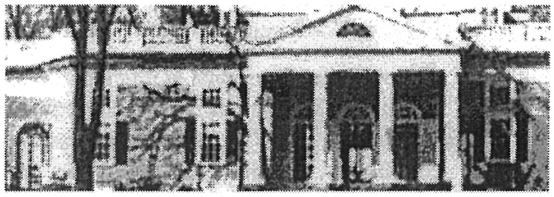

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Climate Change and the Uncomfortable Middle Ground:
The Geoengineering and "No Regrets" Policy Alternative

By: David W. Schnare, Ph.D.
Director, Center for Environmental Stewardship
Thomas Jefferson Institute for Public Policy

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Climate Change and the Uncomfortable Middle Ground: The Geoengineering and "No Regrets" Policy Alternative

David W. Schnare, Esq. Ph.D.[1]
Senior Environmental Fellow
Thomas Jefferson Institute for Public Policy
dwschnare@cox.net

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Abstract

"Climate Change" has occasioned the most fractious, fractured and vituperatively caustic international science and policy debate in recorded history. As localities, states and nations sharpen their legislative proposals on how best to address global warming and the potential for catastrophic climate change, one would think the democratic and scientific processes would build some middle ground where compromise might, if not flourish, at least struggle into existence. That has not yet happened in the United States, in large part because the agendae of the two sides are mutually exclusive and the discourse has reached such vitriolic proportions, the two sides have found no occasion to sit down and negotiate a scientifically sensible, politically acceptable and economically sufficient approach to these risks. This presentation offers the contours of a middle ground – called amongst the less passionate in the debate as "The Uncomfortable Middle Ground". It calls for geoengineering as a means to put off the most catastrophic potential effects, at least for a few decades; an immediate reduction in greenhouse gas emissions (GHGs) where those reductions actually save money (the "no regrets" alternatives); significantly expanded use of and research on low-cost carbon sequestration that removes GHGs from the atmosphere or reduces carbon emissions; and some breathing space within which to further assess some of the global warming theories that, if disproven, would point humanity toward lesser or greater reliance on alternative climate change responses.

Introduction

Without question we can identify the extremes of the Climate Change debate. Some call one side "AGW alarmists"[2] (global warming caused by people) and the other side is called climate change "skeptics".[3] Normally I would find no value in referring to either group in a derogatory manner, at least within a civil debate. The problem we face, in addition to rapidly evolving science, is that the debate itself is not civil. For example, in an internet dust up about this Conference, a serious scientist who is also an exceptionally strong voice arguing that global warming rises from human activity and who is a regular contributor to RealClimate.org, wrote "there are no two sides to this issue – at least not two scientific sides."[4] He argued that science is not done at conferences like this one, but between the covers of scientific journals like Geophysical Research Letters. A perusal of that journal, however, finds well documented, peer-reviewed papers indicating there appears to be some merit to arguments that warming over the past 40 years reflects a normal, if chaotic cycle that may overlay anthropogenic (human caused) warming, but alone explains the majority of observed warming.[5] In this climate, who could expect the layman, including local, state and federal elected officials, to sort this out, much less develop a policy response to the potential threat from global warming?

The policy responses have been as fractured and divisive as the scientific non-debate, with predictable results. That is, no real results. Each side of this argument considers the political proposals grossly improper. Either they are too little, too late; or, too much, too soon.

A fresh look at this policy train wreck suggests that we can argue from either side and come to the same policy proposal –an approach good for at least two or three decades that will forestall the worst catastrophic environmental impacts without undoing the economic progress and opportunity the peoples of the world want and actually need, without invalidating the scientific "certainty" of either the alarmists or the skeptics.

The AGW Argument

We don't need a great deal of scientific language to explain the risks the AGW community wishes to prevent. Two threats dominate their concerns and constitute the most catastrophic of potential impacts, ocean rise and ocean acidification. Figure 1 shows the amount of flooding a 23 foot ocean rise would cause to the Chesapeake Bay. Figure 2 shows what this would look like in Florida. This flooding would cause unspeakably large problems. Using the greenhouse gas theory (GHG) on which AGW science relies, if GHGs rose to a level greater than the equivalent of 450 parts per million of CO_2 (CO_2eq), the global temperature would rise by 2°C, the entire Greenland ice sheet would melt, the ocean would warm and expand and the oceans would rise by 23 feet. Depending upon whom you read, this will happen 100 years from the time GHGs exceed 450 ppm CO_2eq, or within the next two decades thereafter.[6]

Figure 1
USGS Risk of Inundation Map

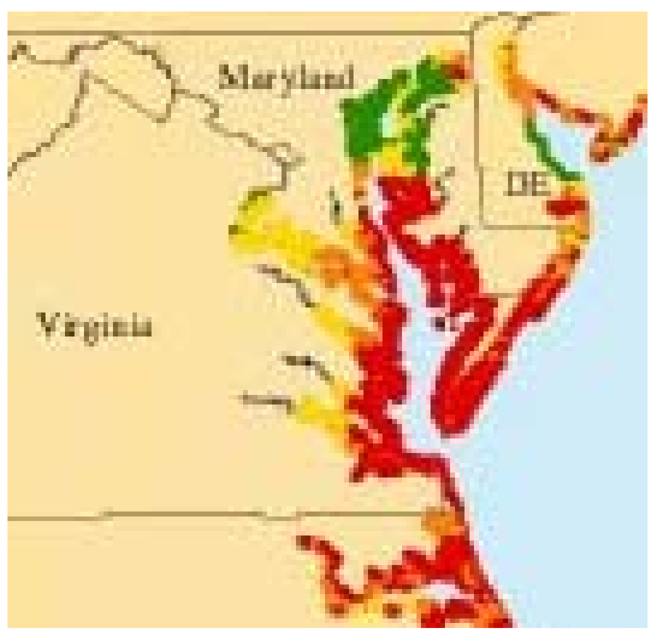
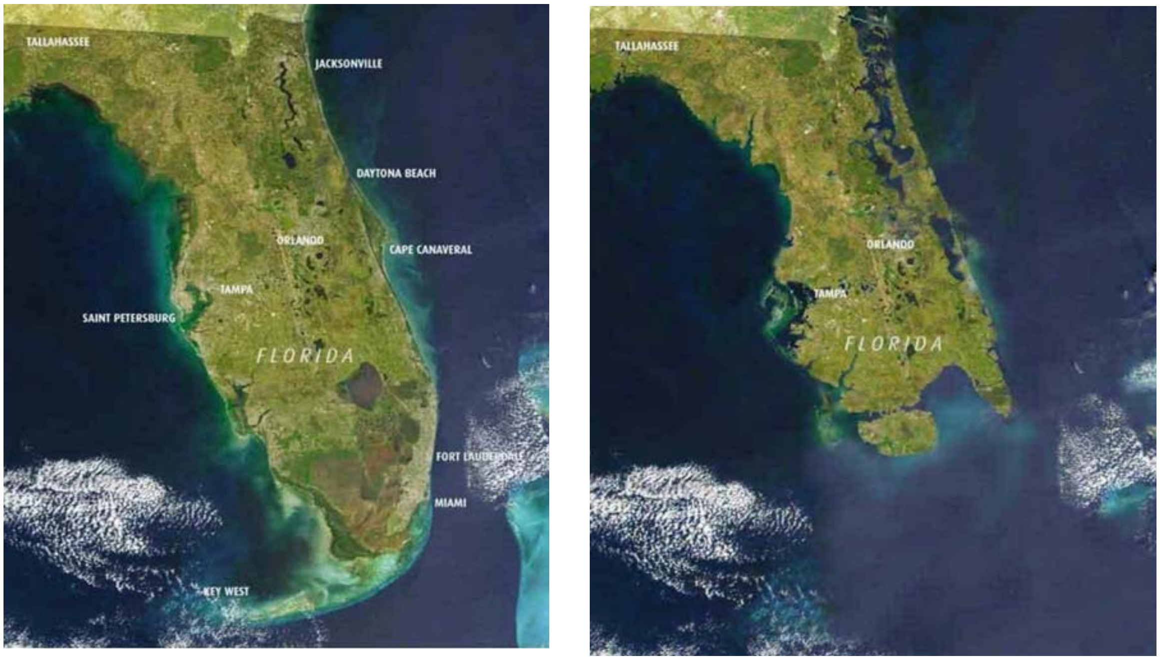


Figure 2
Florida in One Hundred Years



Here's the rub. GHGs rose to exceed 450 ppm CO_2eq in 2005.[7] Thus, under the AGW theory, we would have to eliminate all emissions of GHGs immediately and also have to find a way to extract some of them from the atmosphere.[8] But, that's not enough. We would have to get this done before the temperature actually rose 2°C, as global temperatures will remain high for at least 500 years after carbon dioxide emissions ceased.[9]

In other words, according to the AGW theory, it's too late to prevent catastrophic ocean rise by merely reducing our CO_2 emissions. We must now re-engineer the planetary atmosphere and the global temperature, while we reduce GHGs.[10]

In a typical policy paper, the previous few paragraphs would be sufficient to explain the AWG position. In an uncivil debate, however, trust is dead and it takes more. It takes the leading lights of the policy world to make the argument in their own words. Here are their own words. First from IPCC Chairman Rajendra Pachauri, as told to members of the House Select Committee on Global Warming and Energy Independence:

> "The emission- reduction target laid out in a Senate bill is insufficient to prevent severe effects of climate change. . . . [E]ven if emissions were cut to the 1990 level or just below it, warming would still cause seas to rise and heat waves."[11]

From Matthews and Caldeira:

> "We emphasize that a stable global climate is not synonymous with stable radiative forcing, but rather requires decreasing greenhouse gas levels in the atmosphere. We have shown here that stable global temperatures within the next several centuries can be achieved if CO_2 emissions are reduced to nearly zero. This means that avoiding future human-induced climate warming may require policies that seek not only to decrease CO_2 emissions, but to eliminate them entirely."[12]

From James Hansen:

> Hansen and Sato have said that the threshold for runaway warming is likely to be a 1.7ºC rise above pre-industrial levels. [C]onsidering the inertia in our present fossil-fuel-dependent energy infrastructure and in our political systems, we appear committed to passing the 1.7ºC level unless we cool the earth at least enough to restore the Arctic sea ice.

* * *

> To get the necessary dimension of cooling for enough time to lock in a temperature trend reversal, it might also be necessary, for a few years, to use active cooling techniques too, such as injecting sulphate particles into the stratosphere.[13]

From Mark Cane of Columbia University's Earth Institute:

> "[Geoengineering] is a lousy idea, but it's the best alternative."[14]

The Natural Warming Argument

The global warming debate has become uncivil in part because some want to know who or what caused the problem. In scientific circles, we often think of this as understanding the root causes of physical phenomena and look to both human and natural sources. In political circles it remains exclusively a human blame game. This blame game generally reflects the utility of using environmentalism as a political rather than a scientific philosophy. In that context, environmental activists find it difficult to deal with the notion that a major environmental upset rises from natural causes. Environmental activism generally argues that humans, and their manipulation of the land, air and water, cause all the problems we face. The environmental activist's first response is to remove human influences and let the "natural" processes return the air, land and water to some "natural" state. If global warming results from natural cycles, there is no one to blame and the only way to maintain the civilization is to manipulate the air and water – clearly antithetical to environmental activists.

Those who believe current warming results from natural phenomena do not endorse the general dictum that mankind is the root cause of all environmental problems. Rather they tend to view humanity as part of the natural process – albeit capable of altering those processes. Thus, this scientific community examines natural phenomena for an understanding of these natural cycles and works to determine the degree to which humanity has altered the natural cycles. Petr Chylek offers a summary of the natural warming argument. Before presenting his explanation, however, the divisiveness of the debate requires introducing Dr. Chylek, thus showing that he grounds his discussion is well-founded, peer-reviewed science.

> "Dr. Chylek is a theoretical physicist with the Space and Remote Sensing Sciences group at Los Alamos National Laboratory. Prior to joining LANL, Chylek was Professor of Physics and Atmospheric Science in the graduate program at Dalhousie University in Halifax, Canada where he continues as an Adjunct Professor. He has published over 100 scientific papers in remote sensing, atmospheric radiation, climate change, cloud and aerosol physics, applied laser physics and ice core analysis. His work has been cited more than 3000 times. In addition, Chylek served as Chairman, Scientific Program Committee for The Second International Conference on Global Warming and the Next Ice Age (2006) held at Los Alamos National Laboratory in Santa Fe, NM. The conference included a two-day workshop on climate prediction uncertainties. The papers presented at the 2006 Conference will be published in a special section of the Journal of Geophysical Research."[15]

Dr. Chylek explains the natural warming argument as follows:

> "We are living in a rare period when the earth's temperature is pleasantly warm. Only 16 percent of the last 420,000 years had a climate as pleasant as it is today. Instrumental measurements suggest that the global average temperature increased by about 0.5°C over approximately the last 120 years. Some of this increase was very probably caused by increased atmospheric concentration of CO_2. However, how much of the increase can be ascribed to CO_2, to changes in solar activity, or to the natural variability of climate, is uncertain. The fact that the temperature started to go up around 1890, when man-made production of CO_2 was negligible, indicates clearly that forces other than increasing CO_2 were responsible for the heating that occurred during the first half of the twentieth century. [*See Figure 6 below.*] The fact that currently the surface air is warming faster than the atmosphere suggests that even in the post-1970 warming period, forces other than greenhouse gases are responsible for at least a considerable fraction of the observed warming. Thus, it is highly probable that global average temperatures will go up and down in the coming years, decades, and centuries regardless of what we do."[16]

Plots of temperature over various time-scales clearly document these cycles – ones that obviously predate any increases in greenhouse gases and, as seen in Figure 6, demonstrate that these cycles do not appear to be significantly affected by greenhouse gas emission growth. Figure 3 indicates we are at or approaching the maximum of the 100,000 year cycle. Figures 4-6 show the 1,500[17], 500, 40 and 11 year cycles. Note, although we seem to be at midpoint, ascending the 500 year cycle, we are approaching or near the top of every other warming cycle.

Figure 3
The 100,000 year cycle

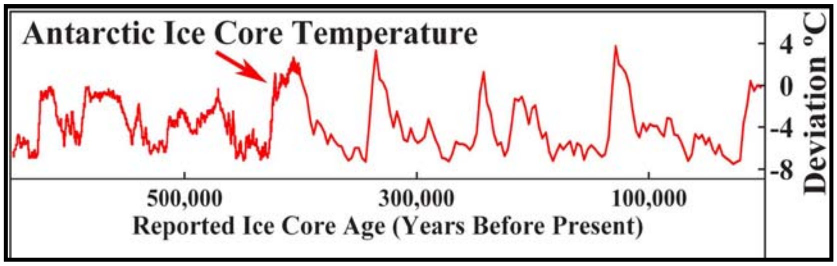


Figure 4
The 1,500 year cycle

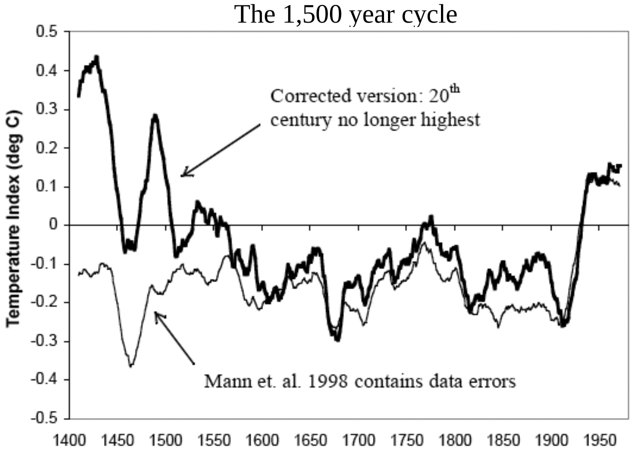


Figure 5
The 1,500 & 500 year cycle

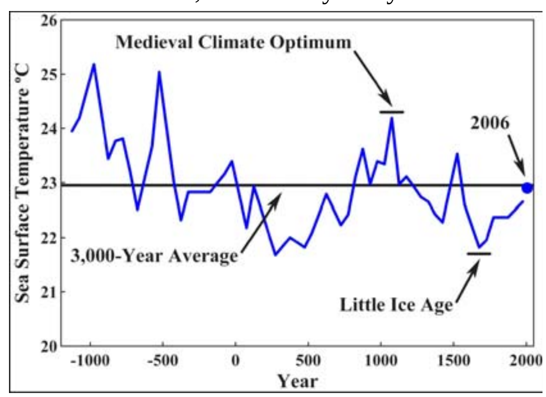


Figure 6
The 40 and 11 year cycles

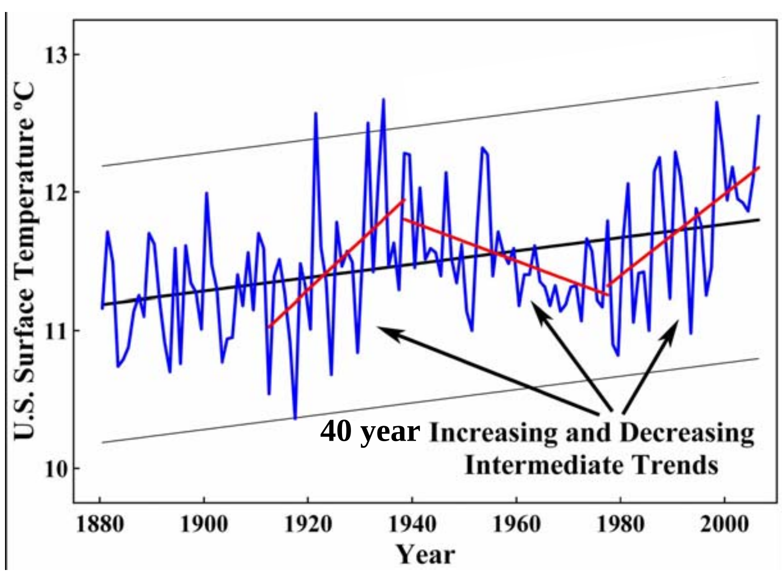


Figure 6 demonstrates one additional, significant finding. The rate of temperature increases in the 1920 to 1940 era, before significant GHG emissions, is the same as during the 1980 to 2000 era. If GHGs were a significant cause of warming in the U.S., one would expect the 1980 – 2000 era to have a significantly greater rate of temperature rise.

The natural warming argument rests on the same quality peer-reviewed science as does the AGW argument. Well before the science became mired in political statements, *e.g.*, Avery (2006)[18], the nation's top universities made important contributions documenting these phenomena.[19] What the natural warming argument does not do is point to a means to prevent catastrophic global warming. Nevertheless, the argument also does not exclude some of the actions the AGW community proposes, including geoengineering, reduction of some GHGs and adaptation.

The Jointly Acceptable Responses to Global Warming

There comes a point, even in as uncivil a discussion as global warming, where the parties in dispute find themselves on common ground. With regard to global warming, the common ground on environmental **impacts** looks somewhat like this:

- The earth is warming;
- Past similar warming events were associated with significant ocean rise;
- Past similar warming events were associated with elevated CO_2 levels and subsequent ocean acidification, (disregarding the issue as to whether CO_2 caused warming or warming caused CO_2 increases);
- Failure to prevent the warming has the potential to cause catastrophic ocean rise and ocean acidification, even if there remains disagreement on the size of that potential;
- Warming, and associated changes in local climates, will have manifold additional environmental consequences that will be "catastrophic" to associated local ecologies, but not catastrophic to mankind. This would tend to shift agriculture toward alternative crops and shift essential crops to alternative lands.

The common ground on **attitudes** toward global warming appear to include the following:

- Humanity does not have the will to reduce GHG emissions to near-zero over the next decade, as required to prevent catastrophic warming under the AGW argument; This attitude breaks into two points:
    - Humanity does not have the technological capacity to reduce GHGs to near-zero over the next decade without massive economic upset and a massive reduction in quality of life; and,
    - No nations are willing to reduce energy consumption in a manner that would forfeit their international economic competitiveness; or, for some nations, forfeit the opportunity to simply join the international community of economically developed nations, as would be require to reduce GHGs to near-zero, or even to more modest levels such as sought under the Kyoto agreement;

- Some nations, including the U.S. are willing to reduce energy consumption when it would reduce energy costs and make these nations more energy-independent;
- Humanity does not have the will to abandon coastal lands that may be inundated, having invested 1,000s of trillions of dollars and personal freedoms in these areas, and in some cases because there are no alternative lands to which humans could move.[20]
- If warming continues, humanity will need to find a way to cool the planet[21] and potentially address ocean acidification[22];
- No one wishes to take steps to cool the planet if it would cause as many or more problems than it would solve.

The common ground on **responses** to global warming appear to include the following:

- Geoengineering will be needed to cool the planet;
- Geoengineering may be needed to de-acidify the ocean;
- Geoengineering may be needed to sequester large quantities of carbon;
- Research on geoengineering needs to accelerate significantly in order for it to be available when it is needed;
- Some energy consumption can be reduced in a cost-effective ("no regrets" manner with the associated benefit of reducing GHGs;
- Research on global warming, GHG reduction, energy alternatives, and geophysical (global) systems should continue in light of the controversy on the cause of warming and the certain failure of political responses to meet expectations under the AGW argument.

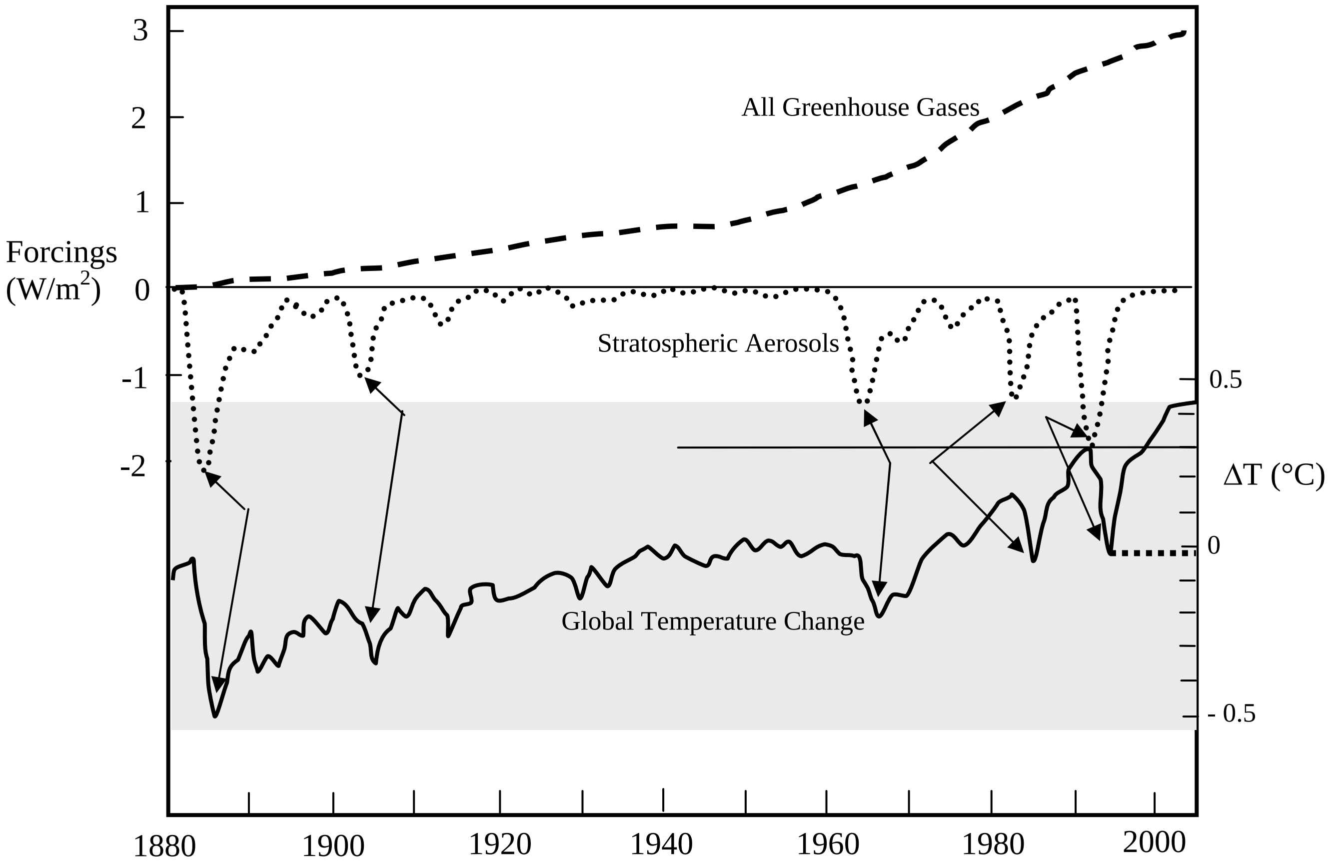
Geoengineering

Geoengineering is the deliberate modification of Earth's environment on a large scale to suit human needs and promote habitability and includes climate modification and ocean chemistry. Seeding of clouds and hurricanes are early, and not always successful examples of efforts to modify a wide area of the environment.[23] The kind of geoengineering needed to cool the planet would occur on a larger scale than past attempts, reflecting the "global" nature of the physical processes at work. These approaches rise directly out of our understanding of global physics and chemistry.

Solar Radiation Management – Aerosols

The approaches most often offered as a means to cool the planet involve reducing the amount of sunlight falling onto the earth.[24] Specifically, we would launch some physical barrier between the earth and the sun. The most developed of these approaches mimic volcanic eruptions. The upper graph in Figure 7 shows two events that "force" temperatures to rise or fall. The lower graph shows changes in global temperatures for the past 125 years.

Figure 7



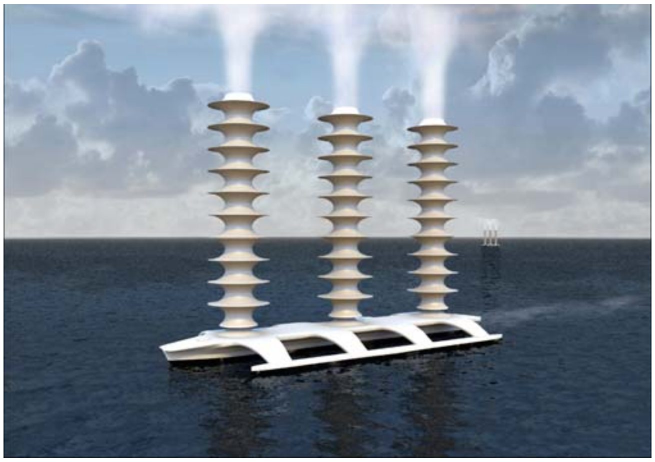
Note the dotted "Stratospheric Aerosols" forcing line. When it dips, global temperature drops as indicated by the arrows. These dips reflect volcanic eruptions and the aerosols take the form of sulfate droplets that emerge from the volcanic eruption and travel high into the stratosphere. Research now underway suggests that aerosol geoengineering could reduce global temperatures by 2°C. The horizontal solid line in the lower graph shows the temperature immediately prior to the eruption of Mt. Pinatubo. The dotted horizontal line on the right of the lower graph shows the temperature reduction possible if the same amount and kind of aerosols were maintained in the stratosphere as emerged from Mt. Pinatubo. That amount of aerosol would produce slightly more than a 0.3 degree C reduction in global temperature, erasing all the greenhouse gas-related temperature rise from the past three decades.

In 1992, the U.S. National Academy of Sciences concluded that use of stratospheric aerosols would work (cool the planet) and that we have the technology necessary to apply this form of geoengineering.[25] *This kind of solar radiation management, done over the next two or three decades, as necessary to prevent catastrophic ocean rise, would provide the time needed to determine what other steps, if any, would be necessary to address events occurring on one-hundred year timescales.*[26] *This is the kind of geoengineering AGW advocate James Hansen is arguing will be necessary.*

Solar Radiation Management – Cloud Albedo Control

Salter, Latham and Sortino,[27] at the University of Edinburgh School of Engineering and the National Centre for Atmospheric Research in Bolder, Colorado, have proposed an ocean-based method of cloud creation using wind-driven ships. Micron-sized drops of salt water serve as condensation nuclei. When sprayed into the marine boundary layer, turbulence will move some into the clouds. Using remotely-navigated, wind-driven sailing vessels (See Figure 8) dragging water turbines to generate the energy for spray, the cloud formation could keep pace with, or even reverse, the thermal effects of increases of atmospheric carbon dioxide concentration. This approach would not address ocean acidification or other CO_2 geochemistry problems, but is another example of a reversible technique with few, if any, environmental side-effects.

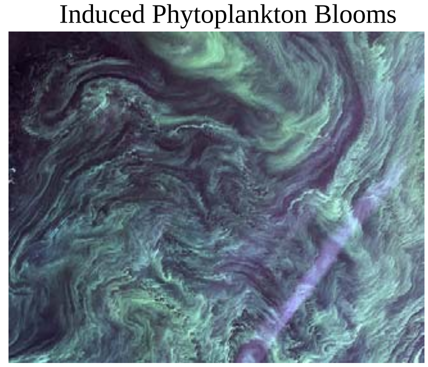
Figure 8
Cloud Albedo Control



Iron and Urea Ocean Fertilization

Iron and urea fertilization involves the intentional introduction of iron or urea into the upper ocean to increase the marine food chain and to sequester carbon dioxide from the atmosphere.[28] It involves encouraging the growth of marine phytoplankton blooms (Figure 9) by physically distributing microscopic iron particles in otherwise nutrient-rich, but iron-deficient blue ocean waters. An increasing number of ocean labs, scientists and businesses are exploring it as a means to revive declining plankton populations, restore healthy levels of marine productivity and/or sequester millions of tons of CO_2 to slow down global warming. Since 1993, ten international research teams have completed relatively small-scale ocean trials demonstrating the effect. The utility of sequestering carbon through this approach relies on the assumption that, upon death, the phytoplankton will fall to the bottom of the ocean. Estimates of this "ocean snow" range from 5 to 50% of the carbon. Commercial applications of this approach have already entered the carbon sequestration market, despite lack of certainty as to the actual amount of carbon sequestered from these methods. The uncertainty may limit the application of these commercial efforts.[29]

Figure 9
Induced Phytoplankton Blooms



Ocean De-Acidification

Increases in CO_2 in the air translate into an increase in the CO_2 concentration in the oceans. The result is a more acidic ocean, one less hospitable to fish and especially to marine forms that form exoskeletins and shells. Cooling the planet, alone, would not solve this problem as the increased levels of anthropogenic CO_2 upset the balance between sea and sky in the same manner. The scientific community has considered three forms of geoengineering that can address this problem. As previously discussed, ocean fertilization pulls CO_2 out of the ocean water. This can help with localized application of the approach but it remains to be seen whether this would work on a global basis.

Alternatively, House, *et al.*, have demonstrated the potential to mimic chemical weather, but significantly accelerate the process. In so doing, chemical plant-sized facilities would extract acids from the ocean water in a manner that sequesters carbon and subsequently pulls CO_2 out of the air, thus reducing CO_2 levels in both air and water. They suggest their approach would accelerate the natural process from centuries to decades.[30]

The third approach would be large-scale application of lime to ocean waters in order to shift the chemical make-up of the ocean in a manner that neutralized acids and allows the ocean to sequester the carbon while pulling CO2 out of the air.[31]

Low-Tech Ocean Carbon Sequestration

A low-tech approach to carbon sequestion that fits within the concept of geoengineering would be to build future coal seams. Strand and Benford propose compressing organic crop residues into bales and sinking them deep into the ocean.[32] Unlike ocean fertilization, simple engineering would ensure these carbon-rich materials would fall to the bottom of the sea and remain there until millions of years pass and depths resurface as new land. The major cost of this approach would be transportation, but when compared with extraction of carbon from air, this would likely present a cost-effective option.

"No Regrets" Strategies

A "no regrets" strategy means taking climate-related decisions or action that make economic good sense, whether or not a specific climate threat actually materializes in the future. McKinsey has evaluated a series of carbon sequestration or carbon emissions reduction actions to determine their cost.[33] Figure 10, from their report, identifies actions that would save money and those that would not and thus would not fall within a "no regrets" policy. Here are the 11 "no regrets" actions and an additional four "small regrets" actions that fall within the $12 per ton threshold now being discussed as a cost ceiling under federal climate change legislation.

The No Regrets Actions

- Modify residential and commercial electronics energy use
- Replace incandescent residential and commercial lighting
- Use fuel economy packages on light trucks and cars

- Apply shell improvements on new residential and commercial buildings
- Apply combined heat and power options in commercial buildings
- Install efficiency improvements on older power plants
- Use conservation silage and non-tillage in agricultural settings[34]
- Install various industrial process improvements that reduce energy needs
- Replace old with new residential water heaters
- Apply modern coal-mining methane management
- Install commercial building energy control systems

The Small Regrets Actions

- Low penetration onshore wind power
- Natural gas and petroleum systems management improvements
- Residential building shell retrofits
- Build nuclear power in place of coal- and gas-fired electrical generating plants

The actions McKinsey examined, but which fall outside the political middle ground at this time include:

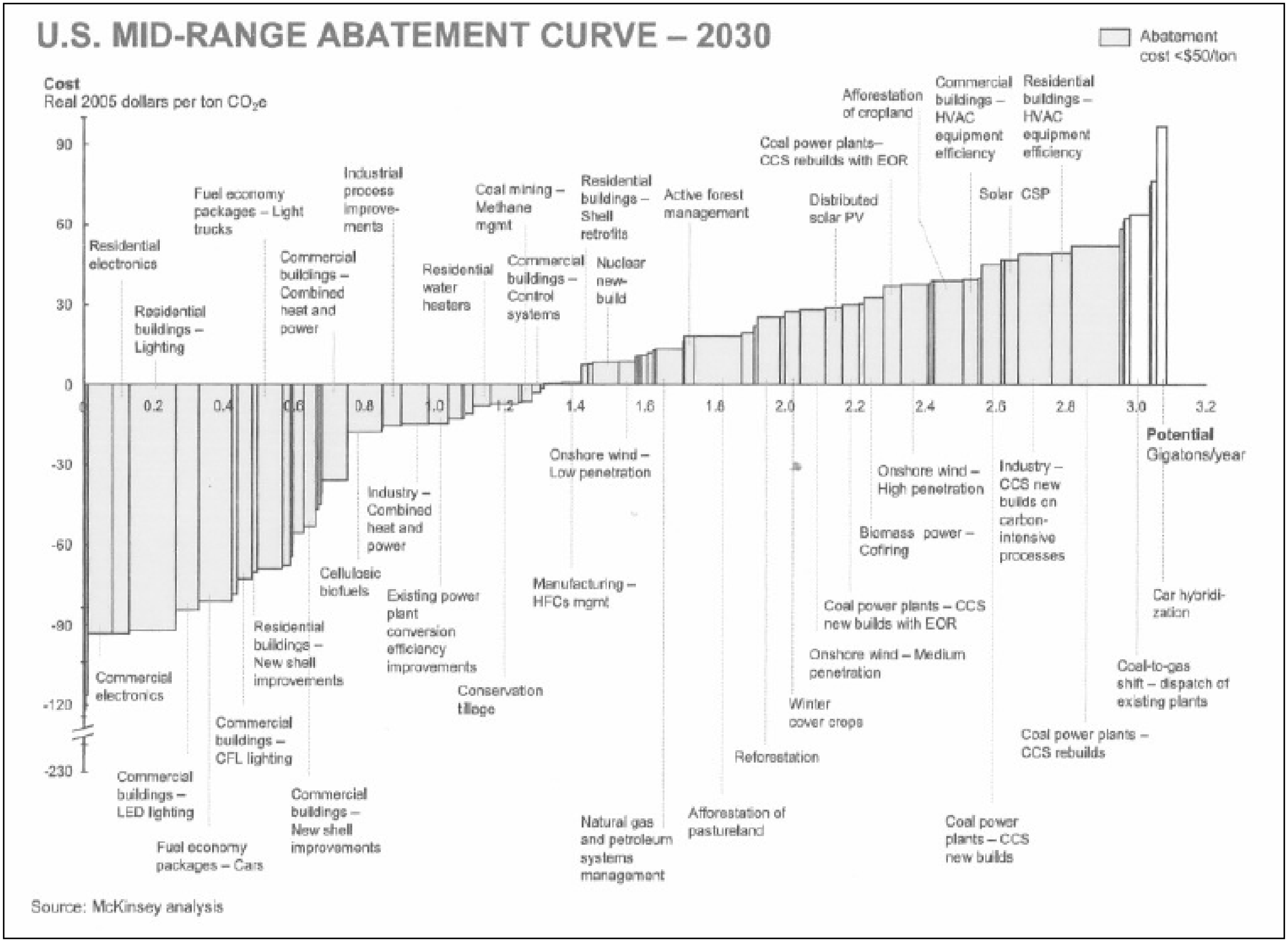
High Cost Actions

- All forms of direct solar power (photovoltaic and CSP)
- Residential and commercial HVAC high efficiency equipment (a LEED element)
- Carbon Capture at coal-fired power plants and carbon-intensive industrial processes
- Re-forestation of cropland
- Medium and high penetration onshore wind power
- Biomass power generation
- Shifting from coal to gas electricity generation
- Hybrid automobiles.

Risk Management

The climate change debate examines the alternatives of “letting nature take its course”, “preventing climate change exclusively through GHG reductions” and the middle ground of “geoengineering, no regrets GHG reductions, and research”. We can distinguish these by examining the climate change risks attendant with each. All parties to this discussion have already agreed that large scale ocean rise and ocean acidification constitute “catastrophic” impacts. The parties do not agree on the probability of these occurring. Alternatively, the AGW community considers local ecosystem changes as catastrophic, while the “natural cycle” community tends to recognize such impacts as normal within the history of the planet, if not within human history, or at least recent human history. These are the major risks at issue.

Figure 10
Cost-effectiveness of Carbon emission reduction actions



Risk management entails more than identifying potential risks. Key to managing risks is knowledge on the likelihood of the risk actually happening. Typically this is written as: P(risk) x Harm(risk) = Expected Harm, where P(risk) is the probability of the risk and Harm(risk) is the nature of the environmental impact. Risk managers attempt to minimize the expected Harm. In climate change, the parties generally agree as to the harm – catastrophic ocean rise leading to inundation of human settlements and ocean acidification leading to destruction of coral and fish populations. They do not agree on the probability of these events occurring. Nor do the parties agree that localized impacts constitute "catastrophic" risks. In particular, the natural cycle community simple sees local impacts as requiring shifts in resource use, rather than the loss of the resource. Further, local ecological impacts pale in comparison to the impacts on humanity associated with ocean rise and acidification. Looking at these risks in this light, one quickly sees the utility of reaching the middle ground of geoengineering and no regrets GHG reductions, compared with doing nothing or relying exclusively on GHG reductions. Table 1 compares the risks of these three options.

Table 1
Climate Change Risk Assessment

Scenario Risk	**Do Nothing** (Natural Cycle Theory)	**GHG Emissions Reduction** (AGW Theory)	**Geoengineering, no regrets GHG reductions, Research** (No Theory at all)
Ocean rise	50% (0% if at the peak of the natural cycles, 100% if still on the way up)	100% (Having exceeded 450ppm CO_2eq)	0% (Using geoengineering to hold temperatures down for 20 years).
Ocean acidification	75% (50% if caused by warming, 100% if caused by CO_2)	100% (Already manifest)	50% (All ocean de-acidification proposals remain paper theory untested in practice.)
Local Ecological Change	100% (Don't know what or where)	100% (Don't know what or where)	100% (Don't know what or where, but it will be different than the other two scenarios)

Three aspects of the most likely form of geoengineering to be used, solar radiation management (stratospheric aerosols), make the AGW community uncomfortable: (1) the uncertainty regarding potential unintended effects these methods may cause; (2) the potential to slow or eliminate work on reducing GHGs, which they consider essential; and (3) the truly catastrophic temperature rebound effect if indeed GHGs caused the problem and for any reasons geoengineering stopped. Two of these three are valid concerns.

The worry about unintended consequences regarding local climates presents no greater, and probably less problem than relying on GHG emission reduction alone. The GHG only option guarantees all forms of catastrophe since it is already too late to apply the approach and it is politically bankrupt in any case. There is no reason to think that solar radiation management would cause greater local ecological harm than that associated with the greater than 2°C increase scenario, complete with ocean rise and all attendant weather effects. Further, careful research attendant with initial use of geoengineering, and research preceding its use, would likely minimize these potential local effects.

The remaining two concerns deserve serious consideration by policy makers. While debate continues regarding whether GHGs would be the sole or dominant cause of potential catastrophic climate impacts, there is no debate that the debate is not over. While no one has proved GHGs are the root cause of warming (which is, of course impossible to prove), no one has proven that they are not the root cause (which is possible to prove). Thus, a prudent policy must include continuing activities to find ways to cost-effectively reduce GHGs. This is especially important to the degree that there may be limits to the utility of solar radiation management, ones that GHG emissions might supersede in future decades. Thus, a decision to apply geoengineering to cool the planet must be paired with a commitment to shift from carbon-based fuel, or otherwise reduce emissions or atmospheric carbon concentrations. A serious shift away from carbon-based fuels makes sense from a national security point of view as well since our current economic prosperity is based in large part on gas and oil from foreign countries.

Conclusion

A dispassionate examination of responses to climate change suggests that we should seek moderate, generally acceptable, if initially uncomfortable policies – polices that have been described as "The Uncomfortable Middle Ground". This calls for geoengineering as a means to put off the most catastrophic potential effects of global warming, at least for a few decades; an immediate reduction in greenhouse gas emissions (GHGs) where those reductions actually save money (the "no regrets" alternatives); significantly expanded use of and research on low-cost carbon sequestration that removes GHGs from the atmosphere or reduces carbon emissions; and some breathing space within which to further assess some of the global warming theories that, if disproven, would point humanity toward lesser reliance on alternative climate change responses.

Endnotes

[1] Dr. Schnare is Director of the Center for Environmental Stewardship at the Thomas Jefferson Institute for Public Policy. He is an attorney and scientist with 32 years of federal and private sector experience consulting on and litigating local, state, federal and international environmental legislative, regulatory, risk management and free-market environmentalism issues. Formerly the nation's Chief Regulatory Analyst for Small Business (Office of Small Business Advocacy), Dr. Schnare has experience on Congressional Staff, as a trial lawyer with the Department of Justice and the Office of the Virginia Attorney General, as senior enforcement counsel at the U.S. Environmental Protection Agency, and as an appellate attorney for private clients. He is a member of the Bars of the United States Supreme Court, U.S. Courts of Appeal for the Second and Fourth Circuits, and the Supreme Court of Virginia. This paper reflects the views of its author and does not necessarily reflect the views of the Thomas Jefferson Institute or the U.S. Environmental Protection agency.

[2] AGW stands for anthropogenic (human-caused) global warming. Those who believe the risk of catastrophic climate change is manifest and requires immediate, civilization and economy changing action are considered "alarmists".

[3] Those who find the bases, assumptions and models used by the AGW community less than compelling, and who are more persuaded that global warming is a natural phenomena that is, at most, mildly affected by human activities have been branded "skeptics".

[4] Ray Ladbury (2008) http://www.realclimate.org/index.php/archives/2008/01/what-if-you-held-a-conference-and-no-real-scientists-came/ at comment 12. Dr. Ladbury is a mid-career physicist at NASA.

[5] *See*, e.g., Anastasios (2007) et al., "A new dynamical mechanism for major climate shifts", Geophysical Research Letters, Vol. 34, L13705, doi:10.1029/2007GL030288, 2007, available at: http://heartland.temp.siteexecutive.com/pdf/tsonis_GRL07.pdf.

[6] Hansen, J. (2007) "Interview", www.grist.org/news/maindish/2007/05/15/hansen/index.html

[7] Flannery, T (2007). "Greenhouse gas levels 'far worse than predicted'", ABC News, October 9, 2007 http://www.abc.net.au/news/stories/2007/10/09/2054191.htm

[8] Mathews and Caldeira (2008), "Stabilizing climate requires near-zero emissions", Geophysical Research Letters, VOL. 35, In Press, DOI:10.1029/2007GL032388, 2008, see abstract at: http://www.ciw.edu/news/stabilizing_climate_requires_near_zero_carbon_emissions.

[9] *Ibid.*

[10] Spratt and Sutton (2008) "Climate 'Code Red' - The case for a sustainability emergency" at p. 41 (citing to James Hansen). http://www.climatecodered.net/ .

[11] BNA Daily Environment Report No. 20 , Climate Change IPCC Chairman Says U.S. Needs to Consider Global Effects When Setting Emissions Target, Thursday, January 31, 2008, Page A-5, ISSN 1521-9402. http://pubs.bna.com/ip/bna/DEN.NSF/eh/a0b5t9v8p7

[12] Mathews and Caldeira (2008), "Stabilizing climate requires near-zero emissions", Geophysical Research Letters, VOL. 35, In Press, DOI:10.1029/2007GL032388, 2008, see abstract at: http://www.ciw.edu/news/stabilizing_climate_requires_near_zero_carbon_emissions.

[13] Hanson (2008) cited in: Spratt and Sutton (2008) "Climate 'Code Red' - The case for a sustainability emergency" at p. 41. http://www.climatecodered.net .

[14] Cane, M. http://www.biconews.com/article/view/6469.

[15] This quotation from Dr. Chylek's vita is available at: http://aerosols.lanl.gov/Members/chylek/Chylek_CV.pdf.

[16] Chylek, P (2002) "A Long-Term Perspective on Climate Change", Fraser Forum, April 2002.

http://heartland.temp.siteexecutive.com/pdf/2329bo.pdf

[17] The lack of civility in the debate over global warming has erupted onto the pages of Wikipedia, just as it has in other fora. *See*:

[18] Avery, D. & Singer, F. (2006), Unstoppable Global Warming: Every 1500 Years. New York, Rowman & Littlefield.

[19] *See e.g.*, Bond, G., et al (1997) "A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Climates", Science VOL. 278 (Nov. 14, 1997), p. 1257; available at: http://rivernet.ncsu.edu/courselocker/PaleoClimate/Bond%20et%20al.,%201997%20Millenial%20Scale%20Holocene%20Change.pdf ; and Russell, J. M.; Johnson, T. C. (2004) "An Equatorial Harmonic of the Holocene 1500 Year Cycle: Cyclic Geochemical Variability in Lake Edward, Uganda-Congo", American Geophysical Union, Fall Meeting 2004, abstract #PP13A-0579 (December 2004) http://adsabs.harvard.edu/abs/2004AGUFMPP13A0579R

[20] Note, a mere 1 meter rise in ocean level would inundate one-third of Bangladesh, causing 25 to 30 million economically challenged people to relocate, with no where to relocate and without the resources to do so, even if they had a place to go.

[21] After listening to my testimony before the Senate Committee on the Environment and Public Works, ranking minority member Senator James Imhoff asked whether I would support using geoengineering if global warming were found to be entirely from natural causes. In partial response, I asked him to consider the potential consequences from ocean rise if we did not.

[22] There remains question as to whether ocean acidification is due to warming or to CO_2 level increases. Certainly it is due to both, but the degree to which it is due to one or the other remains uncertain. Science will not resolve this matter until either there is a significant global cooling event or a significant expansion in our understanding of ocean chemistry, *i.e.*, a vast increase in measurements of ocean conditions and the forces that shape those conditions.

[23] *See, e.g.*, NASA's Project Stormfury, which examined and tested means to reduce the intensity of hurricanes, with no particular success. http://www.aoml.noaa.gov/hrd/hrd_sub/modification.html

[24] *See*, Carlin, Alan, 2007, "Implementation and Utilization of Geoengineering for Global Climate Change Control," Sustainable Development Law and Policy, 7(2): 56-8 (Winter), available at http://www.wcl.american.edu/org/sustainabledevelopment/2007/07winter.pdf?rd=1; Carlin, Alan, 2007a, "Global Climate Change Control, Is There a Better Strategy than Reducing Greenhouse Gas Emissions?" University of Pennsylvania Law Review, 155(6): 1401-1497 (June), available at http://pennumbra.com/issues/articles/155-6/Carlin.pdf; Carlin, Alan, 2007b, "New Research Suggests that Emissions Reductions May Be a Risky and Very Expensive Way to Avoid Global Climate Changes," Working Paper No. 2007-07, National Center for Environmental Economics, USEPA, available at http://yosemite.epa.gov/EE/epa/eed.nsf/WPNumberNew/2007-07; and, Carlin, Alan, 2007c, "Risky Gamble," Environmental Forum, 24(5): 42-47 (September/October), available at http://carlineconomics.googlepages.com/CarlinEnvForum.pdf.

[25] National Academy of Sciences, 1992, Committee on Science, Engineering, and Public Policy, "Policy Implications of Greenhouse Warming", pp. 433-460, available at http://www.nap.edu/catalog.php?record_id=1605.

[26] *See, e.g.*, Rasch, Crutzen & Colman (2008), "Exploring the geoengineering of climate using stratospheric sulfate aerosols: The role of particle size", Geophysical Research Letters, VOL. 35, L02809, doi:10.1029/2007GL032179, http://www.agu.org/pubs/crossref/2008/2007GL032179.shtml.

[27] *See*, Salter & Sortino (2007) "Sea-Going Hardware for the Implementation of the Cloud Albedo Control Method for the Reduction of Global Warming", The Engineer OnLine April 23, 2007, http://www.theengineer.co.uk/assets/getAsset.aspx?liAssetID=25649; *and see*, Salter & Latham, "The Reversal Of Global Warming By The Increase Of The Albedo Of Marine Stratocumulus Cloud", The Engineer OnLine April 23, 2007, http://www.theengineer.co.uk/assets/getAsset.aspx?liAssetID=25650.

[28] Jones, I. & Young, H. (1997), "Engineering a large sustainable world fishery", Environmental Conservation (1997), 24: 99-104 Cambridge University Press, doi:10.1017/S0376892997000167, http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=38139.

[29] Geoengineering Firm Sequesters $4 Million, Wired Science, Feb. 22, 2008, available at: http://blog.wired.com:80/wiredscience/2008/02/geoengineerin-1.html

[30] House, K. et al (2007), "Electrochemical Acceleration of Chemical Weathering as an Energetically Feasible Approach to Mitigating Anthropogenic Climate Change", Environ. Sci. Technol., 2007, 41, (24), pp 8464–8470; https://pubs.acs.org/secure/login?url=http%3A%2F%2Fpubs.acs.org%2Fcgi-bin%2Farticle.cgi%2Festhag%2F2007%2F41%2Fi24%2Fpdf%2Fes0701816.pdf.

[31] Harvey, D. (2008), "Mitigating the Atmospheric CO2 Increase and Ocean Acidification by Adding Limestone Powder to Upwelling Regions", Journal of Geophysical Research - Oceans (in press), available at: http://www.geog.utoronto.ca/info/facweb/Harvey/Harvey/papers/Harvey%20(2008,%20JGR,%20Mitigating%20Ocean%20Acidification).pdf.

[32] Strand & Benford, "The Case for Ocean Sequestration of Crop Residues: Recycling Fossil Fuel Carbon Back to Deep Sediments". Dr. Strand is with the College of Forest Resources, University of Washington and Dr. Benford is with the Department of Physics and Astronomy, University of California, Irvine.

[33] McKinsey&Company, (2008), "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?", available at: http://www.mckinsey.com/clientservice/ccsi/greenhousegas.asp.

[34] There are limits to putting carbon back into soil, but we are far from reaching those limits, and there are considerable additional benefits to sequestering carbon in agricultural soils, including saving farmers money. *See*, Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis, see, http://cdiac.ornl.gov/programs/CSEQ/terrestrial/westpost2002/westpost2002.pdf.

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"... a wise and frugal government, which shall restrain men from injuring one another, shall leave them otherwise free to regulate their own pursuits of industry and improvement, and shall not take from the mouth of labor the bread it has earned. This is the sum of good government, and this is necessary to close the circle of our felicities."

Thomas Jefferson
1801

Thomas Jefferson Institute for Public Policy
9035 Golden Sunset Lane
Springfield, Virginia 22153
703.440.9447
info@thomasjeffersoninst.org
www.thomasjeffersoninst.org