climate benefits may be negligible.

Many now claim a "consensus"—that global warming is occurring, that man's activities contribute significantly to it, and that the science is settled. The question then centers on what to do. Ideally, we should thoughtfully weigh the cost of any proposed remedy against the anticipated benefit. Good policy, therefore, depends on a thorough understanding of the precise amount of warming we can realistically expect to avoid, and what costs would be required to achieve that avoidance. To speak colloquially, what is the bang for the buck?

The recognized authority on global warming science is found in a series of reports issued by the United Nations Intergovernmental Panel on Climate Change (IPCC). The most recent of these reports—the Fourth Assessment Report (or AR4)—was published in 2007.

For a number of reasons, which I will later describe, there is a good deal of uncertainty inherent in the complex computer models adopted by the IPCC; those models are at best incomplete, and arguably aggressive in terms of climate sensitivity to global warming. The climate is "a complex, non-linear, chaotic object" that defies long-run prediction of its future states.[1] Additionally, several aspects of climate science, as reported or interpreted by the IPCC, are poorly understood (or misunderstood) by much of the public, and sadly, by most policy makers as well.

The IPCC has reached a well-publicized conclusion (which purports to be the "consensus" of modern science) that climate change will likely result in a 3°C increase in temperature by the year 2100 (the IPCC actually forecasts a likely range of temperatures between 2°C and 4.5°C, with 3°C being the most likely estimate). This "increase" is not measured from 2008 average temperatures; rather, it represents anticipated warming from the IPCC-selected "pre-industrial" base year of 1750. As of 2008, a warming of 0.75°C has already occurred, according to Susan Solomon, Co-chair of IPCC *Working Group 1*.[2] So by that view, we can expect an additional 2.25°C between now and the end of the century (or the point in time when CO_2 doubles). The IPCC models that generate these results assume that CO_2 levels in the year 1750 were approximately 275 parts per million (PPM). Therefore, CO_2 levels will double when the accumulations reach 550 PPM. As of 2008, the Earth's atmosphere has reached CO_2 accumulations of approximately 385 PPM, and we could reach 550 PPM near the turn of the next century—in the next 100 years.[3]

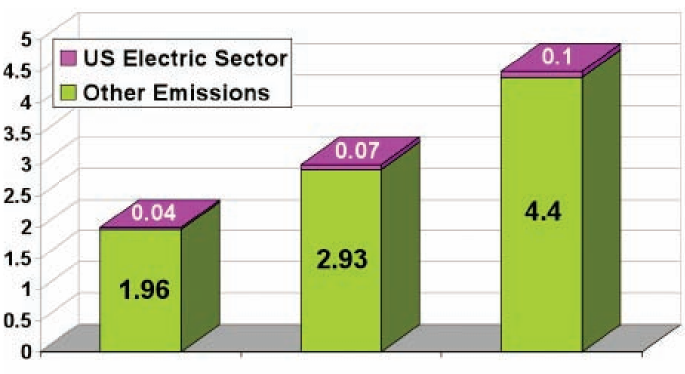
A complete overhaul of the U.S. power sector would only delay seven hundredths of one degree Celsius of warming in the next 100 years.

Assuming the accuracy of the IPCC central estimate of 3°C warming at 550 PPM CO_2, how much of that warming can be avoided by actions, however drastic that we might undertake in the United States? The answer to this question is astonishing. At most, a complete overhaul of the U.S. power sector would only delay seven hundredths of one degree Celsius of

1 Christopher Monckton, *Climate Sensitivity Reconsidered*, 37 Physics and Society 6 (2008), http://www.aps.org/units/fps/newsletters/200807/monckton.cfm.
2 Susan Solomon, presentation to the Norwegian Academy of Sciences, Oslo, Norway, April 2007.
3 See - Potential Impact of a "Carbon Free" U.S. p.7.

warming in the next 100 years. Oh how I wish that all policy makers understood this calculation and the trivial amount of cooling that might occur from the curtailment from U.S. activities—a mere 0.07°C.

Now let's take this idea further: if we were to completely eliminate all carbon emissions from all sources in the U.S.—every car, power plant, factory, and process that in any way combusts coal, gas or oil, in any form—we might expect approximately 0.21°C of temperature reduction over the next century. To reach that calculation I simply recognize that all sources of U.S. CO_2 emissions are approximately three times the emissions from the electric sector alone. Hence, the reduced warming from a complete elimination of all U.S. CO_2 emissions would be about triple the 0.07°C from the electric sector alone or a total of 0.21°C.



Components of Climate Sensitivity Scenarios
Bars indicate the three temperature scenarios for the doubling of CO_2 levels that result in 2, 3 and 4.5°C. "U.S. Electric" caps indicate the small component that might be attributable to the U.S. coal-fired generating fleet.

Some argue that "we must do something" or "we must set the example." To this I would respond in the affirmative: yes, we ought to work in the direction of finding new and renewable resources; yes, we ought to develop new technologies; yes, we should promote the development of "clean coal" through the development of feasible carbon capture and sequestration technologies; and yes, we should embark on a carefully planned nuclear power program. But as we pursue these worthy objectives, let us keep in mind that these will be best achieved with a healthy and wealthy America. At the time of writing this, Congress is considering a $750 billion bailout of the financial industry. The Dow dropped a record 778 points in a single day and further shareholder erosion is likely. Oil is hovering near $100 per barrel, and has recently been above $140 per barrel. The dollar has weakened continuously. With all of these warning signs, we must be careful that we don't further perturb the economy with an ill-advised energy policy calling for drastic carbon reductions that are likely to have no benefit to the environment, and come with enormous expense. Any significant carbon tax or cap-and-trade scheme will damage the economy and possibly bankrupt individuals and companies. If we set that sort of crippling example, no sensible developing country would follow our lead. We need to set an example of progress through technology, efficiency and conservation that promotes a healthy United States, and thereby a healthy world.

The U.S. cannot operate in a vacuum! As we enact domestic policies that hamper U.S. business activity, we might reasonably expect the affected U.S. industries to re-emerge internationally. This outmigration of U.S. industry is already happening. And since the OECD nations (or developed nations, including the United States) have a stable carbon footprint, while the non-OECD nations (including China) are rapidly growing their CO_2 emissions (as they grow industrial activity), the developed countries tend to have low CO_2 emissions per unit of GDP, while the developing countries have relatively higher emissions. For instance, in 2004, the U.S. emitted only 516 tons of CO_2 per million dollars of GDP, while China emitted 2,222 tons of CO_2 per million dollars of GDP.[4]

With China emitting nearly quadruple the CO_2 per unit of GDP, it should not be surprising to expect that an outmigration of U.S. industry would result in a net increase in worldwide CO_2 emissions, as well as other pollutants, as industry re-emerges in developing countries where environmental regulations are much less stringent.

[4] Wikipedia, *List of Countries by ratio of GDP by Carbon Dioxide Emissions*, http://en.wikipedia.org/wiki/List_of_countries_by_ratio_of_GDP_to_carbon_dioxide_emissions (last updated 25 September, 2008).

Climate change legislation was considered (and rejected) in the U.S. Senate in 2008. Yet, there is a commitment to pursue carbon legislation in the next Congress. Credible estimates show carbon “cap-and-trade” settling at a price of about $50 per ton of CO_2. At this rate, a fully implemented cap-and-trade scheme could cost the U.S. electric industry a staggering $100 billion per year—enough money to retire the net book value of every coal-fired plant in America within 3-1/2 years. Another $100 billion would hit transportation, and a slightly lesser amount would fall upon U.S. industry. Now suppose that you were the owner of a carbon-intense business. The carbon tax (or cap-and-trade) might be just the thing to put you out of business. It might become prudent to close your business in the U.S., engage in selling carbon credits because of your newfound “reductions,” and then simply rebuild the business internationally. Does this sound outrageous? Think again. The company I work for would face a carbon cost of $250,000,000 per year; yet our current annual revenues are about $240,000,000.[5] We might be better off to simply close our doors.

Congress needs to weigh this, and other unintended consequences, carefully before enacting any legislation.

Coal-fired generation is the backbone of the current U.S. electricity system, and the most plentiful energy resource in the U.S. Coal-fired electricity accounts for more than two trillion kWh annually, serving nearly half of the entire electric needs of the U.S.

Coal is also our lowest-cost form of energy. Coal energy today costs about one-third the price of natural gas, and natural gas is about one-third the price of oil. As we push the limits on natural gas, it will approach the clearing price of oil (that is to say, it will triple in price). If we refuse to build new coal generation, and consistently badger and hamper existing sources, we will see electric energy prices move toward the price of oil as well—a two- to three-fold increase of the fuel component. In short, we could expect the variable component of electric energy prices to double or triple.

There is also a pronounced effect on electric capacity costs (or fixed costs). Currently the entire U.S. coal-based electric generation fleet has a nameplate capacity of 335,830 MW and a book value of $350 billion.[6] If the U.S. coal-fired fleet were replaced with nuclear, it would cost about $1.8 trillion. If it were replaced with solar it would cost $12.5 trillion, or more. Replacing the baseload system is both impractical and would be costly almost beyond comprehension. Given that such measures would not make a discernable dent in the anticipated warming predicted by the IPCC climate change models, misguided policies such as immediate carbon taxes, or cap-and-trade programs, will grievously damage the U.S. economy. The only effect of these programs, for the foreseeable future, would be to accelerate the out-migration of heavy industry to foreign locations, crippling the American economy and ultimately threatening the research and development necessary to design, refine, and deploy economically feasible non-carbon resources on a meaningful scale.

[5] Carbon costs based on $49/ton as indicated in a report by William W. Beach et al., *The Economic Costs Of The Lieberman–Warner Climate Change Legislation*, The Heritage Center for Data Analysis 15 (2008). The current revenue is approximately $240,000,000, as reported in the Deseret Power 2007 annual report.
[6] Energy Information Administration, Official Energy Statistics from the U.S. Government, (2006).

Goals of This Paper

The primary goal of this paper is to apply an understanding of climate change to a prudent policy path. I will attempt to establish the following concepts:

- If the U.S. chooses an energy policy that eliminates CO_2 emissions from fossil-fueled electricity, with carbon capture and storage, as well as renewable energy replacements, the resulting reduction in global warming over the next 100 years can only be expected to achieve a few hundredths of one degree Celsius—scarcely a measurable number.

- The impact of a radical de-carbonization of our electric infrastructure will be severe, both financially and operationally.

  - Carbon capture technology is not ready for prime time. Once this technology matures it will cause an increase of 50% of generation investment and development to provide the power to run the capture process.

  - Carbon sequestration is also problematic, and may require a network of pipelines that rival or exceed the entire existing oil and natural gas pipeline network.

  - Carbon tax, or cap-and-trade, could result in doubling (or more) the cost of electricity in certain regions of the country. This will result in huge dislocations and disparate economic impacts.

  - The world is facing an incredible demand for new energy sources over the next 50 years. The need can only be met with a full palette of resources, which should include nuclear, clean coal, gas, renewables, conservation, and every form of generation possible.

  - It is virtually impossible in terms of cost, attainability and operability to expect to replace the entire fleet of U.S. fossil-fuel based electric generation with renewable energy inside of a short time frame, such as ten years as suggested by some.

- Legislative proposals must be evaluated in terms of intended and unintended consequences.

  - The cost of carbon legislation is approximately equal to the cost of all U.S. oil imports; yet the benefits are at best highly uncertain, and at the worst non-existent.

  - One possible outcome of U.S. climate legislation is the out-migration of U.S. business to China and other developing nations where less stringent environmental regulations could result in a net increase in global emissions. This could actually leave the planet's atmosphere in a worse condition.

  - One current example of an unintended consequence of a well-intentioned environmental action is the death toll that has resulted from the ban of DDT. Millions of lives have been lost to malaria, yet recently (2006) the World Health Organization gave DDT a clean bill of health for controlling malaria.

In support of the primary goal of this paper, we must understand the causes and mechanisms of climate change. The key elements that lead to an understanding of climate change are as follows:

> *Global climate is determined by the radiation balance of the planet. There are three fundamental ways the Earth's radiation balance can change, thereby causing a climate change:*
>
> *(1) changing the incoming solar radiation (e.g., by changes in the Earth's orbit or in the Sun itself),*

(2) changing the fraction of solar radiation that is reflected (this fraction is called the albedo—it can be changed, for example, by changes in cloud cover, small particles called aerosols or land cover), and

(3) altering the long-wave energy radiated (e.g., by changes in greenhouse gas concentrations).

In addition, local climate also depends on how heat is distributed by winds and ocean currents.[7]

All of these factors have played a role in past climate changes. The earth's temperature response to all these factors is known as climate sensitivity. This concept is critical to an evaluation of climate change, and so this also will be discussed in some detail.

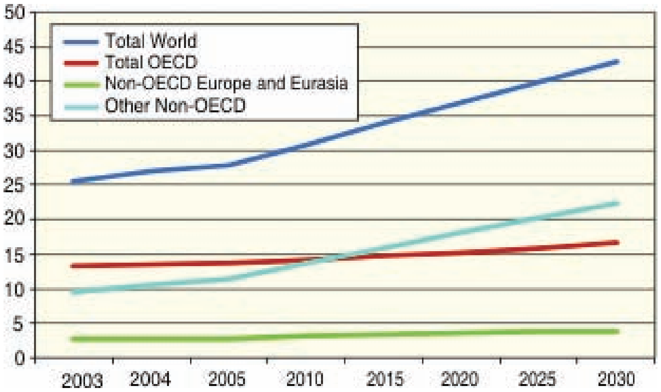
Further, we will discuss and dispel a number of climate change myths, inconsistencies and misunderstandings.

[7] Intergovernmental Panel on Climate Change, *Working Group 1: The Physical Science Basis of Climate Change*, 4th Assessment Report Ch. 6 (2007).

Section I - Potential Impact of a "Carbon Free" U.S.

The U.S. power sector emits about 2 billion tons of CO_2 per year, while the world emits 30 billion tons of CO_2 per year.[8] The emission rates of OECD and non-OECD countries are shown below:[9]

Figure 5. World Carbon Dioxide Emissions by Region, 2003-2030 (Billion Metric Tons of Carbon Dioxide



Note: Explanations for OECD and Non-OECD can be found on EIA's web site: http://www.eia.doe.gov/oiaf/ieo/pdf/appl.pdf
Source: Energy Information Administration, Internal Energy Outlook 2007 (Washington, DC, May 2007).

Note that OECD stands for the Organization for Economic Cooperation and Development. The United States is a founding member of this organization. The OECD nations are considered "developed nations" and non-OECD nations are commonly referred to as "developing nations." China is one of the most prominent of the non-OECD nations.

If we focus on the central IPCC scenario of a doubling of CO_2 atmospheric accumulation (by about the year 2100), how much can we expect to reduce that accumulation by going U.S.-carbon-free? At most, elimination of the U.S. power sector would reduce the 550 PPM case down to 541 PPM.[10]

Note that the assumption here is that the U.S. power sector will emit approximately 2/37 of world emissions for the next two decades. It is less clear what will happen over the next 100 years. This ratio of 2/37 is actually an overstatement of the U.S. contribution to emissions 100 years from today, especially in light of the graphic discussion of the relative flat-line CO_2 emission rate of OECD countries (such as the US) versus the escalating rate of CO_2 emission rate of non-OECD nations, such as China. The day that the world reaches 550 PPM, the contribution from the U.S. power sector will very likely be a much smaller number than 9 PPM. But for the sake of argument, let us proceed on the basis of 9 PPM, for a net of 541 PPM.

The change in temperature is equal to the climate sensitivity factor multiplied by the change in radiative forcing, or:

$$\Delta T = CS * \Delta F$$

$$= 0.81°C/(W/m^2) * 5.35 * \ln(550 \text{ PPM}/541 \text{ PPM})$$

$$= 0.07°C$$

This equation is based on adopting the IPCC "mid" climate sensitivity value of 0.81°C/(W/m^2) from IPCC AR4. The radiative forcing concept is consistent with IPCC findings, and is discussed later in this paper.[11]

Using the IPCC formulae (see above) the predictive climate response over the next 100 years is a temperature decrease of a mere 0.07°C. It is an extremely small number, and drastically demonstrates that we cannot fix the world's problem through U.S. policy alone.

Even if we were to shut down all of our fossil-fueled electricity—which some would advocate—and we did so immediately (or within the next ten years) we could only reduce world temperatures by a miniscule amount—a scarcely measurable 0.07°C over the next one hundred years! I would hope that Congress could know this, and become educated in this regard, before they launch us into an irreversible policy that cannot achieve its stated goal.

[8] Energy Information Administration, Table 9: *U.S. Carbon Dioxide Emissions from Electricity Power Section*, Energy Consumption International Energy Outlook (2007), www.eia.doe.gov; EIA, U.S. Carbon Dioxide Emission from Energy and Industry.
[9] Shown as a reasonable straight line equivalent of the ever-increasing trend of CO_2 emissions.
[10] Calculated as follows: 550 PPM - (2/37)*(550-385) PPM= 541 PPM
[11] See page 27 of this paper.

Section II - Policy Options and Feasibility—Doing the Math and Facing Reality

How to fit the needs of consumers and protect the environment are the top concerns on everyone's mind. Many are just not educated about the various options and their subsequent results. We will now explore some of the most commonly proposed solutions and explain their true feasibility.

Carbon Capture

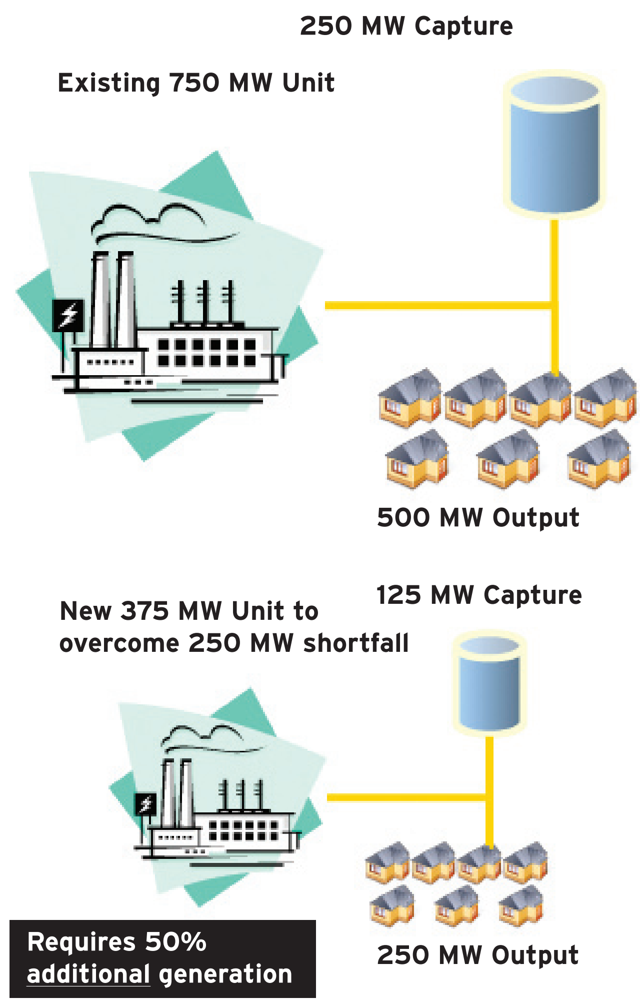
If technology to capture and sequester CO_2 were commercially developed, the cap-and-trade price would moderate to reflect the all-in cost of such technology. Unfortunately, there are no commercially proven carbon capture facilities, other than mini test facilities, and these only capture a small portion of the actual stack output. So pricing is dubious. Still, it is not hard to imagine that a full, commercial facility could easily cost more than the coal-fired plant whose CO_2 it is capturing (especially when you consider that "vintage" pricing of the U.S. coal fleet is less than one-fourth to one-half the cost of a modern facility).

To further complicate matters, the "capture" process is only half the equation. The next step in the carbon-free world is to sequester the carbon. There are few sites where this can be done effectively. It has been estimated that the sequestration effort would involve a network of pipelines that would rival the existing interstate natural gas network. The investment would be staggering. Of course the sequestration sites would require power as well, and careful monitoring to prevent leaks. All in all, it is easy to imagine an investment that would double or triple the cost of electricity in the U.S.

> **"...the average cost of electricity in the United States could triple."**

It has been estimated that carbon capture will require about one-third of the output of the associated electric generation facility. For example, a 750 MW coal-fired electric generator would sacrifice 250 MW to the carbon capture process. This would then require a new 375 MW facility (which would forfeit 125 MW to its own carbon capture) to net back the original loss of 250 MW. Hence, carbon capture of the existing 335,830 MW of U.S. coal-fired generation capacity would be accomplished with 168,000 MW of the new "clean coal" facilities.[12] The cost of such an undertaking would be at least \$4 million per megawatt, or \$670 billion. This investment is nearly double the entire book value of all existing coal-fired generators. When combined with the additional fuel costs, the average cost of electricity in the United States could triple.

Example of Carbon Capture Resource Additions



[12] Energy Information Administration, *Electric Power Annual*, Official Energy Statistics from the U.S. Government, (2006).

Cap-and-Trade

The Cap-and-Trade concept is being seriously considered by Congress as a means to let the free market allocate an allowable level of emissions. The concept goes like this: all CO_2 emitters will be given a cap in their level of emissions. If they are able to operate below the cap then they can trade (or sell) their surplus to another party that will buy in order to operate above its cap. Proponents of this system point to the "successful" cap-and-trade program that was used to deal with SO_2 allowances under the Clean Air Act. (Note that many buyers of SO_2 allowances might debate the success of this program—at one point allowances soared to prices in excess of $1,500 per ton; whereas today they have softened to less than one tenth of that amount). Many politicians favor the cap-and-trade approach over a simple carbon tax because—after all—it is not a "tax" (although it certainly acts like one). Proponents of cap-and-trade argue that this is a market-based solution.

One significant difference between a cap-and-trade of CO_2 allowances, versus SO_2 allowances, is the availability of technological backstop opportunities. Today there are proven technologies to lower one's emissions of SO_2. The emitter can make an economic decision between buying market-based allowances, or simply adding emission controls through capital investment. This technological opportunity does not exist for CO_2. Technology is being explored to capture and sequester CO_2, but there are no proven commercial-scale successes to date.

What about the costs of cap-and-trade? A study conducted by the Heritage Foundation (based on other similar studies done by M.I.T., D.O.E., Charles River Associates, and others) suggests that cap-and-trade of CO_2 will settle at a price in the range of $49 to $130 per ton.[13] This translates to about 5 cents to 13 cents per kWh for electricity in areas that are served by coal-fired plants, and about 50 cents to $1.30 per gallon of gasoline. Since coal serves about 50% of the electric energy in the U.S., we might expect power bills to go up as much as 100%, or more in some regions.

The United States imports about 5 billion barrels of oil per year, and we emit about 6 billion tons of CO_2.[14] Given that oil has recently traded at $50 to $130 per barrel, and if carbon tax (or cap-and-trade settling price) hits a similar range of $49 to $100 per ton, oil and carbon would be roughly equivalent as to both price and volume. Put another way, all of the money that we spend on oil imports would effectively double with a carbon cap-and-trade. This hits all aspects of the economy, and weakens the dollar, pushing us into a spiral where we must compete on the world market for oil with our weakened dollar. This is particularly difficult since our economy uses oil at an intensity that is five times the world average, per capita. It is no wonder that the Senate could not muster the votes in 2008 to support the Boxer-Lieberman-Warner Climate Security Act. The costs were simply too high, especially in light of the $4-per-gallon gasoline that existed at that time.

The same Heritage Foundation study highlights the regional differences in carbon emissions per household across America. The differences are stunning. For example, Utah emits nearly 10 times the carbon, per household, compared to California. Some states, such as Vermont, have nearly zero carbon emissions (electric sector). Others have very high carbon intensity, such as Wyoming. Any cap-and-trade program, or carbon tax, will have immensely different economic impacts on some states versus other states. This disparity needs to be addressed. There are similar disparities amongst utilities and energy providers within individual states. Legislation needs to cautiously address these potential impacts; otherwise, bankruptcies and huge financial losses will result.

Commenting on the proposed Lieberman-Warner Climate Security Act legislation, Andy Weissman, principal author of the *Energy Business Watch*, and a nationally recognized authority on energy issues,

[13] William W. Beach et al., *The Economic Costs Of The Lieberman–Warner Climate Change Legislation*, The Heritage Center for Data Analysis 15 (2008).
[14] Energy Information Administration, *Emissions of Greenhouse Gasses Reports*, Official Energy Statistics from the U.S. Government, (2007), http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html.

noted that there has been no study that adequately addresses and evaluates the incredible shift toward natural gas that will result from the Lieberman-Warner Act. He then went on to say, "We do not appreciate the extent by which the world can rapidly change, and that government has little idea of what…it is really doing." I attended the seminar the day that Mr. Weissman made that statement—the same day that the DOW dropped 778 points due to the crisis in the financial sector. Incidentally, a subsequent speaker at that same seminar, a Vice President of CoBank, identified the financial sector crisis as acting in "total disregard for basic lending and credit parameters." I wondered if we are not, likewise, pursuing a "carbon" path with the same level of disregard for best practices in the energy industry.

No Silver Bullet Solution

Ultimately the carbon challenge must be solved through technology, and that is most likely to come from a healthy and wealthy U.S. If we crush the U.S. economy, we likewise strangle our hopes for American innovation.

With no technology to significantly and inexpensively capture and sequester carbon dioxide, the only other way to generate carbon credits is through changed behavior. This is, of course, one of the goals of so-called carbon legislation. And there are positive examples such as conservation, fuel switching, and renewable resources, to name a few. But according to the "EPRI Prism" study done by the Electric Power Research Institute, we are going to need all forms of energy in order to keep pace with demand.[15] There is no silver bullet solution.

A national campaign known as *Our Energy, Our Future* has been launched asking these basic questions of elected representatives:[16]

- Capacity – What is your plan to make sure we have the electricity we'll need in the future?
- Technology – What are you doing to speed the development of new technology which will allow me to have the electric power I need?
- Affordability – How much is all this going to increase my electric bill and what will you do to make it affordable?

My recommendations would be:

- Capacity – Protect the existing base of resources, while aggressively pursuing all forms of new energy, including renewables, clean coal, nuclear, and other sources.[17]

- Technology – Earmark funds to develop new technologies, including the possibility of carbon capture and sequestration, improved photovoltaic cells, efficient wind turbines, and improved and secure nuclear facilities. All of these technologies will have the greatest chance of coming forth if we can keep America in a relatively affluent circumstance, which affords the greatest opportunity for research and development. We can be the world leader in technical innovation of this sort, but we will damage this opportunity if we engage in carbon policy that bankrupts and disrupts those that are providing electricity today.

- Affordability – Protect the affordability of our existing base of electric production in the U.S., while developing reasonable amounts of renewable resources (something in the range of one-fourth to one-half of the growth rate of new resources). There is no significant climate benefit to be gained by attempting to eliminate U.S. fossil-fueled electricity. As discussed in this paper, the most probable temperature reduction that can be expected from a complete (and impossible) elimination of these fossil-fueled resources is a negligible 0.07°C. There is no adequate "gain" for the "pain" in eliminating our valuable legacy of reliable base-load coal, and efficient natural gas peaking resources. This base provides the most reliable and affordable

[15] Electric Power Research Institute, *The Power to Reduce CO_2 Emissions: The Full Portfolio Discussion Paper*, prepared for the EPRI 2007 Summer Seminar.
[16] www.ourenergy.coop (last visited 20 October, 2008).
[17] This topic is further delineated in the Electric Power Research Institute "PRISM" study.

electricity in the world. We need to build on this base as we add new resources that meet the test of market opportunity, while balancing the needs of the environment.

Wind and Solar Power's "Iffy" Potential

Al Gore has launched a campaign that calls for a complete elimination of carbon-based resources within 10 years—a lofty goal indeed! Mr. Gore likens this project to the JFK moon landing goal of the 1960's, and further describes a carbon-free economy as the common thread that will solve all of our ills—economic, environmental and strategic. To the casual observer (and voter) this sounds very attractive. And the clean, renewable, sustainable resources are touted as "free" energy. So what's not to like about this?

We must first understand what the "carbon free" resource alternatives are. The list is very short, and is dominated by wind and solar. Unfortunately, both of those resources have impossibly poor capacity availability records, and limited siting potential. The best new wind sites tend to be located in the Midwest and Texas, with poor availability of electrical transmission lines. And what of the costs? Wind generators are escalating in cost, and they require subsidies and tax incentives to compete with coal-fired resources. The wind developers know this, and for this reason they consistently pursue Federal assistance for wind development, without which they could not compete.

Regardless of price comparisons (which tend to favor coal) there is also a more compelling argument for the operational benefits of natural gas and base-load coal generation, when compared to wind. Gas-fired electricity is typically dispatchable (which means that system operators can ramp these resources up and down to follow actual load characteristics). Coal has proven its capacity to meet base-load demand requirements. Wind, on the other hand, tends to have an output profile opposite of the electric customer demand profile. During the summer months, wind generation is low during high demand times, and can be shown to reach maximum generation when power demands are down.

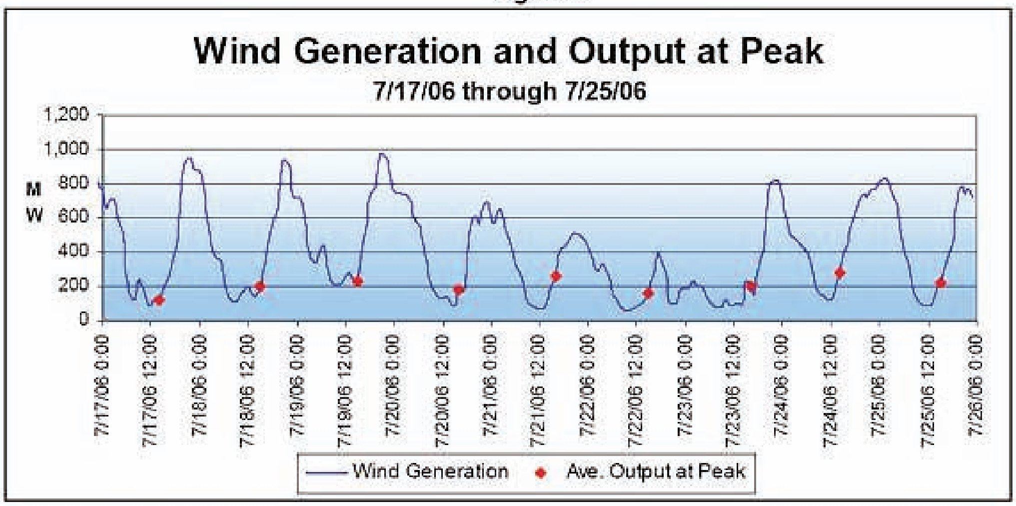
Further, there are significant risks in introducing large amounts of wind power into energy markets. Wind's unpredictable nature tends to destabilize the energy grid and adds volatility to regional energy markets. Dampening these negative effects requires the development of a "shadow grid" consisting of fossil-fueled power plants (particularly gas peaking units) which the wind resources were meant to eliminate. This duplication of costs would be forced onto consumers.

Consider the following quote from the California Independent System Operator (ISO), based on the "2008 Summer Loads and Resources Operations Preparedness Assessment" dated April 28, 2008:

> *California is a national leader in the development of renewable resources. . . . Because California has large quantities of renewable resources already on-line, a significant amount of historical data is available to accurately model and forecast future performance of the various types of renewable resources.*
>
> *Wind generation presents . . . significant operational challenges. Wind generation energy production is extremely variable, and in California, it often produces its highest energy output when the demand for power is at a low point. . . .Typically, during the summer, wind generation peaks when the total system load is low and is at its lowest production levels when the total system load is high.*

The California ISO then produced this graphic:

Figure 5



In the chart above, the blue curve indicates the actual composite wind energy output profile for the entire state of California. The red dots indicate the time of day for the California peak for each day between 7/17/06 through 7/25/06. This period is the peak week for the State as well. The wind "capacity" available at peak demand times is about 200 MW. In other words, wind power is simply not able to match the peak demand requirement. The maximum wind generation is about 1,000 MW, but this occurs off peak. The "nameplate" capacity of these wind generators is about 2,600 MW. Hence, only about 10% (or less) of the wind "capacity" was actually available to meet the peak demand.

The national average production of wind is a meager 22% capacity factor. This means that the wind generator—on average—only produces 22% of its nameplate rating, and most of that is not available during peak demands. Of course the generator will produce close to 100% during brief periods of high wind, and then close to 0% when winds are low (a typical situation during peak-load periods.) For these reasons—the lack of dispatchability and the unpredictability of wind—there is a practical limit to how much wind energy can be efficiently utilized in an electric grid, while still maintaining reliability.

Even if wind could overcome financial and operational challenges, is there any way that we can build enough wind to displace the current base of coal-, gas- and oil-fired electricity? As of 2007, the U.S. produced (and consumed) 2 billion MWh of coal-fired electricity; 893 million MWh of gas-fired electricity; and 66 million MWh of oil-fired electricity. Add to that an expected growth of 2.4% per year, and the ten-year target for this plan of renewable energy becomes 3.7 billion MWh to be produced by newly installed renewable resources. Can we do it?

Consider our track record. We have increased the U.S. base of wind power by a compounded rate of 30% per year for each of the last 5 years. We actually increased the base in 2007 alone by an impressive 46%. So we are making tremendous strides, and have now overtaken Germany as the world leader in wind energy. Today the U.S. has 16,900 MW of wind capacity and more than 32 million MWh of wind energy.[18]

So how much additional wind energy is needed to displace our base of fossil-fueled electricity within the next ten years? We would have to duplicate the entire U.S. installed wind energy system—all 16,900 MW, not once, not twice, but 116 times, or once every 31 days for the next ten years. Obviously that is an impossible task.

Does solar energy promise to substantially meet our needs in the next ten years? Currently solar energy is seriously lagging behind wind energy. It is much more expensive, and has made much less penetration

[18] Energy Information Administration, Table 3: *Electricity Net Generation from Renewable Energy by Energy Use Sector and Energy Source*, Renewable Energy Consumption and Electricity Preliminary 2007 Statistics (2007), http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table3.html.

in terms of installed capacity. However, solar energy has the advantage over wind in terms of coinciding better with daytime and summer peak demands. If the cost of photovoltaic cells can come down (and they probably will), eventually this could be a technology that finds its way onto many a rooftop. But where are we today? The single largest, newest, state-of-the-art solar facility in North America (and third largest solar energy output in the world) was recently installed at Nellis Air Force Base.[19]

Nellis Air Force Base Solar Power System

The impressive system at Nellis AFB rests on 140 acres near sunny Las Vegas, Nevada. Installation was complete in December 2007. The capital investment is listed by Nellis AFB at $100 million. The expected output is between 25,000,000 kWh and 30,000,000 kWh per year.

How many of these systems could be built in the U.S.? This is the first and largest such facility in North America. Could we site and build 100 of these? 1,000? It turns out that, in order to meet our ten-year goal, we would need to build 1,039 of these facilities per month for the next ten years. This incomprehensible build-out would rack up a capital investment (assuming no inflation or upward cost pressure, in spite of the horrendous demand) of $12.5 trillion dollars. The U.S. national debt now exceeds $10 trillion, and gobbles up 37% of U.S. GDP.[20] By comparison, this phenomenal solar investment is equal to 125% of our national debt. And this assumes that we could somehow learn to live on energy that is only available when the Sun is shining, or that we have some sort of amazing breakthrough in battery technology (which of course would add to the cost), and that we could build high-voltage transmission from the desert Southwest to most of the rest of the country (a siting issue). Assuming a modest 7% return on investment (a typical Investor Owned Utility would demand a much larger return) the capital investment of each such solar facility would amortize at a staggering $268 per MWh, between triple and quadruple the existing household electric rate's across the U.S.

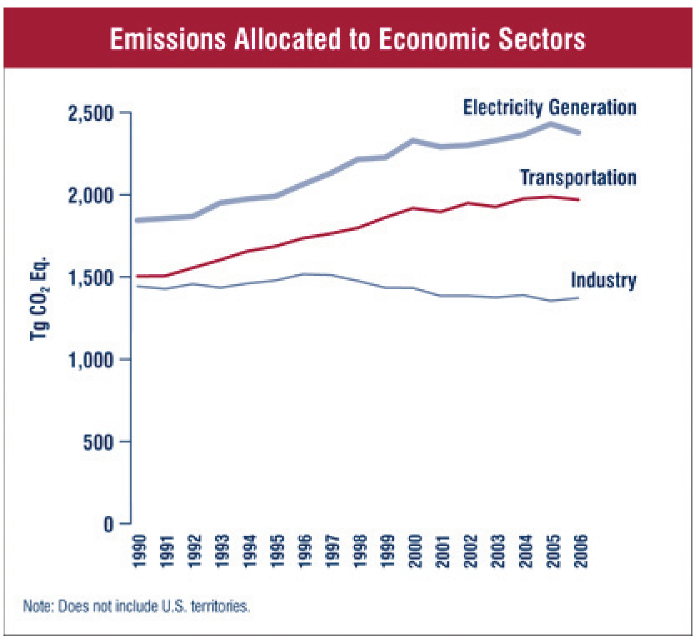
Combining both sources to reach the electricity needs of the U.S. is likewise impossible. The cost of such a venture would be equally unfeasible as using only one source to replace all fossil-fueled electricity.
All of this also assumes that we could even stabilize the electric grid in such a scenario—which we cannot. The Electric Power Research Institute, as well as all mainstream industry experts, considers such a scenario as impossible and ridiculous. In addition, if we eliminate our fossil-fueled resources, we do not magically eliminate the associated debt and capital investment.

[19] Nellis Air Fore Base, http://www.nellis.af.mil/shared/media/document/AFD-080117-043.pdf (last accessed 20 October 2008).
[20] Treasury Direct, *The Debt to the Penny and Who Holds It,* http://www.treasurydirect.gov/NP/BPDLogin?application=np; Katherine Baicker, *Fiscal Challenges: Health Care, Taxes, and Beyond*, Council of Economic Advisers, http://www.whitehouse.gov/cea/cea-fc-20051201.html (last accessed 31 Oct. 2008).

Section III – Intended and Unintended Consequences of Climate Change and Environmentalism

Out-Migration of Industry and Manufacturing

A troubling "changed behavior" that will be a likely result of U.S. carbon control legislation is the exodus of U.S. industry and manufacturing to China, Indonesia, and other parts of the world. Even without carbon legislation this out-migration is already happening. With carbon legislation, the motivation to relocate will become even stronger. Out-migration will accelerate. Consider this graphic from the EPA Website:[21]



For the years 2000 through 2006, note that the Electric and Transportation sectors are trending upward, while the third sector—Industry—is actually trending downward in total CO_2 emissions. This is not due to industrial efficiency, but rather is evidence that the U.S. is literally losing its "hard" industry and manufacturing capacity to China, Indonesia, and other parts of the world. This has an obvious impact on the U.S. economy, but it also has a less obvious—though serious—impact on the global environment. As these industries relocate to developing countries, they are free to build plants with less stringent environmental regulations. So the exodus of a particular industry might save tons of CO_2 emissions in the U.S., but it will reinstate itself internationally with even higher net emissions—anywhere in the range of 1 to 5 times the rate of the comparable U.S. facility. For instance, the U.S. emits 516 metric tons of CO_2 per million dollars of GDP. China emits 2,222 metric tons of CO_2 per million dollars of GDP, and Russia emits 2,577 metric tons of CO_2 per million dollars of GDP.[22] If we close down an industry in the U.S. that is emitting 516 metric tons of CO_2, that same industry, producing the same number of widgets, could be rebuilt in a developing nation such as China and emit four times the CO_2. There is an obvious global disbenefit of that strategy. But such is the track record of the developing world. So this savings in U.S. CO_2 is most likely to result in a net increase in global emissions.

Under legislation such as the Boxer-Lieberman-Warner Climate Security Act, industry will have the incentive to shut down or curtail operations, thus generating "carbon credits" which could then be traded for large sums of money. In many cases, the value of the credits could rival or exceed the profitability of a business. This makes a business closure a much easier decision. In the U.S. we would see numerous business closures, resulting in apparent carbon reductions. We would pat ourselves on the back for reaching our target reductions in CO_2 emissions, but those U.S. business closures would most likely pop up elsewhere in the world where environmental regulations are less stringent. The so-called "reduction" in U.S. emissions would be more than offset with worldwide increases in carbon

The so-called "reduction" in U.S. emissions would be more than offset with world-wide increases in carbon emissions.

[21] Environmental Protection Agency, www.epa.gov/climatechange.
[22] Wikipedia, *List of Countries by Carbon Dioxide Emissions*, http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions (last updated 4 November, 2008).

emissions. This is a negative, unintended consequence of domestic policy intended to curb domestic emissions, but without adequately taking into account the international consequence.

Let us recall that the OECD nations (of which the U.S. is a leader) have essentially flat-lined CO_2 emissions; whereas the non-OECD nations (led by China) are the worldwide source of growth of CO_2 emissions. We ought to be careful not to feed this frenzy with U.S. carbon policy.

Environmental Mandates Have Proven Deadly

On the edge of possible heavy-handed CO_2 legislation, history suggests we revisit an earlier, well-intended environmental mandate—the DDT ban of the 1960's. Based on suspicions that DDT was carcinogenic, and that it would affect birds and the food chain, DDT became a banned substance. Prior to the ban, DDT was used effectively to eradicate malaria in the U.S., Caribbean, and numerous other places. Unfortunately, Africa lagged behind. Now with the ban of DDT there are one million deaths from malaria each year, and 80% of those involve African children. Worldwide there are 350 million cases of malaria.

How did this ban come about? It was largely the result of a book by Rachel Carson called *Silent Spring*. Did Ms. Carson act malevolently? I think not—in fact, I believe she was well-intentioned, but the unintended consequence came about regardless.

Were we too "quick on the draw" with the ban of DDT? Consider this press release from the United Nations World Health Organization, issued 30 years, and 30 million deaths, after the phase out of DDT:

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15 SEPTEMBER 2006 | WASHINGTON, D.C. -- Nearly thirty years after phasing out the widespread use of indoor spraying with DDT and other insecticides to control malaria, the World Health Organization (WHO) today announced that this intervention will once again play a major role in its efforts to fight the disease. WHO is now recommending the use of indoor residual spraying (IRS) not only in epidemic areas but also in areas with constant and high malaria transmission, including throughout Africa.

"The scientific and programmatic evidence clearly supports this reassessment," said Dr. Anarfi Asamoa-Baah, WHO Assistant Director-General for HIV/AIDS, TB and Malaria. "Indoor residual spraying is useful to quickly reduce the number of infections caused by malaria-carrying mosquitoes. IRS has proven to be just as cost effective as other malaria prevention measures, and DDT presents no health risk when used properly."

WHO actively promoted indoor residual spraying for malaria control until the early 1980s when increased health and environmental concerns surrounding DDT caused the organization to stop promoting its use and to focus instead on other means of prevention. Extensive research and testing has since demonstrated that well-managed indoor residual spraying programmes using DDT pose no harm to wildlife or to humans.

"We must take a position based on the science and the data," said Dr. Arata Kochi, Director of WHO's Global Malaria Programme. "One of the best tools we have against malaria is indoor residual house spraying. Of the dozen insecticides WHO has approved as safe for house spraying, the most effective is DDT."

The ban on DDT and more recent government mandates for ethanol illustrate that poor choices can be mandated in times of uncertainty. At present we are in a very similar situation with climate change. Well-intended policies may have disastrous unintended consequences.

Section IV - Understanding Climate Change—The Causes and Mechanisms

This segment will explain the scientific background needed to lay the groundwork for understanding climate change. We will discuss the basic building blocks of climate change, which are:

1. The Earth's energy budget and radiation balance: The Earth always finds equilibrium (this applies to the various natural systems).
2. Solar activity: The Earth receives, essentially, no other energy input other than from the Sun. The role of incoming solar radiation (or Insolation) will be discussed.
3. Radiative forcing: This is fundamental to the thesis of anthropogenic global warming—that man has "perturbed" the balance of nature through carbon dioxide emissions, that these so-called greenhouse gases add to the greenhouse effect, and that the Earth will seek a new radiation balance, and that this will result in higher global average temperatures.
4. Feedbacks: The Earth has numerous feedback systems—both positive and negative feedbacks—that respond to the forcing. The concept of feedbacks is critical to the central assumptions of climate change.
5. Climate sensitivity: This is a measure of how much the Earth's temperature can be expected to change for any given amount of radiative forcing. The climate sensitivity is, in turn, dependent on numerous factors and systems. Feedbacks are at the root of climate sensitivity—including the opposite effects of positive feedbacks versus negative feedbacks, and the "no feedbacks" case (or net-zero feedbacks).

Energy Budget and Radiation Balance

A good starting point to our understanding of climate change must include a simplified discussion of the Earth's energy budget. The main energy input to the Earth is, of course, the Sun, with virtually no additional input from other energy sources in the universe. The Earth achieves equilibrium energy balance (or "radiation balance") when the sum of the energy gains (solar radiation input) equals the sum of the energy losses (thermal radiation output). This is a fancy way of saying that the energy doesn't build up, but has to find a balance. The Earth behaves this way—it always seeks energy balance.

Solar energy enters the atmosphere with radiation of about 1366 Watts per square meter. Since one half the Earth is not facing the Sun at any given time, and since the surface of the Earth is spherical rather than flat, the solar radiation averaged over the entire surface of the Earth is about 342 W/m^2.[23] However, the solar constant varies over the solar cycle, and varies with solar activity (the Sun is not perfectly constant in its energy output), so the actual radiation cannot be stated with complete accuracy.

An understanding of the Earth's radiation balance is vital since it is considered to be the driver of climate change. Once we establish the elements of radiation balance, we can then apply climate sensitivity factors to determine the actual temperature response of the Earth to a perturbation (also known as radiative forcing). For purposes of our discussion, the bottom-line climate change result, therefore, is climate sensitivity to the radiative forcing caused by anthropogenic emissions—particularly of carbon dioxide. Or conversely, how much global warming can be avoided by a given reduction in carbon dioxide emissions? These questions can only be answered through an understanding of the radiation balance and the associated elements of radiative forcing and climate sensitivity to carbon dioxide (and other greenhouse gases). Indeed, if radiation balance, radiative forcing and climate sensitivity could be accurately assessed, the "debate" truly would be over.

Incoming Solar Radiation – Solar Variation and Orbital Wobble

The climatology term *insolation* means, literally, <u>in</u>coming <u>sol</u>ar radi<u>ation</u>. This insolation can be affected by either solar activity or orbital activity.

[23] IPCC, Ch. 1 *FAQ* 1.1.

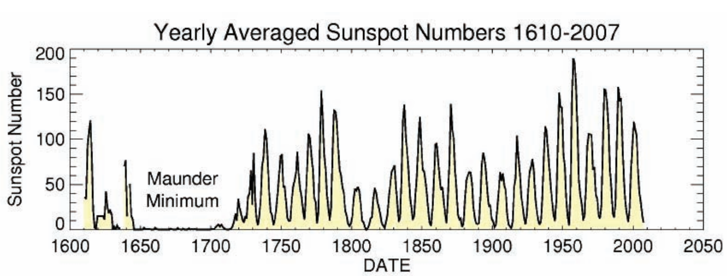
We are all generally aware of the varying solar activity (such as solar storms and sunspot activity). And we are also aware of the seasonal differences between winter and summer, and how these are caused by orbital and axial phenomena; but there are other less well-known influences. For instance, the Milankovitch cycle describes periods where the Earth receives greater, or lesser, solar radiation due to precession, axial tilt and eccentricity of the Earth's orbit. There is scientific evidence that most of the warming and cooling that has occurred in the Earth's history is related to naturally occurring orbital cycles.

The IPCC has stated:

> *Regular variation in the Earth's orbital parameters has been identified as the pacemaker of climate change. . . These orbital variations, which can be calculated from astronomical laws, force climate variations by changing the seasonal and latitudinal distribution of solar radiation.*[24]

I particularly enjoy the analogy of a pacemaker since it suggests a rhythmic activity and also seems to get to the heart of the matter.

In addition to these naturally occurring orbital cycles, where the tilt of the Earth will winterize one hemisphere, while warming the other, the Sun itself is a temperamental creature, exhibiting some tendency toward natural cycles, but also showing great variability. Consider this graphic from NASA:[25]



The Sun has periods of lesser, and greater, activity. For instance, the solar Maunder Minimum of 1645-1715 was a period of cool temperatures that correlated with low sunspot activity. The IPCC has stated:

"…sunspots were generally missing from approximately 1675 to 1715 (the so-called Maunder Minimum) and thus solar irradiance is thought to have been reduced during this period."[26]

By inspection of the sunspot graphic above, it is not too hard to see the "Little Ice Age" that occurred in the early 1800's. The graph also seems to show an increasing trend in solar activity from 1850 until today.

When considering the Earth's energy budget, and possible climate change induced by anthropogenic emissions of CO_2, we must also carefully consider the role of the sun. For additional discussion on this topic please refer to the technical appendix/glossary.

Radiative Forcing – Something Out of the Norm

In simplest terms, "forcing," suggests that something out of the norm has been forced upon a system. In this case (since we are talking about the effects of CO_2 on the climate) the anthropogenic emissions "force" a change in the Earth's energy budget. This is essentially the entire hypothesis of global warming. The central question is this: how significant is the temperature change to be expected from this forcing?

According to the IPCC *Climate Change 2001: Working Group I: The Scientific Basis:*

> *Radiative Forcing of climate change is a modeling concept that constitutes a simple but important means of estimating the relative impacts due to different natural and anthropogenic radiative causes upon the surface-troposphere system. The IPCC Assessments have, in particular, focused on the forcings between pre-industrial times (taken here to be 1750) and the present.*

The United Nations Environmental Programme defines it this way:

> *Radiative forcing is the change in the balance*

[24] IPCC, Sct. 9.2.1.3
[25] NASA, *What's Wrong with the Sun? (Nothing)*, (2008), http://science.nasa.gov/headlines/y2008/11jul_solarcycleupdate.htm
[26] IPCC, Sct. 9.2.1.3.

between radiation coming into the atmosphere and radiation going out. A positive radiative forcing tends on average to warm the surface of the Earth, and negative forcing tends on average to cool the surface.

The IPCC describes the radiative forcing formula of carbon dioxide in a simplified formula as follows:

$$\text{Forcing} = 5.35 * \ln (C / C_0),$$

where (C / C_0) is the proportionate increase in CO_2 concentration, and "ln" denotes the natural logarithmic function.

The equation renders the predicted change in radiative forcing, expressed in Watts per square meter, for a given change in atmospheric accumulations of CO_2.

For instance, assume that CO_2 concentrations today are 385 PPM. Assume also that CO_2 concentrations in the year 1750 (the Base Year described earlier) were 275 PPM. Then the forcing that has been anthropogenically introduced since 1750 is:

$$\text{Forcing} = 5.35 * \ln (385/275) = 1.8 \text{ W/m}^2$$

This calculation agrees with the work of the IPCC.

Using the radiative forcing formula, it can be shown that the total radiative forcing that can be calculated from a doubling of atmospheric CO_2 is 3.7 W/m^2. Since we have already experienced 1.8 W/m^2 as discussed above, we can easily calculate the additional forcing from today through the end of this century as the difference between 3.7 W/m^2 and 1.8 W/m^2, or a net of 1.9 W/m^2.

So what does it mean to have 1.9 W/m^2 of radiative forcing? This is comparable to six, 1500-Watt hairdryers spread throughout a football field (including the end zones). The effect of these hair dryers would be spread throughout the entire atmosphere of the stadium, dispersed evenly and vertically. Imagine sitting at Lambeau Field, on a cold Wisconsin winter day, with six hair dryers poised strategically at various locations on the field. Then these dryers are turned on. How much would you expect the temperature to increase in the stadium? You would be sharing about 9 kilowatts of heating with 72,000 spectators, or about the same heating effect, per spectator, of a cellular phone. Without having actually performed this scientific experiment, I am, however, willing to guess that there would be no measurable warming.

The concept of radiative forcing is central to an understanding of possible climate change.

Among serious climate scientists – whether skeptics or alarmists – there is general agreement about the calculation of radiative forcing. The question then remains as to what effect this forcing will have on actual temperatures. To understand this we must first have a discussion about feedbacks, and then climate sensitivity, which will then lead us to an understanding of the actual temperature response of the planet.

Feedback Mechanisms – Positive Feedbacks Capture Center Stage

An understanding of feedbacks and their role in nature and specifically as this relates to the Earth's energy budget and climate sensitivity, is integral to understanding our climate system. As temperature rises, it causes changes in the atmosphere that either increase or decrease the rate of change in temperature. Such changes are called "temperature feedbacks."

Positive feedback systems tend to be unstable, while negative feedback systems tend to be stable. For example, consider a microphone that receives positive feedback from an amplified sound. A voice feeds into a microphone; an amplifier intensifies the voice, which then is broadcast through a speaker. The speaker volume feeds positively through the microphone back to the amplifier in a positive feedback loop, and *SCREECH!* We have all experienced this when a person begins to talk into a microphone and almost instantly the volume from the room's sound system responds with an escalating (and annoying) screech that can only be silenced by covering up the microphone. Prior to the approach of the person, the microphone-amplifier system was in *unstable equilibrium*. There was no problem evident. With only the slightest input into the microphone this positive feedback system escalated to instability.

This then begs the question whether the Earth is dominated by positive, negative, or net-zero temperature feedbacks. If the net effect of feedbacks is negative or net-zero, this would help to explain why the Earth is able to survive orbital changes, resulting ice ages, with preservation of species, and recovery from extreme events. If positive feedbacks dominate, one must ask why the Earth has not already self-destructed or gone unstable: after all, in the Cambrian era, 550 million years ago, concentrations of CO_2 in the atmosphere were 20 times today's levels: yet the Earth did not fry. A study of feedbacks is crucial to our understanding of the climate sensitivity and resultant modeled forecasts of future temperatures.

Fortunately, most systems in nature are net-zero feedback systems, and these are inherently stable. Yet, the IPCC AR4 dwells on positive feedbacks in the climate system, which adds to the IPCC claimed climate sensitivity factor (to be discussed later). Negative or net-zero feedbacks receive less attention by the IPCC.

An example of an IPCC-identified positive feedback is the warming that will result from polar ice cap melt, which in turn lowers the albedo, which in turn results in less cooling (more warming), which results in more ice melt, etc., etc. This is a positive feedback and this also explains some of the fearful claims that we are near a tipping point if we don't do something now. Another positive feedback discussed by the IPCC relates to water vapor: as the climate warms there will be more evaporation (from oceans and lakes), which will result in more water vapor in the atmosphere, which will add to the greenhouse gases (of which water vapor is the most significant), which will result in more greenhouse effect, which will result in more warming, which will result in more evaporation, etc., etc.
Of course the notion that the planet has inherent, critical, positive feedback responses that are triggered into motion by the forcing of man, also suggests that the climate is inherently unstable: for that is the nature of positive feedback systems. A menacing microphone will harmlessly do nothing until it is perturbed. Likewise the *unstable equilibrium* of the Earth could go on for eons of time but for the interference of man. This is the essence of the global warming debate. Take away the expectation of positive feedbacks and you take away many of the catastrophic predictions of global warming.

One example of a negative feedback of CO_2 emissions is the fact that higher concentrations of CO_2 result in higher stimulus to plant growth, which naturally absorbs CO_2, returning the system to equilibrium. Another negative feedback can be described as follows: a warming ocean results in more evaporation. The evaporation results in more rainfall in some regions so that the water vapor content in the atmosphere actually decreases, rather than increases as suggested under a strictly positive feedback scenario. The resulting rain and weather cause more cooling. Furthermore, the increased rainfall would tend to increase plant growth, which in turn would naturally sequester more carbon dioxide. Additional evaporation may also result in more cloud activity (causing more albedo, (albedo defined, see page 31) and therefore more cooling). These are examples of negative feedbacks that tend to restore equilibrium by natural processes.

The IPCC AR4 dedicates significantly more discussion to positive feedbacks than it does to negative feedbacks. A search of the IPCC AR4 report found numerous mentions of positive feedbacks, with few mentions of negative feedbacks.

A very valid question that deserves considerable discussion could be framed something like this: What are the various potential positive and negative feedbacks of climate change, and which will predominate? The answer to this question lies in the study of climate sensitivity.

Climate Sensitivity – The Temperature Response to a Given Amount of Forcing

We have just discussed the concepts of radiative forcing, and feedbacks. How can we use these concepts to understand and predict the actual temperature response that can be expected as a result of a doubling of CO_2 concentrations? The answer to this question resides in the concept of climate sensitivity.

Climate sensitivity (CS) can be described as the temperature response to a given level of radiative forcing and feedbacks. It is expressed in degrees Celsius per unit of forcing (with forcing expressed in Watts per square meter). For instance, if we use the IPCC central estimate of 3°C temperature increase based on doubling of CO_2, and recalling that the "forcing" calculation yielded 3.7 W/m², we can then solve for the climate sensitivity as follows:

$$CS = 3°C / 3.7\ W/m^2 = 0.81°C / (W/m^2)$$

The IPCC chooses to simplify this step in their literature, and go directly to the temperature results. So using the IPCC approach, the IPCC "climate sensitivity" for a doubling of CO_2 is between 2°C and 4.5°C, with the central estimate of 3°C. The IPCC is simply saying that the planet will warm by about 3°C at the point in time that there is a doubling of CO_2. This simplification includes feedbacks. We should also remind ourselves that the warming and the doubling of CO_2 concentrations are both in reference to the year 1750. In other words, the planet is expected to warm 3°C between the year 1750 up to the year (approximately) 2100.

So what is the influence of feedbacks in the IPCC climate sensitivity? To answer this question, it is helpful to consider the "no-feedbacks" scenario of climate sensitivity. The "no-feedbacks" scenario is a case where we isolate the warming effects of CO_2, and do not further inflate, nor deflate, these effects with the influence of feedbacks, whether positive or negative, such as evaporation, cloud formation, precipitation, ice melt (and resulting loss of albedo), plant growth, and so forth. By taking this approach we can then determine what portion of "global warming" is directly due to CO_2 emissions, and what portion is due to feedbacks.

The "no-feedbacks" climate sensitivity factor is approximately 0.31°C / (W/m²) or 1.2°C of warming when we reach a doubling of CO_2.[27] This "no-feedbacks" scenario indicates a warming that is only about one-third of the IPCC central estimate of 3°C. Therefore, about two-thirds of the warming forecast by the IPCC is a result of net positive feedbacks.

It is also useful to compare the climate sensitivity response of the planet that existed prior to human-induced CO_2 emissions. There is general scientific agreement that the overall "greenhouse effect" provides natural warming of about 32°C, at a rate of 92 W/m². At that rate, the natural climate sensitivity is about 1.2°C, or nearly identical to the "no-feedbacks" case. Could it be that the Earth reaches a state of energy balance equilibrium that looks a lot like the "no-feedbacks"case? If so, we might question the correctness of placing of so much confidence in the impact of positive feedbacks, while ignoring negative feedbacks.

It should also be noted that net feedbacks may be negative, or in other words the climate sensitivity may be even lower than the no-feedbacks case. This might help to explain why there has been no net warming in the past decade, and a cooling since 2001.

For additional discussion on climate sensitivity, please refer to the Technical Appendix.

[27] Christopher Monckton, *Climate Sensitivity Reconsidered*, 37 Physics and Society 6 (2008), http://www.aps.org/units/fps/newsletters/200807/monckton.cfm.

Section V - Climate Change Myths, Inconsistencies and Misunderstandings

More reasons to hit the "pause button" before enacting massive climate change legislation

Myth: CO_2 causes most of the warming. Fact: Warming temperatures actually cause increases of CO_2.

In his movie, *An Inconvenient Truth*, Al Gore graphically demonstrates that the historic temperature record (dating back 650,000 years) shows cycles of temperature increase and decrease, as the Earth goes in and out of various ice ages. He then shows a separate graph of carbon dioxide levels over the same time frame. He then draws the conclusion, in a very "folksy" way, that the two graphs "seem to fit" one another, like Africa and South America in plate tectonic theory. Mr. Gore suggests that these two graphs—temperature and CO_2—over 650,000 years, are evidence that every time CO_2 goes up, temperature goes up. Every time CO_2 goes down, temperature goes down. The audience is lead to conclude that CO_2 is the cause of all temperature increases. This is, in essence, his entire evidentiary argument for man-made global warming. He then goes on to show some coal-fired power plants spewing red and black clouds of what he calls "global warming pollution" (by the way, CO_2 is not only odorless to human senses, but is also invisible to the human eyes).

"To say that CO_2 causes temperature increases is like saying that lung cancer causes smoking."

In reference to these two graphs—temperature and CO_2 over a period of 650,000 years—scientists have clearly shown (and the IPCC agrees) that the CO_2 curve lagged the temperature curve by 800 years or more. In other words, it is more correct to say that increasing temperature causes a natural release of CO_2 into the atmosphere, and not the other way around. As Chris Horner put it, "To say that CO_2 causes temperature increases is like saying that lung cancer causes smoking" *(The Politically Incorrect Guide to Global Warming)*. Indeed it is clear that the oceans contain a sink (or natural ability and tendency to absorb and store CO_2). This sink is hundreds of times larger than the combined world total of carbon dioxide emissions. Also, by Henry's Law, the oceans release CO_2 as temperatures increase because it takes a long time for ocean temperatures to respond to air temperatures. Given the mass of the oceans, this CO_2 release lags the air temperature increase. So is Al Gore debunked with this argument? Yes, in the sense that Mr. Gore has been far too simplistic—and possibly misleading—in leading the audience to draw this conclusion. While the current record is clear that man is influencing atmospheric levels of CO_2, the question then comes down to an analysis of the radiative forcing of the anthropogenic CO_2, and the climate sensitivity to that forcing, if any, as it pertains to temperature.

The Scholastic Reader recently published a special edition, "The Down-to-Earth Guide to Global Warming" by Laurie David and Cambria Gordon, First Edition September 2007. On page 18 of this "Juvenile Literature" there is a graph that shows CO_2 and Temperature (essentially the same graphs shown in The Inconvenient Truth). The graph is a true highlight of the book because it folds out, with a catchy label that says, "Lift to see how well CO_2 and temperature go together." Instead of putting the temperature graph on an upper chart, and CO_2 on the lower chart—as Mr. Gore does—the Scholastic Reader put both graphs on the same axis. This had the consequence of clearly highlighting the lead/lag phenomena discussed above. A savvy juvenile reader might notice that temperature went up first, followed by CO_2. What to do? The Scholastic Reader inverted the legend so that the reader would conclude that CO_2 went up first, followed by temperature (and not the other way around). This "error" was discovered by Willie Soon, physicist at the Solar, Stellar, and Planetary Sciences Division of the Harvard-Smithsonian Center for Astrophysics. Dr. Soon *contacted Scholastic Reader but was told that they were aware of the mistake, but did not see fit to make a correction; otherwise their young readers would "get the wrong idea."*[28]

It is worth noting that the temperature record over the past 2000 years in no way correlates with CO_2 concentrations but does correlate well with the actual solar radiation record. For most of the past 2000 years, CO_2 levels were nearly constant; yet temperatures were anything but constant, considering the "Maunder minimum," the medieval warming period, and the subsequent "little ice age." These events seem to correlate more accurately with solar activity than with CO_2 concentrations.

It is scientifically understood and unquestioned that temperature increases lead CO_2 increases, and not the other way around. The various interglacial periods (ice ages) that have occurred in the history of the Earth are caused by predictable orbital patterns of the Earth (so-called Milankovitch Cycles), and are not caused by carbon dioxide. In fact, the IPCC has stated that the rise and fall of carbon dioxide levels during these interglacial periods actually lags behind the rise and fall of temperature by hundreds of years.[29]

Myth: Melting polar ice caps will cause catastrophic rises in sea levels.
Fact: Sea level rise is forecast for only 15 inches in the next 100 years. Polar caps are not the main cause.

Sea level increase is not expected to be anywhere near 20 feet, as some are lead to believe. The most recent IPCC report shows a sea level increase range of 0.18 m to 0.59 m (7 inches to 23 inches) over the next 100 years.[30]

Fears are simply unfounded that global warming will result in complete flooding of Manhattan, large portions of Florida, and other sensitive locations. Compare this ungrounded fear with the most recent IPCC AR4 report:

> *Sea level is projected to rise between the present (1980-1999) and the end of this century (2090-2099) . . . by 0.18 to . . . 0.59 m.*
>
> *. . .Thermal expansion is the largest component, contributing 70 to 75% of the central estimate in these projections for all scenarios. . . . The Antarctic Ice Sheet will receive increased snowfall without experiencing substantial surface melting, thus gaining mass and contributing negatively to sea level. . . . The Antarctic Ice Sheet is projected to remain too cold for widespread surface melting.*[31]

The Antarctic (which contains the vast majority of the world's ice) is cooling; thus it is expected to be a negative contributor (in other words, the Antarctic will actually grow, not melt). As can be seen, there is much public misconception regarding sea level. To the extent that man is having an influence on global warming, man's effect on sea level is small and extremely gradual. The quantity of Arctic ice is minor compared to either Greenland or the Antarctic. The Arctic is largely comprised of sea ice, or ice floating on water, while Greenland and the Antarctic are mostly "land ice." Sea ice can melt and yet not contribute to sea level increase.[32]

By definition, a floating ice cube displaces exactly the volume of water that equals the weight of that ice cube. So even though the ice cube is floating, or protruding above the level of the water in which it is floating, when it melts the level of the underlying liquid will remain unchanged. You can try this experiment by placing an ice cube in a cup of water, note the water line, let the ice melt, and then note that the water line has not changed. For this reason, the IPCC 4th Assessment Report estimates that the future effect on sea level rise due to sea ice melt is

[28] Science and Public Policy Institute, *A Fundamental Scientific Error in "Global Warming" Book for Children*, (2007), http://scienceandpublicpolicy.org/other/childrensbookerror.html.
[29] IPCC, Sct. 9.2.1.3.
[30] IPCC, Ch. 5.
[31] IPCC, Ch. 10.
[32] IPCC, Ch. 5.

approximately zero. The average citizen does not understand this, and would have the impression that the oceans are going to rise because of melting of the polar ice caps, especially the North Pole. This is simply not the case.

The IPCC projection for sea level increase over the next 100 years is in the range of 7 inches to 23 inches (with the midpoint being only 15 inches). It is noteworthy that 70 to 75% of the cause of expected sea level rise as identified by the IPCC, is thermal expansion of the oceans rather than ice melt. The idea is that oceans expand in volume as they warm, and that global warming will naturally result in warming of the oceans. But oceans are massive when compared to the atmosphere. Therefore, according to the IPCC, this thermal expansion process will require millennia to fully occur.

Myth: Carbon Dioxide is the dominant greenhouse gas.
Fact: Water vapor dominates.

Greenhouse Gases (GHG) include water vapor, carbon dioxide, methane, and a few other gases. It turns out that, by far, water vapor is the single most significant GHG, both in terms of volume and effect. Water vapor accounts for 90% of all GHG by volume. The next most significant GHG is CO_2. Together, these two gases provide most of the greenhouse effect. Methane is currently garnering less attention because, for reasons not fully understood, but probably arising from large-scale deforestation, methane concentrations in the atmosphere have stopped increasing, although anthropogenic activities have continued mostly unabated.

Most people recognize that carbon dioxide is a greenhouse gas. In fact, CO_2 receives so much attention that other GHG's pale in terms of notoriety; yet, most people have no idea how little CO_2 is actually in the atmosphere. One might hear some anecdotal story of the millions or billions of tons of CO_2 that are annually released into the atmosphere, yet how significant is the overall atmospheric CO_2 concentration? And how much of that is due to the activities of man? When posed with this question, most "lay" people will guess that the atmosphere is comprised of between 1% and 20% CO_2. With the exception of someone that actually knows the answer, I have yet to hear an intelligent guess of less than 1% CO_2. It turns out that the correct answer is much, much smaller than 1%. CO_2 exists in the atmosphere (as of 2008) at 385 parts per million (PPM). By comparison, an amount of 1% equals 10,000 parts per million, which would overstate the actual volume of CO_2 by nearly 2500%! Of that actual 385 PPM, at least 275 PPM exists naturally, with no influence from man. Anthropogenic CO_2 concentrations in the atmosphere amount to one-one-hundredth of one percent of the total atmosphere. It is easy to see why CO_2 is often referred to as a "trace gas."

Note: Is it possible that a warming planet would cause more ocean evaporation, in turn resulting in more precipitation, resulting in direct cooling from rain and weather, and an indirect cooling from increased albedo due to the increased snow surface area that results? In other words, does the Earth have natural, built-in cooling mechanisms to self-regulate in response to external forcing of a warming mechanism such as additional CO_2 GHG?

CO_2 in the Atmosphere
The amount of CO_2 in the atmosphere coming from the U.S. electric-power sector versus naturally caused CO_2 is minimal. For reference, imagine that the 90,388 spectators in Ben Hill Griffin Stadium represent the atmosphere. Of the people in the stands:

- 35 people equal the total amount of CO_2 in the atmosphere
- 10 people equal the amount of all man-caused CO_2
- 3 people equal the U.S. share of all man-caused CO_2
- 1 person equals the U.S. electric-power sector's share of CO_2 in the atmosphere

Myth: The Earth is warmer than it has ever been.
Fact: The Earth is cooler today than during most of its history.

Consider the following quote from the IPCC:

> *During most of the past 500 million years, Earth was probably completely free of ice sheets (geologists can tell from the marks ice leaves on rock), unlike today, when Greenland and Antarctica are ice-covered.*[33]

Note: In the Medieval Warm Period Greenland was actively farmed by Vikings (while today it is covered in ice). Clearly it was warmer during the Medieval period than it is today.

The following quote from the IPCC WG1, summarizes the global climate change situation:

> *Climate on Earth has changed on all time scales, including long before human activity could have played a role. Great progress has been made in understanding the causes and mechanisms of these climate changes. Changes in Earth's radiation balance were the principal driver of past climate changes, but the causes of such changes are varied. For each case—be it the Ice Ages, the warmth at the time of the dinosaurs or the fluctuations of the past millennium—the specific causes must be established individually.*[34]

Myth: Temperature records provide a high degree of certainty.
Fact: Checkered measurements cast a shadow on temperature data.

In her presentation to the Norwegian Academy of Sciences, March 2007, Susan Solomon, the IPCC co-chair of *Working Group 1: The Scientific Basis*, makes temperature claims based on "…high-quality long records using thermometers worldwide." At this point in our discussion we will consider these temperature claims. So how does one take the temperature of the planet? Ideally we would have carefully calibrated thermometers, each strategically placed throughout the globe, with locations carefully selected to avoid fallacious temperature inputs. Oh that such were the case! In reality we have an uncontrolled fleet of thermometers scattered throughout the planet, under control of various government and private interests. In fact, after the fall of the Soviet Union as a result of the Cold War, thousands of temperature stations located in cold, Soviet climates (such as Siberia) were decommissioned. Immediately after this the "average" temperature of the Earth went up (no surprise!).

What about our domestic fleet of NOAA recognized temperature sites? The website www.surfacestations.org has dedicated itself to scrutiny of these sites. Findings suggest that more than two thirds of the sites have corrupt data, especially because of urbanization. The temperature sites are placed in parking lots, next to air conditioning units, beside buildings and other structures, thus changing the pristine nature of the data. The data corruption is generally biased in the direction of warming. One must then question how much of the warming evident in today's temperature record is only an indication of bad data and urban sprawl.

The Urban Heat Island Effect has been shown to affect temperatures in urban areas by several degrees. There are numerous articles on the Internet that describe this phenomenon. One that I particularly enjoy is a site that discusses a high school science project that attempts to quantify the Urban Heat Island Effect in Phoenix, Arizona. The science experiment showed the Urban Heat Island Effect to be about 7 degrees Fahrenheit.[35] It is not surprising that populous areas often show a stronger warming trend than the more rural areas.

A study of California surface temperature trends was conducted from 1940 to 1996. Using NASA GISS temperature data the following was found:

[33] IPCC, Ch. 6 FAQ 6.1.
[34] IPCC, Ch. 6.
[35] Decide for yourself whether the Urban Heat Island Effect merits significant consideration. Climate Skeptic, *Measuring the Phoenix Urban Heat Island,* (2008), http://www.climate-skeptic.com/2008/02/measureing-the.html.

- Counties with populations less than 100,000 showed warming temperature trends of 0.0°C to 0.15°C per decade
- Counties of 1,000,000 showed warming temperature trends of about 0.4°C per decade
- Los Angeles county (population 8.9 million) showed warming temperature trends of about 0.5°C per decade, or 5°C in 100 years

In other words, the urban areas showed much more warming than the rural areas. The only plausible explanation is the Urban Heat Island Effect.

One might think that the Urban Heat Island Effect is limited to only the populous, warm-climate metropolitan areas. Such is not the case. Consider an account that appeared in the Journal of Geophysical Research by Kenneth M. Hinkel and Frederick E. Nelson. The northern Alaska village of Barrow, with a population of 4,500, depends on natural gas for space heat and electricity. The area is entirely underlain by permafrost. Since 2001, an area of 150 km^2 has been carefully monitored, with 70 temperature logs located strategically throughout the area. Hinkel and Nelson found that there is a pronounced Urban Heat Island Effect in Barrow, Alaska, which strongly correlates to natural gas usage (and associated heat loss in buildings and electrical generation). The UHI was calculated as the difference in the group averages, and was found to be 2°C warmer in the "urban" area than in the rural tundra. Occasionally the UHI exceeded 6°C.[36]

Myth: The melting of Kilimanjaro is caused by global warming. Fact: Sublimation and precipitation are the cause.

One interesting aspect of the cryosphere is the concept of sublimation. This is the ice equivalent of evaporation, where ice will change state from a solid to water vapor, without first melting to liquid. While this may seem impossible or counter-intuitive, all of us can see this in a simple, real life example. Have you ever noticed that the older ice in your kitchen freezer becomes smaller? This is due to sublimation. The ambient temperature in the freezer never gets above 32°F, yet the sublimation occurs. A similar experiment would be to watch ice or snow "melting" in the winter at a location that never gets above 32°F, and is not exposed to sunlight. You may have noticed this circumstance in your own backyard.

The melting of Mt. Kilimanjaro has been carelessly attributed to global warming. It is true that Mt. Kilimanjaro is declining in the extent of its ice formation, but the "melting" of Kilimanjaro has been steadily occurring for at least 100 years, even though we were being warned of global cooling or an impending ice age in 1975. The decline of the Kilimanjaro glacier is more accurately attributed to sublimation because it occurs at temperatures that are below freezing. Since this occurs at temperatures that are below freezing, by definition it is not a result of warming.

It is estimated that two-thirds of the ice that is lost from Kilimanjaro goes straight into the atmosphere through sublimation. And finally, it is now understood that the "melting" of Kilimanjaro is primarily caused by changes in local precipitation patterns, not warming temperatures: therefore, the glacial mass is sublimating faster than the recharge rate that would come from higher local precipitation patterns.[37]

Myth: The Greenhouse Effect causes most warming. Fact: Weather is a wild card.

With the greenhouse effect the earth enjoys an average temperature of approximately 58°F. Without the greenhouse effect, the earth would be a frozen waste, with an average temperature of about 0°F. It is therefore tempting to simplistically ascribe 58°F of warming as the quantified amount of greenhouse effect. However, this is not quite the case. In his book, *Climate Confusion*, Dr. Roy Spencer points out

[36] Kenneth M. Hinkel & Frederick E. Nelson, *Anthropogenic Heat Island at Barrow, Alaska, During Winter: 2001-2005*, 112 Journal of Geophysical Research (2007).
[37] Jonathan Amos, *Kilimanjaro's Ice Set to Linger*, BBC News (2007), http://news.bbc.co.uk/2/hi/science/nature/6561527.stm.

that the greenhouse effect, absent any weather, would actually warm the Earth to about 140°F; however, this otherwise deadly temperature is moderated downward by the effects of weather (in all of its forms) and various planetary circulation systems, especially ocean circulation. The effects of weather have a more significant influence on temperature than one might realize. This can be observed when a clear, hot summer day of above 100°F is followed, the very next day, by stormy conditions with temperatures never exceeding 75°F. Even though the two days are in the same season, the same solar radiation, the same tilt of the Earth, and so forth, the temperature variation between the two days is significant—all because of weather. Weather tends to make warmer locations of the globe cooler, and cooler locations warmer. It is like a great equalizing pump that makes a large share of the planet habitable.

It seems ludicrous to think that we can forecast climate, especially when considering this wild card of weather. The change in climate over the next 100 years will be far less than the change in temperature that can occur from one day to the next, due to weather.

Section VI - Summary

The climate change discussion is riddled with complexity, uncertainty, ideology, and unintended consequences. The Earth's climate systems are not fully understood. Complex models are grasping for answers despite uncertainty. Climate forcings, including clouds and aerosol effects, are not fully understood. Likewise, there is still much to learn about feedbacks and climate sensitivity. There is much confusion—at least in terms of lay understanding—of sea level rise, the behavior of the cryosphere, and the trends at the Antarctic compared to the Arctic.

The U.S. electric sector contribution to temperature increase is less than seven hundredths of one degree—a seriously negligible amount. This is based on the IPCC forecast of a 3°C global increase in temperature by the year 2100 (or when CO_2 doubles).

Carbon dioxide is not the only driver of temperature, and in fact may not be the primary influence on climate. Temperatures can (and will) be affected by numerous factors such as the solar radiation, Urban Heat Island Effect, uncertainty of climate sensitivity, and so forth.

Where science and reason flounder, ideology flourishes. Emotions rage; participants in this debate are labeled as either "alarmists" or "deniers." I would hope that we could get past the extremes and apply reason and wisdom as we explore the best energy policy. We should be cautious that international pressures do not overcome prudent domestic energy policy. An economically healthy America will have the best opportunity to develop technologies that can efficiently and methodically lead to a prudent transition from carbon resources. A misguided carbon tax, or cap-and-trade program, will grievously damage the U.S. economy, will accelerate the out-migration of heavy industry, and will have no beneficial effect on future climate.

In closing I'd like to share a quote from Roy W. Spencer, Principal Research Scientist at the University of Alabama at Huntsville, and PhD in Climatology:

> *Belief in catastrophic global warming has little scientific basis, and perpetuates the bad habit that scientists have of predicting environmental doom.*[38]

In 1847, Mark Twain noted this bad habit of scientists when he wrote,

> *There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.*

Mark Twain also wrote, "The report of my death was an exaggeration."[39]

Perhaps the alleged death of planet Earth is also an exaggeration!

I have great hope in the ingenuity and innovation of America. I believe that we can, and will, find new and cleaner sources of energy. But this must be done wisely, methodically, and patiently, with proper balance of economic and environmental objectives. The climate question will be solved by a free and prosperous society, and the United States of America can and will be the leader in this regard.

[38] Roy Spencer, *Climate Confusion: How Global Warming Hysteria Leads to Bad Science, Pandering Politicians and Misguided Policies that Hurt the Poor* 172 (2008).
[39] www.twainquotes.com (last accessed 31 Oct. 2008).

Section VII - Further Discussion and Glossary of Key Terms

The Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change or IPCC is an intergovernmental body formed by a collaborative effort of the World Meteorological Organization (WMO), headquartered in Geneva, Switzerland; and the United Nations Environmental Programme (UNEP), headquartered in Nairobi, Kenya. Both the WMO and UNEP are themselves agencies of the United Nations, each having large staffs and bureaucratic structures. Hence, the IPCC is, in essence, the "grandchild" of the UN, with the WMO and UNEP being the parent organizations.

> *The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of climate change, its potential impacts and options for adaptation and mitigation. IPCC reports should be neutral with respect to policy, although they may need to deal objectively with scientific, technical and socio-economic factors relevant to the application of particular policies. Review is an essential part of the IPCC process. Since the IPCC is an intergovernmental body, review of IPCC documents should involve both peer review by experts and review by governments.*[40]

The IPCC does not claim to do original research, but rather it does "peer review" of existing literature. The review is condensed into "Assessment Reports." The most recent of these is the IPCC 4th Assessment report, or AR4, published in late 2007. This report was studied extensively in the development of this paper.

Below are definitions of several other important concepts that will help decipher the science needed to understand the impacts of CO_2 on climate change.

The IPCC assumes previous knowledge of this information in all of their reports, so for those of us who aren't scientists, here are some basic explanations.

Aerosol Effect – Tiny Particulates of Matter in the Air

For purposes of climate science, an aerosol is defined as any particle in the atmosphere. Examples include: sulfate emissions from energy production; particulate emissions (smog); and dust particles caused by volcanoes, wind and weather. Aerosols are important to the climate because they have a tendency to reflect radiative energy; therefore, aerosols have a cooling effect on the climate. In the 1970's, there were widespread claims that aerosols (pollution) could trigger another ice age, with much of this fear coming after an observation of a 30-year cooling trend. Consequently, the term "global dimming" began to receive much attention.

The cooling effect of aerosols diminishes much more quickly than the warming effect of CO_2. Aerosol forcing will immediately cool the planet, such as after a volcanic eruption, but as the dust settles, the forced cooling effect goes away. The effect of CO_2 emissions, on the other hand, may take decades to diminish.

Aerosols play an important role in climate change because they provide a significant negative forcing (cooling influence).[41]

The IPCC AR4 assigns a "medium to low" level of scientific understanding to the Aerosol Effect. The IPCC also assigns a wide uncertainty range to the Aerosol Effect. Aerosols clearly have a significant cooling influence.

Albedo Effect – A Measure of Light Reflection

The word "albedo", from the Latin *albus*, denotes "whiteness." A planetary body that was perfectly reflective (a whitebody) would have albedo, or

[40] IPCC, *Principles Governing IPCC Work*, (2006).
[41] See the graphic "Radiative Forcing Components", pg. 37.

reflectivity, of 1.0, whereas a "blackbody" would have a reflectivity of 0. "Graybodies" include everything in between. The Earth (as a system) is a "graybody" with albedo 0.31, or 31%. The sources of the Earth's albedo include clouds, ice, the atmosphere itself, and any aspect of the Earth that reflects incident radiant energy rather than absorbing and emitting it. About two-thirds of the Earth's albedo comes from cloud cover. The next most significant source of albedo is ice; however, the major ice caps are located where the Sun's rays are less direct, and therefore the reflection is less significant.

The IPCC AR4 assigns a "low" level of scientific understanding (LOSU) to the cloud albedo effect from anthropogenic aerosols. There is no effective way yet determined to model clouds and fully understand their feedbacks. The uncertainty range of the cooling from cloud albedo could completely eclipse all of the forcing effect of anthropogenic CO_2 emissions.[42] Clouds receive little IPCC attention; yet the cooling effects of clouds, and the climate feedbacks, could easily be the Achilles Heal of the arguments for the climate catastrophe portended from emissions of carbon dioxide. Clouds could easily be more significant than the entire effect of all anthropogenic CO_2 emissions.

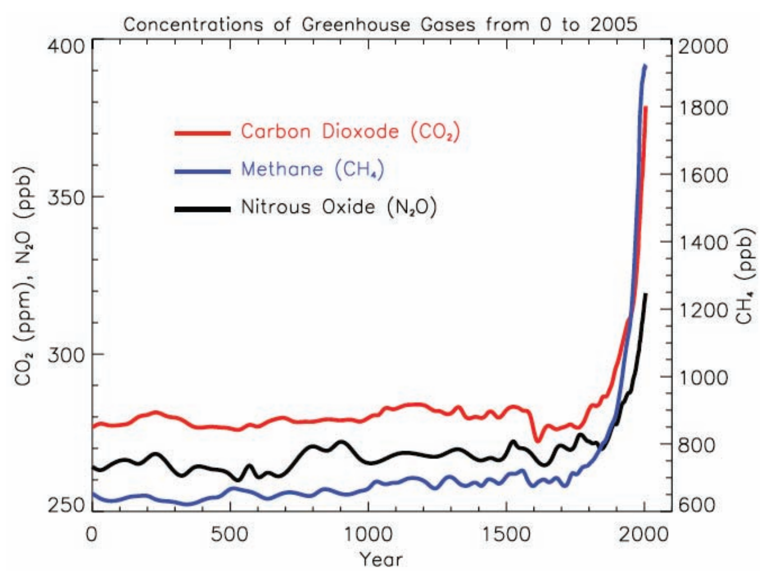
Anthropogenic – Man-Made or Human-Caused

The term "anthropogenic" signifies "of human origin." Examples include "anthropogenic" carbon dioxide emissions from cars, power plants and industrial processes. This terminology is commonly used to segregate effects and processes that come from human activities as opposed to those that are found naturally, or without the influence of man. The term derives from anthropoid, meaning a higher form of apes.

Base Year 1750 – Before Man-Made CO_2 Began in Earnest

In IPCC parlance, the year 1750 is the defined starting point of the industrial era, the dawning of man's contribution to global CO_2 atmospheric concentrations. It is broadly recognized that there was little effect of man's influence on carbon dioxide emissions prior to 1750. Of course, CO_2 is the target of most climate policy discussions. As of the year 1750, it has been determined that carbon dioxide accumulations in the atmosphere were approximately 275 parts per million (PPM). This is widely regarded as the "natural" component of atmospheric concentrations (or the portion that existed without man's influence).

The following graph indicates the trend for three GHG's—Carbon Dioxide, Methane, and Nitrous Oxide—over the past 2000 years.[43] Note that CO_2 is measured in parts per million, while Nitrous Oxide and Methane are both measured in parts per billion. Also, Methane has flattened post 2000, although this period is not shown on the graph. It is also evident that up until now (2008) we have grown the worldwide atmospheric CO_2 levels to approximately 385 PPM—an increase of 110 PPM since 1750. In other words, 275 PPM is generally considered "natural" and the increment of 110 PPM is considered to be "anthropogenic."



There is much attention paid to the notion of a "doubling" of CO^2 concentrations. This doubling is in reference to the base year of 1750. Since CO_2 concentrations stood at about 275 PPM in the year 1750, a doubling will occur when CO_2 concentrations rise to 550 PPM. This is anticipated to occur, more or less, in the year 2100, if current trends continue.

[42] See the discussion and graphic in the radiative forcing section of this paper, pg. 35.
[43] IPCC, Ch. 2 FAQ 2.1.

Carbon Emissions – How Much We Emit

How much carbon dioxide is created (emitted) with the combustion of a carbon-based substance such as gasoline or coal? The weight of gasoline is approximately six pounds per gallon. So how many pounds of carbon dioxide are emitted after the combustion of one gallon (or six pounds) of gasoline?

Most people when asked this question will guess something in the range of one pound of CO_2 per gallon of gasoline.[44] The correct answer is 20 pounds of CO_2 per gallon. One might ask, how is that possible? How can you get 20 pounds of CO_2 from six pounds of gasoline? The answer: refined gasoline is comprised of nearly 87% carbon, by weight. When the carbon molecules combine with oxygen (after combustion with air) they will emit from the tailpipe primarily as carbon dioxide. Carbon dioxide emissions weigh 3.67 times as much as the simple carbon that participated in the combustion process. Hence, the gaseous CO_2 emission from combustion of a fossil fuel actually weighs more than the carbon intense fossil fuel that is burned in the first place.

The above phenomenon is also generally true for coal. As a rule of thumb, one pound of coal combusted through a typical coal-fired power plant will result in about two pounds of CO_2 emissions. It is also correct (as a rule of thumb) that a coal-fired power plant will emit approximately one ton of CO_2 per MWh (or 1000 kWh) of electricity produced. According to the Energy Information Administration, in 2007, U.S. Coal plants produced approximately 2 billion MWh of electricity, and according to the EPA, those same plants emitted about 2 billion tons of CO_2. The U.S. emits about six billion tons of CO_2 from all sources combined (power, transportation, industry and manufacturing, etc.).

Climate Change - The New "Global Warming"

The term climate change has all but replaced the original term global warming. It is a convenient adjustment. By definition, climate change is a safe bet since the climate is always changing (getting warmer or cooler, more humid or more arid, etc.). It is like betting that a coin toss will be either heads or tails. If it rains: climate change. If there is a drought? Climate change.

The now-outdated terminology of "global warming" was problematic because scientists, including the IPCC, have determined that the globe is not universally warming. Most notable is the persistent cooling trend in the Antarctic, and also the fact that the globe actually cooled from about 1945 to 1975 (with widespread warnings of an impending ice age), and the cooling trend that has occurred since 2001. There has been no warming trend in the past ten years. These various trends have occurred despite the steady and continued rise of atmospheric CO_2.

CO_2 Equivalents

Human activities result in emissions of four principal greenhouse gases: carbon dioxide; methane CH4; nitrous oxide (N2O); and various halocarbons (or gases that contain bromine, chlorine, and fluorine). The carbon dioxide equivalent rating for each of these gases is a measure of the particular global warming potential (GWP) of a gas compared to the global warming of CO_2.

For instance, the GWP of methane is 23 times greater than CO_2. Nitrous oxide is 296 times more potent than CO_2. Sulfur hexafluoride SF6 is 22,200 times more potent, but obviously these gases are emitted in much smaller quantities.

Cryosphere – Cool Reflections

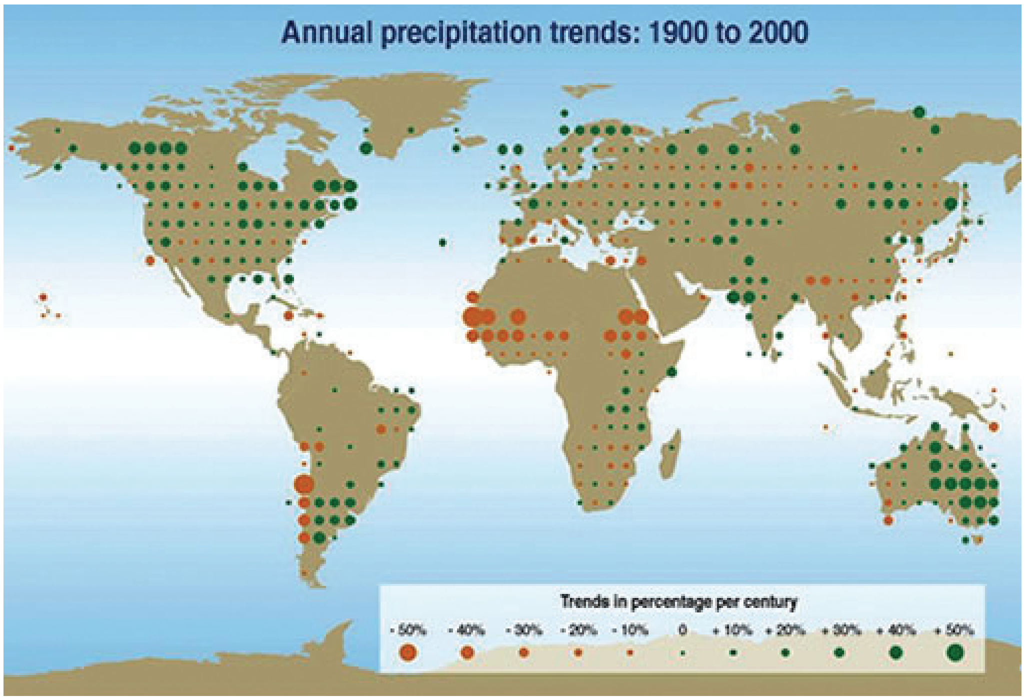
The cryosphere is the Earth's system of frozen water, whether in the form of ice, snow, glaciers, or permafrost. It derives from the Greek word kryo, which means cold.

The cryosphere deserves mention because it is integral to the climate change question. There are numerous feedback processes with land and oceans, precipitation

[44] *How Can a Gallon of Gasoline Produce 20 Pounds of Carbon Dioxide?*, http://www.fueleconomy.gov/Feg/co2.shtml (last updated 20 October, 2008).

and runoff, where the cryosphere plays a critical role. Since ice and snow have high albedo they also tend to cause cooling. In North America, winter snow pack has actually shown an increasing trend over much of this century (not what you would expect in a world of global warming). It is thought that this is caused by an increasing trend of precipitation.[45]

Randy Julander, snow pack specialist for the state of Utah, and also a member of the Governor's Blue Ribbon Advisory Committee on Climate Change, has indicated that Utah snow packs are not noticeably different today than they were over prior decades. In other words, he is not seeing a "climate impact" on Utah snow. He also points out that Utah is, if anything, in a wet cycle. Over the paleoclimate record, Utah has historically had a stronger tendency to be in a drought condition. The past 100 years are among the wettest on record. He also believes that over time (perhaps thousands of years) that Utah will once again find its way into a drought cycle, but not because of global warming; rather as a repeat of a natural cycle that has been evident for millennia.



The "green" dots indicate regions of greater precipitation in the past century, while "orange" dots indicate lesser precipitation. It is clear that we are not in a drought.

Greenhouse Effect - Keeping Earth Comfortable

Greenhouse gases trap heat within the surface-troposphere system, (again, the key physical effect is not heat trapping but the reduction of the rate of cooling—hence a net warming to achieve equilibrium). This is known as the greenhouse effect. Without greenhouse gases the Earth would be an uninhabitable frozen wasteland, with average temperatures of about –18°C, or approximately 0°F. With the presence of greenhouse gases, the worldwide average temperature is approximately14 C° or 58°F — on average a very comfortable planet indeed.

How much future temperature increase will be due to man's carbon emissions? This is a subject of debate and speculation; however, most would agree that there has been some warming, but it is unclear what portion can rightly be ascribed to man. At CO_2 doubling, the IPCC forecasts additional anthropogenic warming between 2°C and 4.5°C, while others would assert an amount less than 1°C.[46]

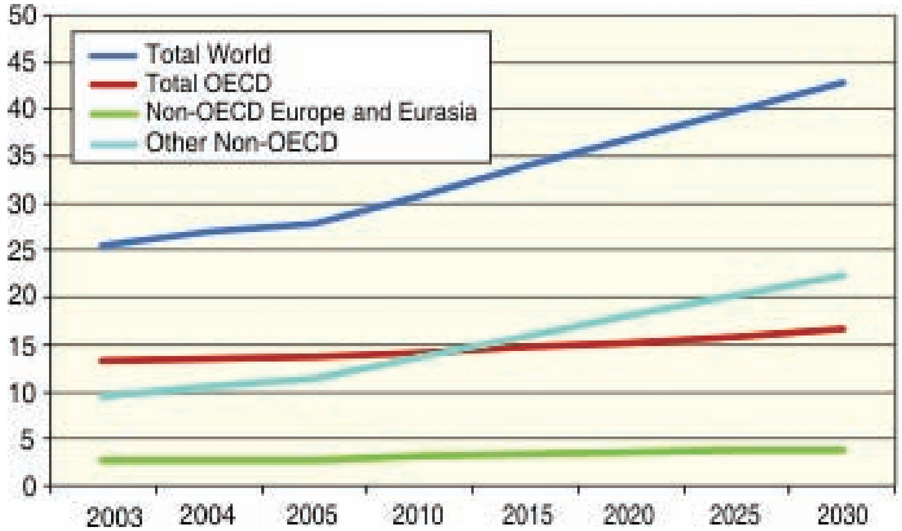
It is not possible to assign a direct proportion of greenhouse effect to any particular GHG, since the gases behave interactively. But we can use a climate model, then remove a gas and test the fraction of long-wave radiation that is absorbed in the absence of that gas. Using this methodology, in the removal of all CO_2, the LW radiation absorption drops from 100% to 91%. In other words, if there were no CO_2 at all, we would still have 91% of the current greenhouse effect. Water vapor is the dominant greenhouse gas. It has

[45] UNEP/GRID-Arendal, Vital Climate Graphics – Update, (2008), http://www.vitalgraphics.net/

[46] Monckton, 37.

also been argued that water vapor is not necessarily considered a forcing, but rather a feedback.[47]

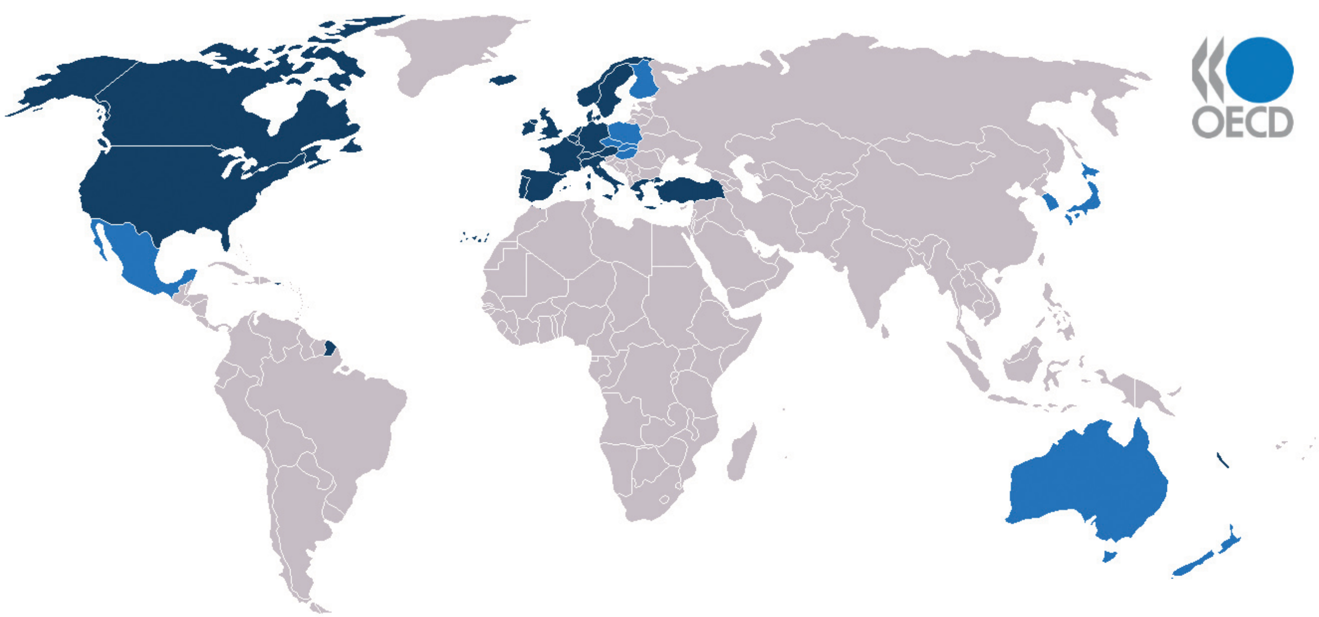
Figure 5. World Carbon Dioxide Emissions by Region, 2003-2030 (Billion Metric Tons of Carbon Dioxide



Note: Explanations for OECD and Non-OECD can be found on EIA's web site: http://www.eia.doe.gov/oiaf/ieo/pdf/appl.pdf
Source: Energy Information Administration, Internal Energy Outlook 2007 (Washington, DC, May 2007).

OECD and Non-OECD Nations – Emission Trends

OECD stands for the Organization for Economic Cooperation and Development. The world as a whole emits nearly 30 billion tons of CO_2 per year. It is important to note that the OECD nations (or developed nations, including the United States) have a relatively stable carbon footprint, while the non-OECD nations (including China) are rapidly growing their CO_2 emissions. China has already surpassed the United States. Currently the "developing" countries, as a group, are about equal to the "developed" countries, as a group, in terms of CO_2 emissions. By 2030, the developing nations will probably exceed the developed nations in emissions by more than 5 billion tons per year. The chart shows a graphical representation of the emissions of OECD and non-OECD nations, and the map depicts the definition and location of those nations.



The Organization for Economic Cooperation and Development, (OECD) countries are shown in blue above.

[47] RealClimate, *Water Vapor: Feedback or Forcing?*, (2005), http://www.realclimate.org/index.php/archives/2005/04/water-vapour-feedback-or-forcing/

Section VIII - Technical Appendix

Radiative Forcing - Calculations and Observations

The IPCC describes the radiative forcing formula of carbon dioxide in a simplified formula as follows:

$$\text{Forcing} = 5.35 \ln (C / C_0),$$

where (C / C_0) is the proportionate increase in CO_2 concentration, and "ln" denotes the natural logarithmic function.

As discussed earlier, the equation renders the predicted change in radiative forcing, expressed in Watts per square meter, for a given change in atmospheric accumulations of CO_2. For instance, assume that CO_2 concentrations today are 385 PPM, and that CO_2 concentrations in the year 1750 (the Base Year described earlier) were 275 PPM. Then the forcing that has been anthropogenically introduced since 1750 is:

$$\text{Forcing} = 5.35 * \ln (385/275) = 1.8 \text{ W/m}^2$$

We can predict the additional amount of forcing that might occur at a future point where atmospheric CO_2 concentrations reach some higher level than today, such as a doubling of natural concentrations. Since the natural CO_2 concentrations in the year 1750 were 275 PPM, a doubling will occur by definition when CO_2 concentrations reach 550 PPM. The forcing equation then becomes:

$$\text{Forcing} = 5.35 * \ln (550/275) = 5.35 * \ln (2) = 3.7 \text{ W/m}^2$$

Note that the forcing of 3.7 W/m^2 represents the increase in radiative forcing since the year 1750, all the way until some future year when CO_2 reaches 550 PPM (perhaps near the year 2100). To get the increment from today until the year that CO_2 doubles we simply do a subtraction:

$$\text{Forcing} = 3.7 \text{ W/m}^2 - 1.8 \text{ W/m}^2 = 1.9 \text{ W/m}^2$$

Another way to get this result is to run the radiative forcing formula again, with 385 PPM as reference point "a", and 550 PPM as reference point "b":

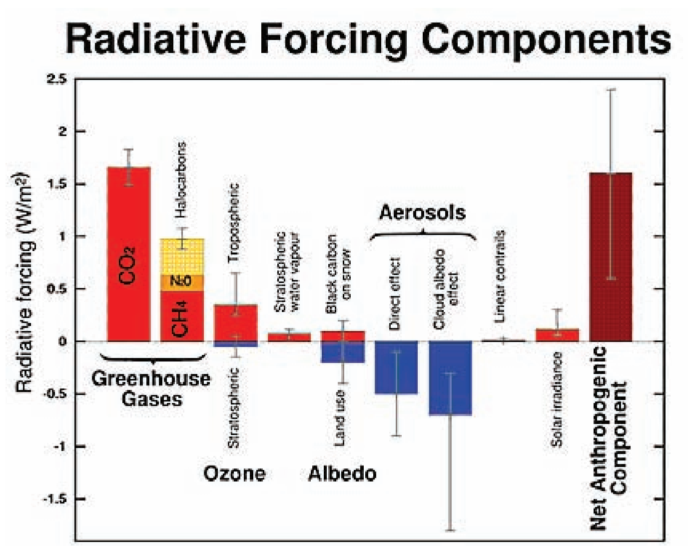
$$\text{Forcing} = 5.35 * \ln (550/385) = 1.9 \text{ W/m}^2$$

As should be expected, we get the same result.

The radiative forcing formula, although it may look complex, is actually a very simplified way of approximating the radiative forcing effect of additional quantities of CO_2. It should also be noted that the formula is logarithmic. This is math talk for something that has a decreasing rate of increase. Maybe that description just adds confusion, but consider this:

- The natural radiative forcing of all greenhouse gases is approximately 92 W/m^2;
- The natural CO_2 level of 275 PPM has radiative forcing of 32 W/m^2;
- At 385 PPM (an increase of 110 PPM from "natural" levels) the radiative forcing only increases by 1.8 W/m^2 (or about a 2% increase to the natural greenhouse effect).
- At 550 PPM (an increase of 165 PPM from 2008 levels) the radiative forcing increases by another 1.9 W/m^2.

The IPCC shows in the following chart, the radiative forcing of CO_2, as well as other forcings:[48]

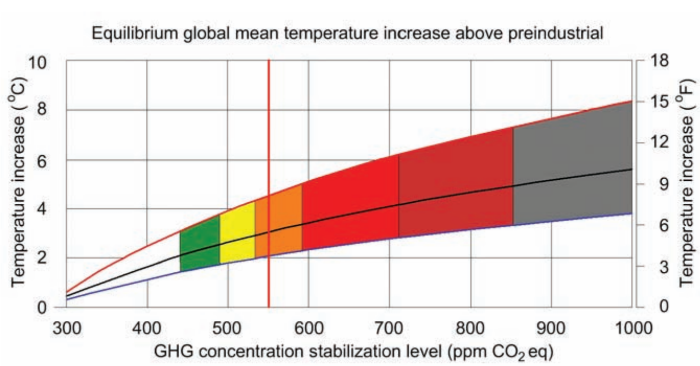


The "bars" in this graphic indicate the IPCC "best estimate" of the various forcings as per AR4. Positive

[48] IPCC, Ch. 2.

values result in warming, while negative values result in cooling. The "gray" straight line indicates the likely range of deviation from the expected result. The total of all forcings is shown as "Net Anthropogenic Component." The amount indicated is approximately 1.6 Watts per m^2, with an uncertainty range of about 0.7 W/m^2 to 2.4 W/m^2. CO_2 levels are assumed to be 380 PPM. (The chart was developed when 380 PPM was the then-current concentration.) It is also worth noting from the chart above that the "cloud albedo" effect from anthropogenic sources of aerosols (which is discussed in Section VI of this paper) has a negative forcing of about -0.8 W/m^2, with an uncertainty that extends to about -1.8 W/m^2 — an amount that could entirely offset the warming effects of CO_2, shown above at +1.7 W/m^2.

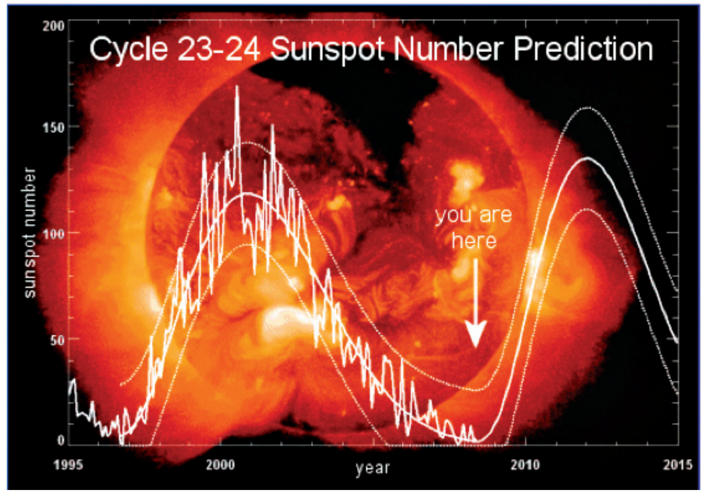
As CO_2 levels increase, the radiative forcing effect of CO_2 diminishes. Note that the radiative forcing of the first 110 PPM increase in CO_2 is about the same as the radiative forcing from the next 165 PPM. This is also evident in the following graphic from IPCC AR4:



In this graphic the temperature increase is a product of radiative forcing, and climate sensitivity to increasing levels of carbon dioxide. Note the natural logarithmic (or reverse exponential) slope to the curve, where ever-increasing concentrations of CO_2 have a diminishing effect on temperature. Note also that the CO_2 curve at 550 PPM, indicated by the vertical red line, intersects the temperature at 2°C, 3°C, and 4.5°C which are the IPCC likely ranges of temperature response.

Solar Radiation - A Key Factor in Climate Change

As further discussion on insolation and solar activity, consider the following graphic from NASA:

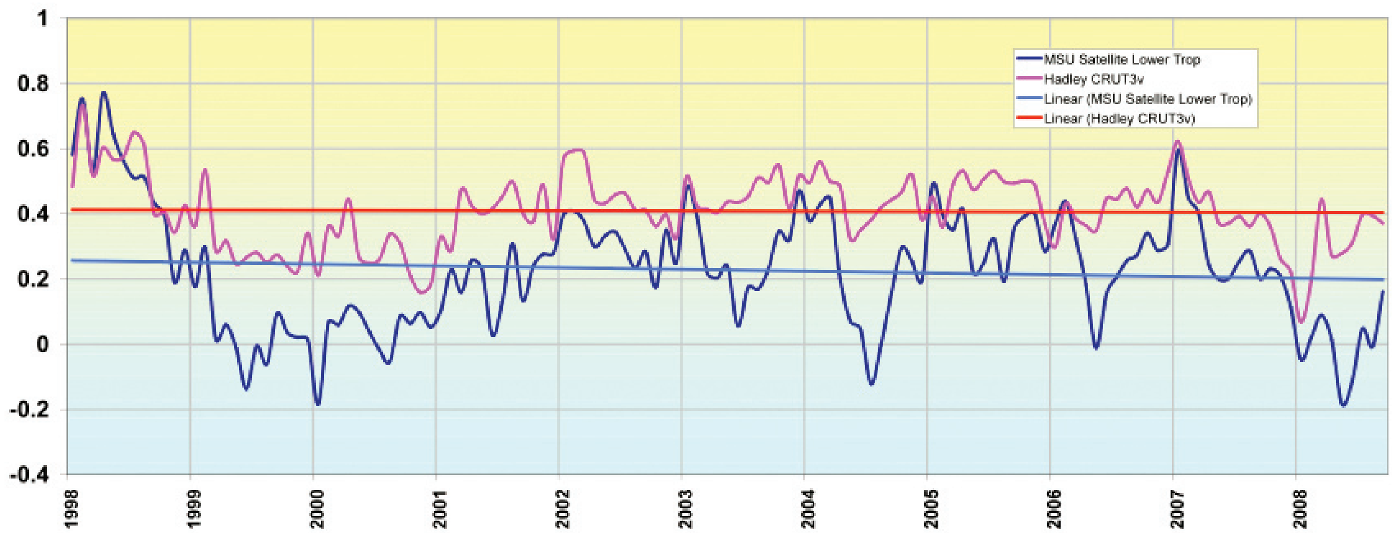


Above: The solar cycle, 1995-2015. The "noisy" curve traces measured sunspot numbers: the smoothed curves are predictions. Credit; D. Hathaway/NASA/SFC.

The Sun has a well-recognized 11-year cycle, which can be seen in detail in this graphic, and over a long period of time in the previous graphic. At times the Sun will violate this cycle, as it did during the Maunder Minimum and to a lesser extent during the Little Ice Age. Today (2008) the Sun is at a minimum of the current "Cycle 23." It is interesting to note that the Kyoto conference was held in 1997, just in time for a ramping up of sunspot activity (and thus warming) that occurred in the late 1990's through 2000. Then starting in about 2001, we began to experience modest cooling, which coincides with a trend of lesser sunspot activity. The years 2007 and 2008 were relatively cool years (again look at the correlation of sunspot activity).[49]

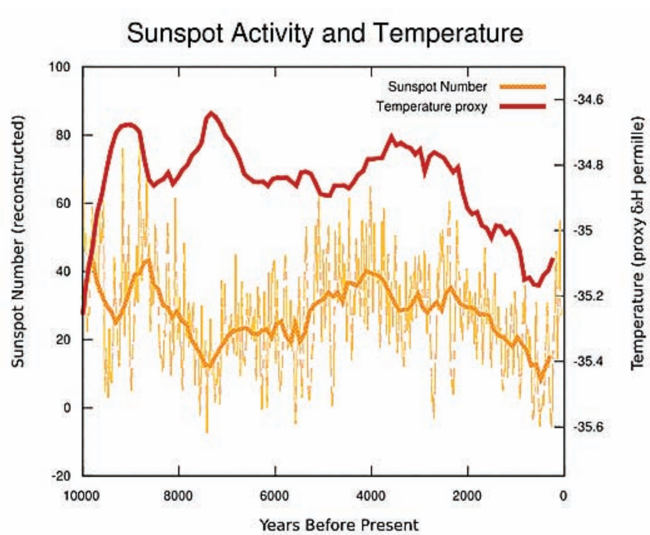
This is also evident in the following graphic, where it is obvious that the temperature trend since 1998 has indicated slight cooling, in spite of continued trends increasing world-wide CO_2 emissions.

[49] Christopher Essex, *What do climate models tell us about global warming? Pure and Applied Geophysics*, 135, 125-133 (1991).



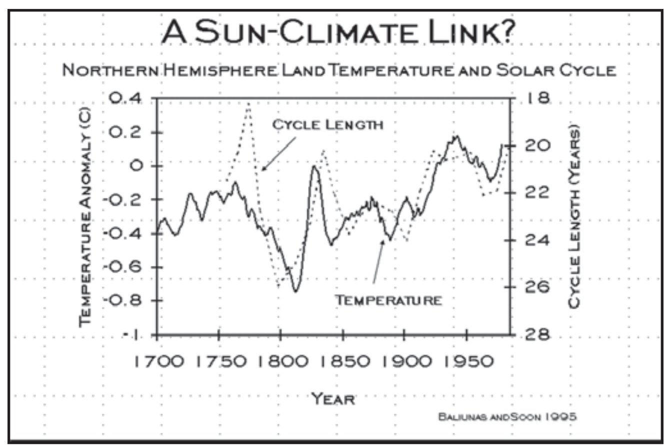
This is the latest decadal plot from February 1998 to February 2008 of global temperatures from Satellite (UAH MSU lower troposphere) (blue) and land and ocean variance adjusted surface (Hadley CRU T3v) (rose)

Scientific efforts have been made to compare solar activity to the temperature curves over long periods of time. Consider this graphic:[50]



(Red) EPICA Dome C Proxy Temperature Data
(Orange) Reconstructed Sunspot Number

Clearly, temperature patterns cannot be explained by carbon dioxide alone. The Sun must be considered. In fact, the fastest anthropogenic increase in CO_2 emissions has occurred since WWII; yet much of that period was associated with a cooling trend. Note the following graphic comparison:[51]

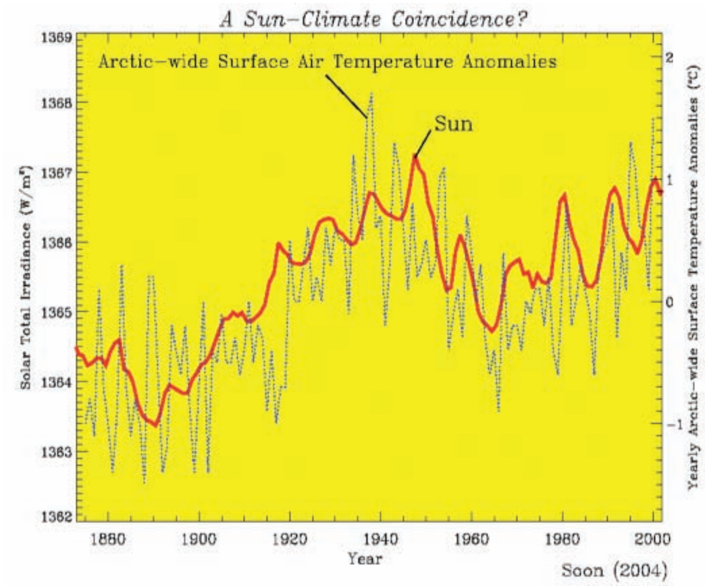


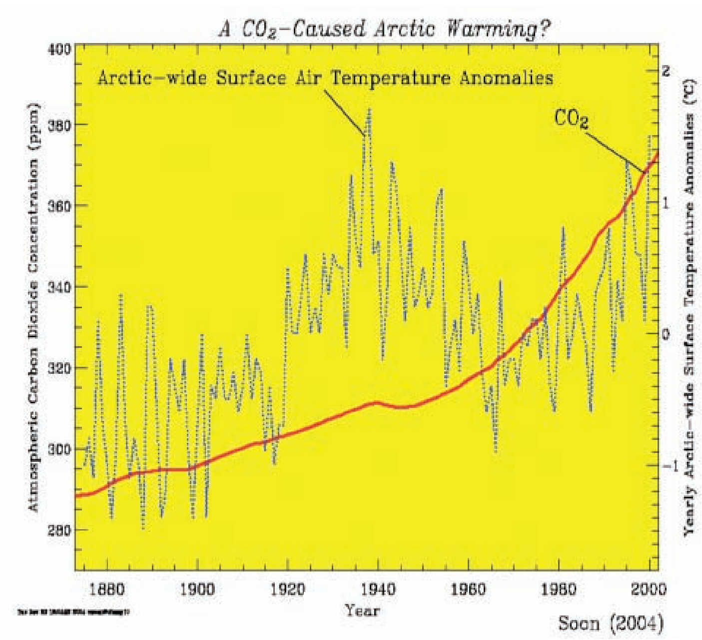
There is general agreement that temperatures ramped upward from about 1905 to 1940, then trended downward from 1940 to 1975. Temperatures have been increasing since 1975, with some flattening or cooling experienced in the past few years. This trend correlates reasonably well with solar activity.

[50] Jean Jouzel, et al., *EPICA Dome C Ice Cores Deuterium Data*, World Data Center for Paleoclimatology (2004), ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/epica_domec/edc_dd.txt; S.K. Solanki, et al., *11,000 Year Sunspot Number*, World Data Center for Paleoclimatology (2007), Reconstruction.ftp://ftp.ncdc.noaa.gov/pub/data/paleo/climate_forcing/solar_variability/solanki2004-ssn.txt

[51] Baliunas and Soon, *A Sun-Climate Link? Northern Hemisphere Land Temperature and Solar Cycle.* (1995).

The panel below shows graphs of Arctic temperatures, correlated with Solar activity (the top panel) and also with CO_2 activity (the bottom panel). Note that temperatures correlate much better with solar activity than with CO_2 activity:[52]





The "Greenhouse" Misnomer

Carbon dioxide, which can be measured with some certainty, is neither a heat or energy source nor sink. Having more CO_2 in the atmosphere merely reduces the rate at which the Earth would cool itself—this is why the phrase "greenhouse warming" is misleading scientifically.[53]

Climate Sensitivity – Calculating the Response to a Given Amount of Forcing

Climate sensitivity (CS) can be technically described as the temperature response to a given level of radiative forcing, or degrees Celsius per unit of forcing (with forcing expressed in Watts per square meter). To wit:

$$CS = °C / (W/m^2)$$

For example, for a given radiative forcing (for example, 1.8 W/m^2) we can multiply this forcing by a climate sensitivity factor (for example, 0.81°C / (W/m^2)) and arrive at the temperature response of 1.46°C as follows:

$$T = (1.8\ W/\ m^2) * 0.81°C / (W/m^2) = 1.46\ \text{Celsius}$$

The IPCC loosely defines climate sensitivity in a shortcut manner by describing it simply in terms of degrees Celsius. For instance, they say (in their "mid" case) that the climate sensitivity for a doubling of CO_2 is 3°C. Since the radiative forcing of a doubling of CO_2 is 3.7 W/m^2, then the actual climate sensitivity factor is 0.81°C / (W/m^2), or:

$$CS = \Delta T / \Delta F$$

$$= 3°C / (3.7\ W/\ m^2)$$

$$= 0.81°\ C / (W/m^2)$$

Hence, a CS of 3°C, or a CS factor of 0.81° C / (W/m^2), are really one in the same.

Climate sensitivity includes feedback mechanisms, and is typically arrived at after running a more complex, multi-dimensional atmosphere-ocean general circulation model, or AOGCM. There is no scientific consensus of a perfect, quantifiably correct climate

[52] Willie W. H. Soon, Geophysical Research Letters, 32 Harvard Smithsonian Center for Astrophysics (2005).
[53] Essex, 125-133.

sensitivity factor that will reliably predict future temperature response (particularly when one considers the inherent chaotic nature of climate); however, the IPCC asserts that the climate response to a doubling of CO_2 will fall in a range of 2°C to 4.5°C, with 3°C being the mid estimate. Since the IPCC does not declare outright the various CS factors, one can easily calculate these as follows:

$CS_{2°C}$ = 2°C / [5.35 * ln(550/275)] = 0.54°C / (W/ m^2)

$CS_{3°C}$ = 3°C / [5.35 * ln(550/275)] = 0.81°C / (W/ m^2)

$CS_{4.5°C}$ = 4.5°C / [5.35 * ln(550/275)] = 1.21°C / (W/ m^2)

The temperature responses to these ranges of climate sensitivity are graphically represented by the IPCC as indicated in the previous section.

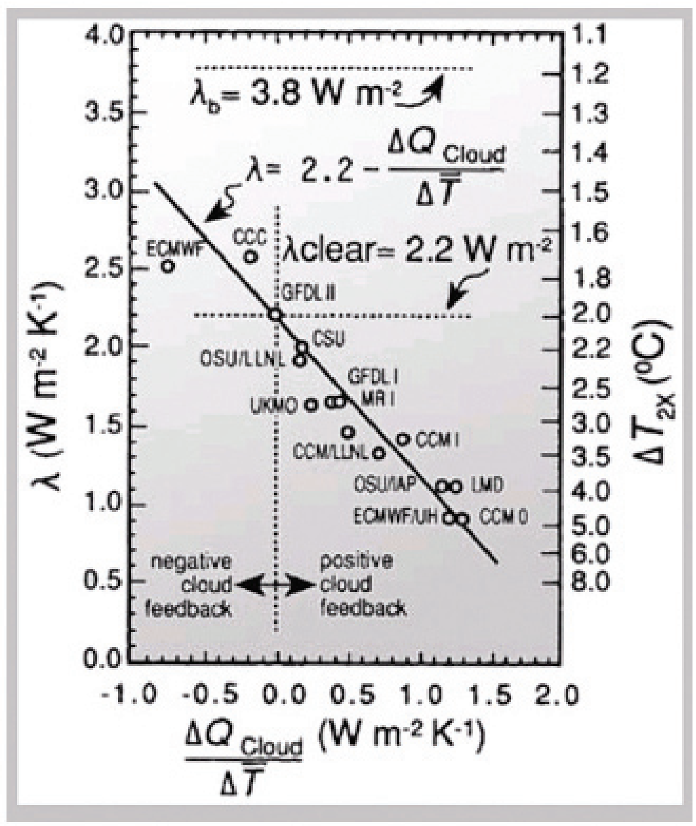
As recently as 2001 the IPCC had declared a climate sensitivity factor of 0.50°C / W/m^2 to be universally accepted.[54]

> *The climate sensitivity parameter (global mean surface temperature response ΔTS to the radiative forcing ΔF) is defined as ΔTS / ΔF = λ. . . . In the one-dimensional radiative-convective models, wherein the concept was first initiated, λ is a <u>nearly invariant parameter</u> (typically, about 0.5°K W−1 m²; Ramanathanet al., 1985) for a variety of radiative forcings, thus introducing the notion of a <u>possible universality</u> of the relationship between forcing and response (emphasis added).*

Now, inexplicably, the "nearly invariant parameter" of 0.5°C / W/ m^2 has increased to a factor of 0.81°C, or an increase of more than 60%. Unfortunately, we lack any IPCC discussion to validate the most current belief that the planet is now 60% more sensitive than was perceived only a few years ago. It is also worth mentioning that there are other credible estimates that hold climate sensitivity to be less than the range suggested by the IPCC—much less![55]

In *Science Bits* a "study of studies" reviewed 14 Atmosphere-Ocean General Circulation Model (AOGCM) climate model results. The study then plotted the climate sensitivity temperature prediction as a function of the "Albedo" (or cloud effect) assumed in each model.[56] The results are shown on the following graph.

Note that the models have vastly different assumptions for the feedback effect of clouds, with the positive feedback models predicting temperatures that ranged from 2.2°C to 5°C, while the negative feedback models predicted temperatures of about 1.6°C to 1.7°C. The "no cloud feedback" case intersected the temperature curve at 2°C, yielding a climate sensitivity of approximately 0.5 W/m^2. (Note that the CS of 0.5°C/ (W/m^2) is consistent with the "nearly invariant parameter" set forth in IPCC 2001.) The climate sensitivity across all cases varied by a factor of about 3, from low to high, with the principal difference being cloud feedbacks.



[54] IPCC, Ch. 6

[55] A thorough discussion of climate sensitivity and temperature feedbacks can be found from the following source: Lord Christopher Monckton, *Climate Sensitivity Reconsidered*, Physics and Society, (2008), http://www.aps.org/units/fps/newsletters/200807/monckton.cfm. The author argues a climate sensitivity factor that is less than one-third the IPCC mid-case sensitivity of 0.81°C / (W/ m^2).

[56] ScienceBits, http://www.sciencebits.com/OnClimateSensitivity, (last accessed 20 October, 2008).

The author goes on to reconstruct various historical temperature responses of the Earth using past climate variations to empirically estimate the global climate sensitivity, using values for (1) the Last Glacial Maximum (LGM), (2) 11-year solar cycle over the past 200 years, (3) 20th century global warming, (4) Phanerozoic comparisons (past 550 million years), and also (5) Eocene and Mid-Cretaceous periods. Each of these is measured assuming the response of the tropical temperature to Cosmic Ray Flux (CRF) variations, or to CO_2 variations.

The resulting empirical climate sensitivities are as shown in the graph on the opposite page.

There are a couple of interesting findings from this study. First, the CRF cases (those which incorporate effects of the Sun) have relatively consistent values for climate sensitivity. In other words, we get the most consistent climate prediction when we account for the influence of the Sun. These studies showed climate sensitivity of approximately 0.25°C / (W/m^2) to 0.45°C / (W/m^2). Compare this to the IPCC "low" case climate sensitivity of 0.54°C / (W/m^2), which is about 60% greater than the average of these study results. The IPCC "mid" case climate sensitivity is 138% higher than this study. So who is correct?

Another way to look at climate sensitivity would be to take the current temperature response and divide by the current radiative forcing. The IPCC estimates that the Earth's temperature without the greenhouse effect would be approximately –18°C.[57] As things stand today, the Earth's average temperature is about 14°C. So the current greenhouse effect, including the effects of weather, has increased Earth's temperature by 32°C (which is net of all feedbacks, including clouds and weather systems). The radiative forcing of all greenhouse gases that exist today is approximately 92 W/m^2.[58] Hence, one way to view the current climate sensitivity is:

$$CS_{\text{today overall}} = 32°C / 92\ (W/m^2) = 0.34°C / (W/\ m^2)$$

It is interesting how closely this agrees with the empirical study above.

Let us now look at another indication of climate sensitivity. The IPCC co-chair of *Working Group 1: the Scientific Basis*, Susan Solomon, prepared and presented a PowerPoint presentation at the Norwegian Academy of Sciences, March 2007. The PowerPoint presentation was included as an informative preface to the release of the IPCC AR4. After the title page, the first slide boldly declares, "The World Has Warmed." It then shows a map of the globe, color-coded with various indicative levels of warming, or cooling, and it is noteworthy that both of the poles are colored as "cooling" regions of the planet. Then the slide claims, "Globally averaged, the planet is about 0.75°C warmer than it was in 1860, based upon dozens of high-quality long records using thermometers worldwide, including land and ocean." If we accept the assertion of Ms. Solomon and assume that all of the 0.75°C warming since the Little Ice Age can be attributed to human-induced emissions of CO_2, we can derive a climate sensitivity as follows:

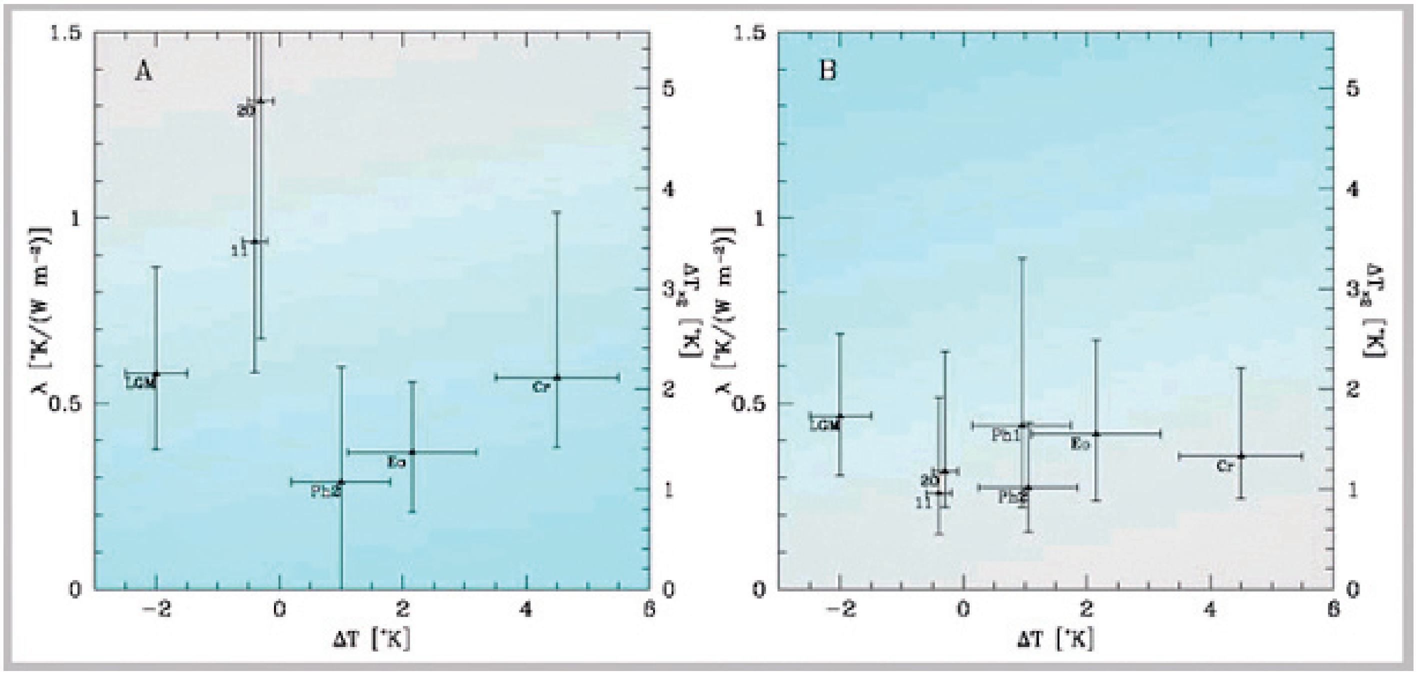
$$CS = 0.75°C / [5.35 * \ln(385/275)] = 0.39°C / (W/m^2)$$

If we were to make a small downward adjustment in the temperature record to account for such things as solar activity and the Urban Heat Island Effect (discussed later in this paper), we could easily arrive at the 0.34°C / (W/m^2) sensitivity factors described above.

Now, do I insist that 0.34°C / (W/m^2) is the correct number? For reasons discussed in the previous paragraphs, it does seem reasonable. But the actual climate sensitivity could be lower or higher, depending on feedbacks. Yet, when we look at climate sensitivity from several approaches, a factor of 0.34°C / (W/m^2) seems supportable. My sense is that the higher IPCC climate sensitivities are overstated.

The climate sensitivity factors presumed in the IPCC AR4 are upwardly biased with positive feedbacks. If the planet responds with net-zero, or negative, feedbacks then the climate sensitivity will be lower than

[57] IPCC, Ch. 1.
[58] RealClimate, *Water Vapor: Feedback or Forcing?*, (2005), http://www.realclimate.org/index.php/archives/2005/04/water-vapour-feedback-or-forcing/



The panel (a) above left, is calculated without the Cosmic Ray Flux (CRF) contributions to radiative forcing. The results show wide variation. The panel (b) above right, assumes that the CRF does affect climate, and results are more consistent.

what the IPCC currently claims. The entire question of climate change comes down to climate sensitivity, and a fundamental question of climate sensitivity is the feedback system of the planet. This is, indeed, the pivotal question of climate science.

One other point bears mentioning: In the *Summary for Policy Makers*, the IPCC asserts with 90% confidence that temperatures will rise by at least 2°C, and as much as 4.5°C when atmospheric concentrations of CO_2 double (somewhere near the turn of the next century). What is less clear—but implicit in this statement—is the fact that these temperature increases are, according to IPCC methodology, in reference to the year 1750. Based on the radiative forcing formula, we have already experienced some of this increase, perhaps up to 0.75°C. So what remains is a temperature increase in the range of 1.25°C to 3.75°C. This should be clarified in the IPCC documents. Further, if the climate sensitivity actually is 0.34°C / (W/m^2), then we only have about 0.65°C of warming that will gradually occur between now and the time when atmospheric CO_2 doubles (approximately the year 2100). This does not suggest the sort of alarm that is conducive to the policy response sought by the IPCC.

It is also interesting to note that, in terms of radiative forcing of CO_2, we are at the "half-way" mark today. What does this mean? In the formula, note that:

$$\text{Forcing} = 5.35 * \ln (C/ C_0)$$

It turns out that for C = 385 PPM (namely, the current CO_2 levels) and C_0 = 275 PPM (namely, the "base year" 1750 levels) the formula renders about one-half of what you get when CO_2 doubles. To be precise, this "one-half" will take place in a couple of years, when CO_2 concentrations reach 389 PPM, as follows:

$$5.35 * \ln (389/275) = \tfrac{1}{2} * 5.35 * \ln (550/275)$$

So why is this important? If we use the IPCC central climate sensitivity estimate of 3°C for doubling of CO_2, then we should have already experienced one-half of the warming, or 1.5°C. But according to the IPCC, we have actually experienced only 0.75°C, or one half of one-half of 3°C. The IPCC forecast seems to overstate the climate sensitivity by a factor of two, or it could suggest that the climate has a slow transient response to growing levels of CO_2. Either way, the IPCC forecast for the year 2100 seems overstated.

Notes: