Appendixes

Hot Lies and Cold Facts: Global Warming Deniers vs. Climate Science

Powerful interests, cranks, and honest dupes continue to dispute the mainstream scientific consensus about global warming. Unfortunately we have to take the time to counter their propaganda - a victory for the carbon lobby. It is as though we were in the midst of trying to seriously improve public education, and suddenly had to stop and fight an attempt to remove the theory of evolution from biology text – oh wait…

Usually on catastrophic environmental issues, you consider the precautionary principle - weighing very small chances of catastrophe against great harm if they occur. Global warming is on the same scale, but with overwhelming rather than tiny odds of disaster if unchecked. It is rather as though a group of small children found a loaded gun - one with twelve chambers, eleven of which contain bullets. They decide to play Russian Roulette anyway; after all they might get lucky and pick the chamber without ammunition.

The greenhouse effect exists. As a bumper sticker says about the speed of light "186,000 miles per second; it's not just a good idea; it's the law." Most sunlight penetrating the earth's atmosphere to reach the surface does so in the form of visible short wave light. When it reaches the surface, much of it is converted into longer wavelength thermal energy - infrared. It tries to bounce back out into space again, but some of the longer wavelength energy cannot penetrate the carbon dioxide and other greenhouse gases in the atmosphere; thus solar energy is trapped and helps heat the planet. If greenhouse gases did not produce global warming the surface temperature of the planet would be too cold for humans to survive. The average surface temperature would slightly less than zero Fahrenheit degrees, instead of the nearly sixty Fahrenheit degrees it actually is[324]. The greenhouse effect is about as controversial as the round earth hypothesis.

Deniers seem confused about where the burden of proof lies. Basic meteorology tells us that increased levels of greenhouse gases lead to increased global warming. Fossil fuel use increases greenhouse gas levels in the atmosphere. All data available, including some of extremely high quality, shows that greenhouse gas levels and temperatures are rising. If deniers want to argue that warming is not occurring, or that something other than greenhouse gas level increases is the primary cause, the burden of proof is on them to suggest a plausible explanation and provide evidence for it. It is not the responsibility of mainstream science to take the time to demolish every evidence-free wild speculation they invent - although so far this has been done.

Not only the Intergovernmental Panel on Climate Change of the World Meteorological Organization and the United Nations Environmental Programme expressed consensus on the dangers of human caused global warming[325]. So has every scientific society in the U.S. with climate science expertise[325] including National Academy of Sciences, The American Meteorological Society, the American Geophysical Union, and American Association for the Advancement of Science. Further, between 1993 and 2003 the ISI database lists not one paper disputing global warming published in English language scientific peer reviewed literature[325]. (I'm sure a few have sneaked into obscure publications with careless editors.)

Global warming denial is a propaganda ploy, not a scientific position.

For example, deniers argue that an increase in greenhouse gases from fossil fuels will not significantly warm our climate. After all, atmospheric water vapor is directly responsible for far more of the greenhouse effect than carbon dioxide, methane, and other extraction and combustion products. Sadly, when such gases warm the air just a little, the atmosphere absorbs more water vapor - multiplying the effect into a significant one. In short, it is the other greenhouse gases that determine how much water vapor the atmosphere holds.

Deniers also claim that plants will absorb the extra carbon through normal processes of photosynthesis. Plants breathe carbon dioxide the way we breathe oxygen; increased carbon dioxide, in the absence of other changes does increase growth. Many commercial greenhouses use this principle. Unfortunately, exposure to temperatures they are not adapted to, more violent storms, and disruptions in water supplies, and increased insect populations higher average temperatures encourage, will destroy far more plant life than increased CO2 can encourage. There is also evidence that prolonged unbroken CO2 increases may limit the ability of most plants to use micronutrients, leading to an actual decrease in plant growth[326].

Let's compare theory to data. From the same NASA page cited earlier[324]:

> *According to the Intergovernmental Panel on Climate Change (IPCC), since the industrial revolution, carbon dioxide levels have increased 31 percent and methane levels have increased 151 percent. Paleoclimate readings taken from ice cores and fossil records show that these gases, two of the most abundant greenhouse gases, are at their highest levels in the past 420,000 years.*

So we've added significantly to the amount of carbon dioxide (and methane and NO2) in the atmosphere. Theory says this should have increased water vapor in the atmosphere and therefore temperature.

Citing NASA again[324]:

> *Temperature data gathered from many different sources all across the globe show that the surface temperature of the Earth, which includes the lower atmosphere and the surface of the ocean, has risen dramatically over the past century. The IPCC estimates the increase has been between 0.4°C and 0.8°C. Worldwide measurements of sea level show a rise of 0.1 to 0.2 meters over the last century. Readings gathered from glaciers reveal a steady recession of the world's continental glaciers. Taken together, all of these data suggest that over the last century the planet has experienced the largest increase in surface temperature in 1,000 years.*

Some deniers still fight a last ditch battle against admitting that warming is taking place - for example citing satellite data that seems to indicate less global warming than measured on the surface.

Satellite data measures different layers of the atmosphere than surface temperature; so you would expect results to be different than on the surface. Unlike surface data (that goes back to the 19th century), satellite results mostly cover the very short period from 1979 forward. That period includes both the Mount St. Helens volcanic eruption and ozone depletion - both of which could be expected to lower temperatures in the upper atmosphere. It also turns out there were measurement errors - including heating on the radiation sensor itself and satellite drift.

A new study by scientists from the National Center for Atmospheric Research and the Lawrence Livermore National Laboratory, supported by the U.S. Department of Energy and the National Oceanic and Atmospheric Administration, with contributions from the National Science Foundation corrected for all these factors[327]:

> *The group found a warming trend of 0.16°F per decade in the layer between about 1.5 and 7.5 miles high, compared to a trend of 0.02°F in the previously published UAH analysis. Both estimates have a margin of error of nearly 0.2°F (plus or minus).* [my interpolation: since the study covered 1979-1999 the total warming trend was 0.32°F - greater than the margin of error.] *According to the authors, the new results are a closer match with surface warming, as well as with four computer-model simulations of 20th-century climate produced by NCAR and Los Alamos National Laboratory.*
>
> *As a further check on the new satellite data set, the team examined regional patterns. Using a statistical technique, the group analyzed the 20th-century simulations and searched for an underlying "fingerprint" of climate change. For instance, the rates of warming in the satellite-monitored data vary by latitude from north to south. The authors found that the overall fingerprint of climate change in the models resembled this and other regional patterns found in the new satellite data set.*

In other words, allowing for the effects of ozone depletion and volcanic eruptions, and correcting for undisputed measurement errors, actual measurements approximate those predicted. Data confirms the theory.

Remember that if we were to decide that satellite data and standard meteorological records are unreliable, we would still have the glacier ice core results and measured increases in sea level[324] – plus measured warming of the oceans[328].

Deniers also like to claim the global warming (that they say isn't happening) is not human caused. In the past they argued that data show less warming than climate models predict. Currently, between cooling due to ozone destruction, and the corrected satellite data mentioned above, that dog not only won't hunt - it wants to lie very still in a corner and whine.

Instead they now argue that the peak of a long-term sun cycle[329], rather than greenhouse gases, causes rising temperatures. This long-term peak, however, is in magnetic flux - which has not been linked to temperature variations. Other deniers ascribe rising temperatures to the Milankovitch cycles - predictable variations in solar warming due to long term changes in earth's orbital distance from the sun. These cycles take place over many centuries, however, and cannot explain the size of the changes that took place within a single hundred years (the 20th century) - let alone the warming that occurred in the last two decades of that century. What about the shorter-term eleven-year and twenty-two year irradiance cycles - in which natural variations occur in the amount of solar energy reaching the earth's surface? According to the National Oceanic and Atmospheric Administration[330] "*... the trend in solar irradiance is estimated at ~0.09 W/m2 compared to 0.4 W/m2 from well-mixed greenhouse gases*". So, increases in greenhouse gas production explain at least four times as much of the warming trend as the irradiance cycle does - most analysts say much more.

Another denier position is that global warming will be mild and benign. Canada will grow oranges; Kansas will raise bananas; vineyards will cover England - and everyone will do the "Happy! Happy! Joy! Joy!" dance.

The overwhelming weight of the evidence goes against this rosy scenario. The Intergovernmental Panel on Climate Change projects that without drastic reductions in human caused greenhouse emissions, the Earth's average surface temperature will increase between 2.5° and 10.4°F (1.4°-5.8°C) between 1990 and 2100[331]. This may not seem like much. After all, night and daytime temperatures often differ by more than this range. Unfortunately this small average variation will cause much greater swings day to day. One way to understand the magnitude of such a change is the following quote from the Union of Concerned Scientists website[332]. "*Temperatures only 5°-9°F cooler than those today prevailed at the end of the last Ice Age, in which the Northeast United States was covered by more than 3,000 feet of ice.*"

The IPCC report puts it more cautiously[331]: "*The projected rate of warming is much larger than the observed changes during the 20th century and is very likely to be without precedent during at least the last 10,000 years, based on palaeoclimate data.*"

When it comes to the consequences the IPCC predicts[331.15]:

> *Higher maximum temperatures and more hot days, Higher minimum temperatures, fewer cold days and frost days, reduced diurnal temperature range over most land areas, increase of heat index over land areas, more intense precipitation events, increased summer continental drying over most mid-latitude continental land , associated risk of drought interiors, increase in tropical cyclone peak wind, increase in tropical cyclone mean and peak precipitation intensities*

This is expected to be worse in the global south, which will see more heat waves, more floods more droughts, more intense rain, more and stronger cyclones and topical storms. Food production there will drop precipitately; the greater number and intensity of cyclones, floods and storms, punctuated by the occasional drought, combined with decreased capability to deal with them will drastically enlarge the number of famines and global refugees. There will be more extinction, and more endangered species. This also means more species changing habitats - thus an increase in pests and the spread of disease (which will be encouraged to begin with by the warmer climate).

Growth in the more spectacular forms of poverty will increase the quieter forms that are just as deadly. Absolute hunger, and malnutrition, lack of access to clean water or to medical care will grow. Unchecked global warming will probably kill more in the poor nations than an unending major war would.

The same thing will happen on a smaller scale in the richer north; it too may expect more disease, more pests, and more extinction. If warming is not too severe, the rich nations may avoid famines and massive population displacement. But northern agriculture is not likely to flourish on planet greenhouse.

Aside from simple lower production, there are also questions of instability. Suppose, for example, that a wheat-growing region becomes suitable for banana production. One interesting question this raises is, will raising a luxury crop (bananas) instead of a staple (wheat) necessarily be equally profitable in a world where demand for staples vs. luxury food is increasing? More to the point - **when** does this hypothetical farmer make the switch? Temperatures will rise gradually but not steadily; there is no predicting exactly what year to plough up the wheat, and put in the banana trees. Worse, because of the instability mentioned, a year suitable for wheat may follow a year suitable for bananas. The poor farmer, aside from the usual problem of how well her crop will do, now has to decide what crop to plant. And of course she faces other problems from global warming - more storms, more high winds, more tornadoes and hurricanes if she plants in an area that suffers from them. She may yet face more droughts and floods. She will certainly face more insects, other crop pests, and more (and probably exotic) plant diseases.

I suspect a lot of global warming deniers have never talked to an actual farmer. I don't think they understand how much very small changes in climate from the optimum for a particular crop can affect yield. Farmers have enough problems weather and pest common to the areas they cultivate. Floods in areas that never flooded, heat waves on land which suffered only from frosts, attacks by entirely unfamiliar pests are not inconveniences to farmers – they are catastrophes. Deniers overlook, too, the role cold plays in the lifecycle of many plants. There are crops that only reproduce when subject to frosts, others that reproduce better in cold temperatures than hot ones. It has already been documented that higher night temperatures result in lower rice production[333], and possibly in lower production of other grains such as wheat and corn.

The suffering of the poorer countries will combine with direct effects to harm the rich nations. More refugees will drive down wages - either through immigration into the wealthy nations or by providing cheaper labor outside it. The diseases and pests are likely to travel northward and mingle with the newly flourishing native ones. Especially if combined with a growing refugee population, this will put additional strain on the health care system - so health care will be more expensive. Less food will be available; food prices will rise. Damage at home (and probably refugees from abroad) will combine to increase housing demand and costs. Without assuming more inequality, crime, and less social spending (all of which seem likely in a world that allows all this) even the rich part of planet greenhouse sounds like a miserable place to be poor, working class, or middle class compared to our current world.

History supplies a useful comparison. Fossil fuel burning and massive forest destruction, the two major contributors to both human caused air pollution and human caused global warming both escalated drastically around 1750 - the beginning of the industrial revolution. The consequences of escalating air pollution were felt from the start. We are only beginning to feel the consequences of global warming now. In 1995, the World Health Organization estimated that air pollution from fossil fuel killed more than 460,000 people annually[334]. A 1997 Lancet study suggested that number would rise to 700,000 a year by 2020[335]. This number is ~250 years after the industrial revolution, following decades of effort at mitigation. The carbon balance only altered enough to have major consequences for humans in the last few decades. Actual measurable harm began much more recently than that. We are in, essentially, the same position when it comes to global warming that we were with air pollution in 1750. Change occurs more rapidly than it did in the 18th century. If left unchecked we can expect greenhouse damage to escalate during this century as rapidly as damage from air pollution did in London between the 19th and 20th centuries. In 1873, 268 excess deaths were reported from a "pea-souper" in a period of a few days[336]. In 1954 the worst smog ever recorded in London killed around 4,000 people within one four day period[337]. A recent study suggests that current global warming killed around 160,000 people in 2000[338] due to increases in disease, heat waves, flooding, drought, hurricanes and tornadoes. By historical analogy (and not by scientific analysis) we could expect this to escalate to a bit less than 2.4 million annually by 2050 (if unchecked). This proves nothing - but provides a good sanity check on the previous numbers, showing that they make sense historically.

This leads to another point raised by global warming deniers. Global warming, which is not happening, and due to natural causes, and good for you, is too far advanced to do anything about. (Denier debating tactics resemble a story the Talmud tells. It seems that one family was accused of borrowing a jar from another, then taking it back cracked. The accused family offered three defenses: they never got the jar; it was already broken when they received it; and they returned it undamaged.) And it is not longer only deniers saying this. A number of climatologists and environmentalists are starting to panic, to fear that it is too late that we are doomed, doomed, doomed.

What they fear is that emissions must, just by virtue of how long change will take at this point rise well above the point where an irreversible feedback cycle begins, and that warming then continues regardless of what human beings do about emissions.

However leading climate scientists argue that the odds are still against catastrophe (though worse than we would like) if we start in time – by around 2010. Two facts give us this chance:

1) Climate change has thermal lag; it takes time after greenhouse gases are in the atmosphere for them to produce warming.
2) Many of the greenhouse gases other than CO2 – methane and so forth have much shorter lifespans in the atmosphere than carbon dioxide.

So if we start reducing emissions by 2010, we will still overshoot the safe level of 400 PPM, maybe even reaching 475 PPM of CO2 equivalent. If, at that time, we have been reducing emissions steadily since 2010, the drop in methane and other non-CO2 greenhouse gas may drop concentrations back to a safe level before the atmosphere reacts.

Malte Meinshausen, Reto Knutti and Dave Frame provide a useful analogy[339]: it would be as if we turned on our oven, and then just as the dial hit 475, noticed the cat had wandered inside. If we reacted quickly enough, and turned the oven off before it actually reached that temperature. the cat might survive. Right now climatologists think our odds are lot better than those of the cat in oven; around 75%. A one in four chance of disaster is not happy news of course; but people get those kind of odds in hospitals every day, and still survive.

Now it is true that significant global warming that has already occurred. But, IPCC documents show that if we drastically reduce greenhouse emissions, we probably still have time to prevent the worst consequences. Human beings are adaptable. If we can prevent the greenhouse effect escalating drastically, we will find a way to adjust to the changes that have already happened, or are too late to prevent. Worst case scenarios do not have to happen.

Readers who know something about global warming may wonder why, when looking at the consequences of not acting, I chose this particular scenario. It is after all, the mildest, most optimistic of the plausible "business as usual" projections. If Pollyanna, Pangloss, Anne of Green Gables, Mr. Micawber, and Rebecca of Sunnybrook Farm were climate scientists this is the example they would pick. Why not describe some of the more probable and horrible possibilities?

Because the least harm we can expect from unchecked global warming is enough reason to put enormous efforts into stopping it. The most optimistic plausible case is the equivalent of a major war, year after year for hundreds of years. I don't think that looking at worse possibilities than this gains us anything. Depression and terror aren't energizing; they don't help us fight better.

Imagine for a moment that you needed to walk on a two by four supported a few inches off the ground a distance of a several yards. Depending on your balance you might find this easy, difficult, or impossible. Now imagine that instead of a few inches off the ground it was set at a great height to bridge a chasm across jagged rocks. I don't know about you, but for me the challenge just got much harder. Now imagine trying to cross it while someone shouted over and over again: "If you fall you die. If you fall you die." Constant reminders of the stakes do not contribute to solving the problem.

I considered adding a second appendix titled "The Plural of Apocalypse" that dealt with genuine worst case scenarios. But I decided the demands of honesty are met by simply pointing out that these are real possibilities and (unfortunately) not simply wild speculation.

It is, after all, pretty clear that phasing out fossil fuels over the course of 30 years gives better than even odds. Further because the scenario I've outline phases in efficiency as existing infrastructure is retired emission reductions are slightly better than linear – meaning that we would probably reduce them by 70% or better within 20 years, and complete a total or near total phase out within thirty. That is actually better than most optimists currently think possible.

If that was not sufficient, we could phase in some of the carbon sequestration techniques that have been developed – powering them by wind generators, or other inexpensive forms of variable renewable energy as they are developed. Because we don't care what time of day or year carbon is sequestered as long as it is sequestered we would not need to worry about electricity storage issues; we could use the power as it came. Note that this is **not** a substitute for reducing emissions. (For one thing reducing emissions is much cheaper.) But once emissions are at (or near) zero this would be a way of reducing the damage that has been done. And if that is not fast enough, we can phase out fossil fuels much faster and more expensively either by retiring inefficient infrastructure fast or by phasing in expensive renewables. But we should take no longer than 30 years to reduce emissions to close to zero; there is even a good chance it will be enough.

In short we need to follow the first law of holes: when you are in one, stop digging.

End Notes

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