SENSRI

Water, Energy, and Global Warming

Michael D'Aleo and Stephen Edelglass, revised & updated July 1, 2009

During this scientific era we have learned to speak of causes and effects. While this language can be useful, it can also mislead, as when the public is brought to focus upon El Niño as the "cause" of altered weather patterns around the world. Yet El Niño is a seamless part of the global weather picture, and is as much the result of ongoing changes as their cause. By itself it explains nothing. An undue focus on causes and effects encourages us to fragment the earth's natural cycles and lose sight of their integral unity.

We suspect that this affinity for well-defined causes (often portrayed as villainous or sensational) throws light on the current debates about global climate change. The fixation upon a single atmospheric constituent --carbon dioxide (now widely viewed as a dangerous pollutant) - may have encouraged us to ignore elements of the larger picture. Our intention here is to illuminate another part of that picture (although in a way that may prove startling): it appears that perfectly "harmless" water vapor and the actual quantity of energy produced with it may be at least as much the villains as carbon dioxide.

Some Questions

Perhaps nothing evokes fear of humanity's destructive impact on the environment more than global warming. The past decade brought many news reports of unusual weather and natural disasters. Commentators speculated that hurricanes, droughts, hot spells, floods, and ice storms were due to global warming. But while many people are concerned about the apocalyptic implications of warming, very few, including the scientists reporting the data, are looking at the whole complex of phenomena associated with the idea. Are carbon dioxide emissions really the primary cause? Recently in the U.S. we have seen other "greenhouse" gasses begin to receive more attention. Is *global* warming, as it is currently envisioned, the main cause of climate destabilization, or might other elements be at least partly responsible?

In 1861 the English physicist, John Tyndall, suggested a relationship between the earth's atmospheric levels of carbon dioxide and global temperature (1). Tyndall theorized that increasing levels of carbon dioxide in the atmosphere would trap more of the earth's thermal energy before it radiated into space. That is, carbon dioxide would create an insulating layer around the earth, causing atmospheric temperatures to rise.

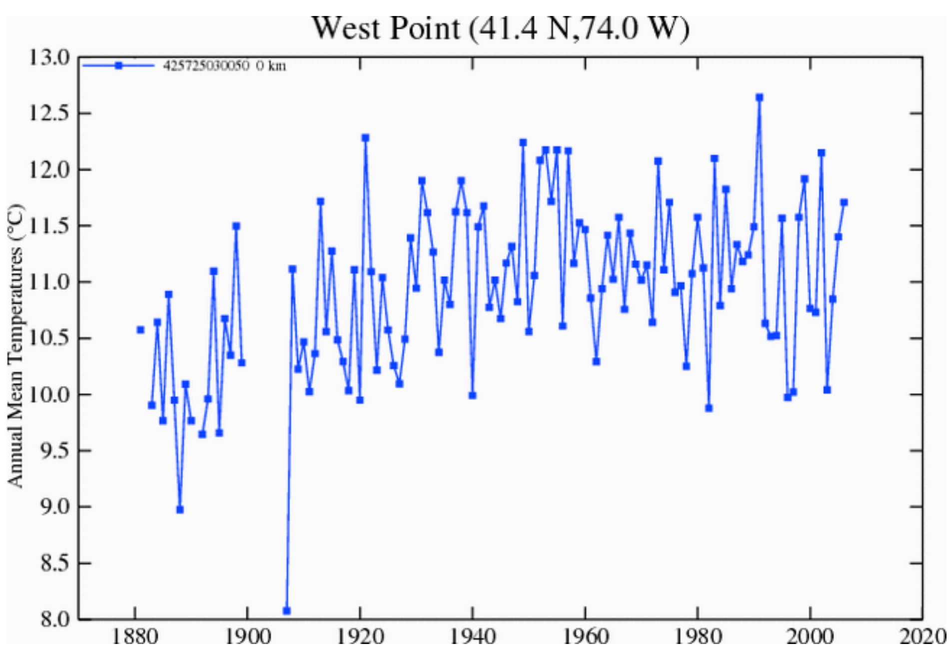
Emissions of carbon dioxide come from natural sources such as volcanic activity, forest fires, and animal and plant respiration. They also come from fossil fuel combustion, industrial processes, and other human activities. At the same time, various natural processes remove carbon dioxide from the atmosphere--for example, the oceans absorb it, and plants require it for photosynthesis. So carbon dioxide is essential for life. But a problem may arise when mankind produces more carbon dioxide than these natural processes can accept. Since we are doing that now, it is natural to wonder whether we are looking at the cause of global warming.

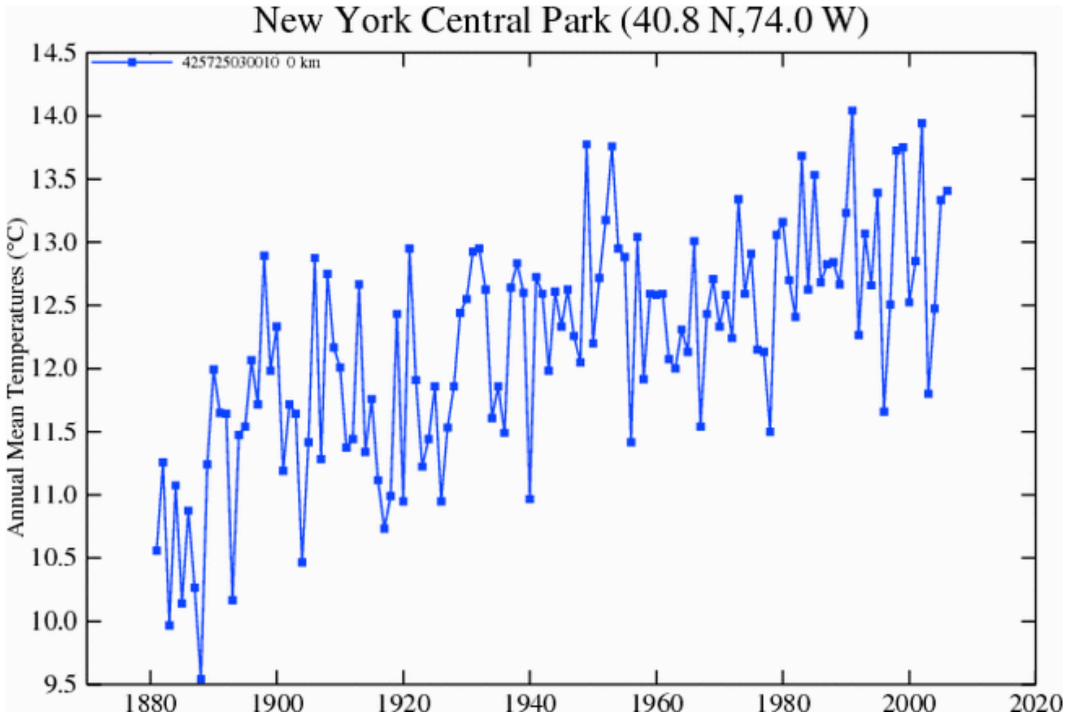
But has there actually been warming over the past century, and if so, how much?

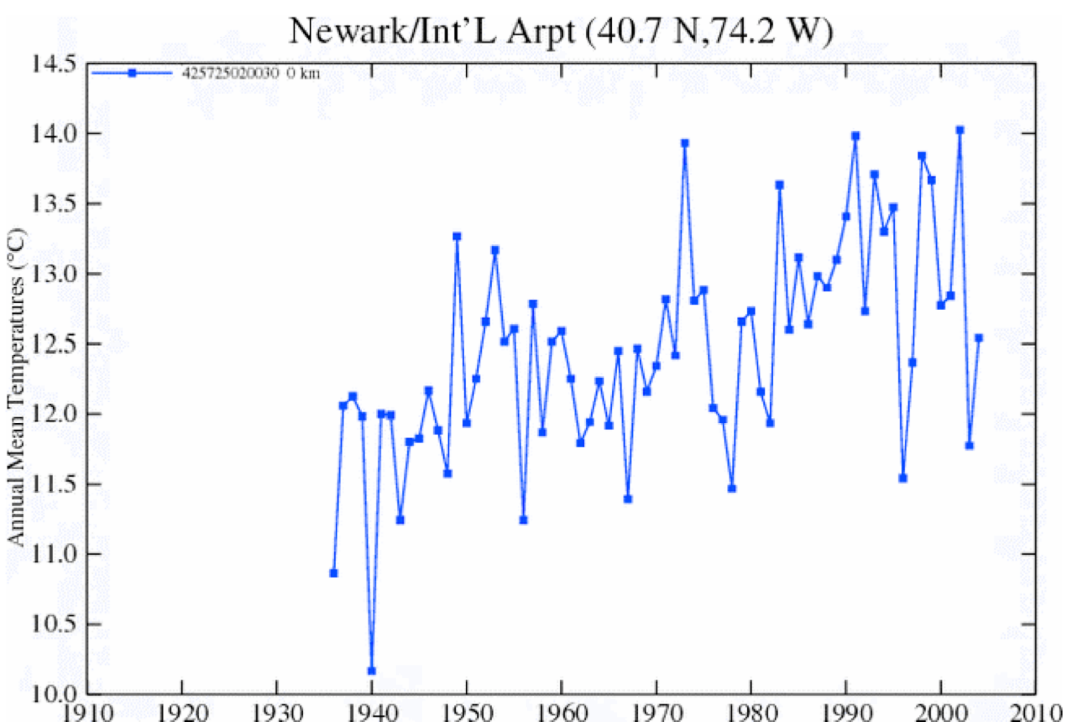
The problem underlying the current debate is that there are two conflicting sets of data. Ground-based data consists of thermometer readings taken at weather stations in various cities and rural areas throughout the world. Some of this data is complete and meticulously maintained, while other portions appear less rigorous. When averaged, it indicates a change of approximately 0.6 degrees C since record keeping began in the nineteenth century (2). Most of this increase occurs in the second half of the twentieth century, with the greater part, 0.2 to 0.3 degrees, coming after 1975. While these figures may seem small, they are potentially significant for climate change. It is interesting to note that since 1998, the rapid increase in worldwide average temperature has largely leveled off and that statistically, there is a very small cooling trend in the last decade

A second set of measurements, available only since 1980, derives from satellites and balloons that scan the temperature of the lower atmosphere across the *entire* surface of the planet. These measurements show an increase ranging from under 0.1 degree C to essentially zero (3). So while the first method indicates a rather substantial change, the second suggests a more modest change. In the past, much of the wrangling focused on which set of data was correct.

The picture becomes more interesting when a comparison is made between urban and rural ground-based weather stations. Urban stations show a significantly greater temperature increase. In fact, many rural stations show no change at all. This has led scientists to speculate about the existence of a so-called "heat island effect", which might affect our global temperature measurements. In the late 1990s, NASA completed a study of this effect in Atlanta, Georgia. The study showed temperatures inside Atlanta up to 8 degrees F higher than the surrounding countryside. The suggested explanation is that man-made materials such as concrete and asphalt store more of the sun's heat energy than forests do (4). A number of studies also found significant temperature differences between downtown business districts and downtown treed parks. The treed parks were up to 7 degrees F cooler than adjacent business areas (5, 6). To get an idea for how the temperature records can vary so dramatically between rural and urban areas, the following three graphs are taken directly from a NASA Website. (6b) Note that the West Point station (located alongside of Harriman State Park, approximately 40 miles due north of Central Park in New York City), does not show any of the recent warming indicated by the Central Park, New York data set or the Newark, New Jersey temperature record (located 12 miles southwest of Central Park). A novel explanation for this difference was developed in the original version of this paper and is discussed below.







Another interesting phenomenon is the suspected link between forest fires and global warming. These fires may play a significant role in contributing to global temperature changes. At least one study suggests that up to 40% of the global greenhouse gas emissions may result from combustion due to forest fires that occur around the world. The report notes that forest destruction further reduces plant absorption of carbon dioxide (7).

The link between global temperature increases and increased levels of carbon dioxide is actually quite complex and not without its share of uncertainty. By analyzing gas bubbles trapped in ice core samples, one group of scientists found that the levels of carbon dioxide in the atmosphere, previously thought to be constant, actually varied significantly during the last 11,000 years prior to the industrial age.

They also found that during some earlier periods the temperature increased *before* the carbon dioxide levels began to rise, sometimes with as much as a 400-to-1000-year lag (8). While this does not imply there is no link between global temperature and carbon dioxide levels, it does suggest that other mechanisms may help determine global temperature variation over time.

Finally and perhaps most puzzling: scientists have noted that while many weather stations worldwide have been reporting increases in average temperature, there also appears to be a worldwide decrease in global rates of evaporation. This was unexpected, since warm air can receive more moisture than cool air and thus, warmer air favors evaporation. In 1998 two researchers suggested that perhaps the decreasing evaporation rates at the stations were counterbalanced by higher rates of evaporation in other landscapes (9). However, there are no observations to support this suggestion.

Has some mechanism put more water into the atmosphere, thereby reducing the global rates of evaporation?

Water Cycles and Their Alteration

Water is essential for life. There are cycles of water transformation from the individual organism all the way up to the scale of the entire earth. As always, a certain balance must be achieved to prevent what supports life from becoming destructive. The farmer hopes for a balance of rain and sun for a good crop. Too little rain and the crop withers; too much brings decay and rot.

Water also plays a significant role in the earth's thermal balance. The specific heat of water (the amount of heat required to raise the temperature of one gram of water by one degree centigrade) is higher than for almost any other material. The heat of vaporization of water -- the amount of energy needed to convert water from a liquid state to a vapor state at its boiling point is over 2,200,000 J/kg (40,700 kJ/kgmol)! This same amount of energy is released to the surroundings when high-temperature water vapor condenses to from liquid water.

The adage, "A watched pot never boils" pays tribute to water's massive ability to absorb heat. Nearly everyone has experienced the moderating effect of the ocean and large lakes on the climate of nearby cities. These masses of water are slow to warm in hot weather, and slow to cool in cold weather.

When a fossil fuel is burned, it produces not only carbon dioxide, but also water vapor (steam). For example, water vapor issues from every running automobile. On cold days this vapor is often visible as it cools and condenses upon exiting the exhaust pipe. The tremendous capacity of steam to store or release thermal energy is utilized by all fuel-based power generating plants including nuclear plants. Table 1 shows the proportional amounts of water and carbon dioxide resulting from the combustion of some common fuels (10).

Table 1. Specific heat at approximately 100°C

	J/kg-°C	J/m^3-°C	kJ/kgmol-°C
Water (liquid)	4,217	4,039,000	76
Water vapor	2,060	1,208	37
Air	1,014	1,208	30
Carbon dioxide	942	1,292	42

Here, in Table 2, the ratio of water to carbon dioxide emitted from various fuels is examined, demonstrating the importance of water vapor in fuel combustion.

Table 2. Water/carbon dioxide ratio for fuels per reacting unit (kgmol)

Fuel	Reaction	water	carbon dioxide	ratio
Hydrogen	H_2+O_2 --> $2H_2O$	2	0	infinite
Methane	CH_4+2O_2 --> $2H_2O+CO_2$	2	1	2.00
Propane	$C_3H_8+5O_2$ --> $4H_2O+3CO_2$	4	3	1.33
Octane	$2C_8H_{18}+25O_2$ --> $18H_2O+16CO_2$	9	8	1.13
Coal	$4C_{149}H_{325}SN_{13}O_{25}+871O_2$ --> $650H_2O+596CO_2$	650	596	1.10
Diesel	$2C_{14}H_{30}+43O_2$ --> $30H_2O+28CO_2$	30	28	1.07
Cellulose	$C_6H_{10}O_5+6O_2$ --> $5H_2O+6CO_2$	5	6	0.83
General	$C_xH_y+(x+y/4)O_2$ -->$(y/2)H_2O+xCO_2$	y/2	x	y/(2x)

Assume that 1 unit of octane (the main component in gasoline) is completely combusted, then exhausted at 150 degrees C, and then cooled to an ambient temperature of 30 degrees. The thermal energy released is summarized in Table 3. This shows that the thermal effect of the water vapor is more than *ten times* that of the carbon dioxide. This difference would be even greater for fuels that produce a higher percentage of water vapor, such as methane. Additionally, the thermal resistance or insulating properties of water vapor and carbon dioxide are essentially identical in value. So the insulating (greenhouse) effects that are of concern for carbon dioxide are even more troubling when we consider water vapor emissions.

Table 3. Thermal energy (kJ) released from gasoline combustion

Carbon dioxide:	8 units x 42 kJ/kgmol-°C x 120°C temp. change
	= **40,300 kJ**
Water vapor:	9 units x 37 kJ/kgmol-°C x 50°C temp. change +
	9 units x 40,700 kJ/kgmol latent heat/condensation +
	9 units x 76 kJ/kgmol-°C x 70°C temp. change
	= 431,000 kJ

It is worth noting that "cleaner burning fuels" such as natural gas or nuclear power, often touted as solutions to global warming, actually emit higher percentages of water relative to carbon dioxide. As presently conceived, a fuel cell utilizing pure hydrogen as a fuel would emit *only* water or water vapor.

Cities and industrial areas, of course, are primary sources of water vapor production via combustion. But they also channel water into the atmosphere by other means. Cities present vast evaporative surfaces preventing the return of water to underground aquifers. (The evaporation of water from hot asphalt after a summer rainstorm is particularly noticeable.) Water from city surfaces is channeled into storm sewers, where it is finally put into a holding pond or river, from which further evaporation occurs. Additionally, ground water tables are falling in many cities.

But if water tables are falling, where has the water gone? You might assume that levels have risen in surface bodies of water, but this has not been observed. Apparently the water has gone into the atmosphere.

Cities are not the only sites of large-scale, human-caused water vapor emission. Deforestation by burning releases tremendous amounts of water into the atmosphere: the tree itself is 50% water; combustion of the remaining 50% (carbohydrates and cellulose) produces more water; and destruction of the forest canopy exposes the moist forest soil to evaporation by sun and wind. Anyone who has walked in a dense forest will attest to the dampness of both the soil and air compared to adjacent fields.

Given present rates of deforestation, the potential for regional climate modification is considerable, quite apart from the production of greenhouse gases such as carbon dioxide. Deforestation releases more water vapor than carbon dioxide.

Water Emissions and Climate Modification

If we have been releasing more water into the atmosphere, might it be falling out of the sky somewhere? There is little evidence for increased precipitation on a global scale. The National Oceanic and Atmospheric Association reports a small (one percent) increase in precipitation over land in the twentieth century, while the same report notes a general increase in cloud cover over both land and oceans in recent decades (2). For the most part, areas experiencing long wet spells seem to be counterbalanced by other areas experiencing drought.

The fact that there seems to be little overall increase in precipitation despite increasing human contributions of water vapor suggests that the atmosphere's water content might be rising. However, this would not be a *global* effect. Water vapor, unlike carbon dioxide, does not diffuse easily through the atmosphere and is therefore concentrated near the earth's surface.

Further, the atmospheric water vapor content will be higher near the sources of water vapor -- for example, near cities and areas undergoing deforestation -- rather than being evenly dispersed in the manner of carbon dioxide. Higher atmospheric water vapor would be expected near cities on a continuing basis, as a result of the combustion of fossil fuels. It would also be expected near deforested areas on a short-term basis; once deforestation is complete, the effect would cease.

All this has definite implications for climate modification. In the first place, given the higher temperature of the products of combustion, the release of energy when water vapor is condensed, and the insulating effects of water vapor, we should expect an increase in the cities' average yearly temperature. As we have seen, this "heat island effect" has already been reported, although the link to water vapor and combustion processes has been widely missed.

Human Energy Production

All energy production ultimately manifests as thermal energy. A very general calculation is therefore possible by taking the overall energy produced in the U.S. in 2007 and assuming it to be evenly distributed on a per capita basis. For example:

In 2007 the U.S. produced: 101.92 quads of energy (1 quad = 1×10^{15} BTUs) (11)

The population of the U.S. in 2007 was: approx. 301 million people (12)

The resulting energy use per capita was: 80×10^{15} BTU/year / 301 million people = 338 million BTU/person-year

For a densely populated and commercial region such as Queens County, New York, assuming equal usage per capita (2007 population estimate of 2,263,858) (13), the human energy production of the county per year would be: 338 million BTU/person-year x 2,263,858 people = 7.6×10^{14} BTU/year.

Given that the solar energy input for this region of the U.S. is approximately 471,327 BTU/ft^2-year (14), the solar energy input for the 109 square miles (13) of Queens County is 4.71×10^5 BTU/ft^2-year x 2.8×10^7ft^2/mile^2 x 109 mile^2 = 1.4×10^{15} BTU/year

Thus, the human energy production in Queens as a percentage of the solar energy input turns out to be a rather astounding (7.6×10^{14} BTU/year) / (1.4×10^{15} BTU/year) = 54%.

Of course, most of this energy production releases water vapor, and our calculation leaves aside the further insulating and thermal properties of this vapor. (You'll have noticed, for example, that a cloudy night is generally warmer than a clear night, and that a hot desert cools off significantly at night due to a lack of water in the air and immediate surroundings.)

A second expectation is that moisture-rich metropolitan air should produce rain when it moves over cooler, rural areas. This is exactly what the NASA study of Atlanta found (4).

In a similar way, we can look at the amount of water released from fossil fuel combustion. U.S. oil usage in 2007 was 20.65 million barrels per day, or 867 million gallons per day (15). The per capita usage is therefore 2.88 gallons/person-day. Given that 1.1 gallons of water are produced for each gallon of octane (gasoline) combusted, the total amount of water produced in Queens County would be (16) 2.88 gallons/person x 1.1 gallons water/gallon octane x 2,263,858 people = 7 million gallons of water/day

However, oil usage accounts for only about 1/3 of total fossil fuel consumption, the rest being natural gas and coal. We will multiply the average per capita consumption of oil by a factor of three to get an approximation of the total water output per capita per day due to fossil fuel combustion. If this water were equally distributed over the 109 square miles of the county, it would be equivalent to an annual increase in rainfall of 3.9 inches per year. The average annual rainfall for Queens County is 42.82 inches/year (17). Needless to say, not all the additional rainfall would fall within the county, but these figures suggest the relative significance of the added water.

Applying the same calculations to a rural area such as Herkimer County, New York (with a population of 65,809 on an area of 1412 square miles), one sees only a tiny fraction of the effects seen in urban areas (13). For example, human energy production turns out to equal only 0.1% of solar input.

Reconciling the Data

The role of water vapor and energy consumption also helps to explain *both* sets of temperature data mentioned earlier. Even though global levels of carbon dioxide are fairly consistent worldwide, temperature variations are not. But these temperature variations -- including the urban-rural disparity -- do correlate well with energy consumption and local water vapor production.

Moreover, there appears to be a strong correlation between areas of deforestation and temperature change, as our analysis suggests should be the case. Temperature increases in the Amazon region and Siberia, where significant deforestation is under way, seem to be unusually high (18). Now, one might note that these regions are interior landmasses, and therefore distant from the moderating thermal effects of the ocean. One might further hypothesize that perhaps the entire earth is warming, but the oceans are moderating the warming effect in coastal areas.

However, this seems unlikely. The interior areas of the United States such as the Midwest Plains do not show warming, and these areas are not being deforested; rather, farmland has replaced prairie grassland. The same could be said for the interior grasslands of other continents. These areas show no significant warming. This suggests that the moderating effect of the oceans may not be sufficient to explain the data for continental interiors. The effects of ongoing deforestation may be responsible.

Finally, the decrease in measured evaporation rates now also finds explanation. While the decrease is puzzling when taken only in conjunction with a thesis of global warming, it makes sense once we add human-related sources of water vapor to natural evaporation. Furthermore, as expected, the atmospheric water vapor content in North America (the one place where reliable data are available) has been increasing during the two-decade period starting in 1973 (19).

On the view presented here, one would expect to see *some* correlation between carbon dioxide levels and temperature change, since both water vapor and carbon dioxide are major products of combustion. But water vapor's dominant role fits better with the overall pattern of global data, helping to resolve the contentious debate between those who see global warming and those who don't. Local and regional warming *are* occurring, even if the global picture shows no clear warming trend.

One additional note: the role of increased cloudiness and its albedo (reflective) effect is not discussed here, and requires further study.

Addendum:

Since the original version of this paper was first published in 2001, a very interesting study was conducted by some NASA scientists and university researchers. In a paper published in the research journal Hydrological Processes, these two scientists, Burian and Marshall, reported their findings of a significant increase in the rain patterns downwind of the city of Houston, Texas that they attribute to the urbanization of the area. The date of this report correlates very strongly with the premise laid forth in this article. (20)

We Are Environmental Causes

In sum, atmospheric warming -- the warming for which we currently have the clearest evidence -- is a local and regional phenomenon more than a global one, and it appears to be due more to human-caused energy production and water emissions than to carbon dioxide emissions.

This is not to take a position for or against global warming as such. Nor is it to downplay the potentially grave significance of *any* large-scale alteration of the natural environment. Nor again is it to dismiss the global significance of local and regional warming. When a NASA study of the metropolitan Atlanta area finds that the rainfall in rural areas southeast of the city was the result of Atlanta's "heat-island" effect, we can no longer deny mankind's effect on the greater environment. The possibilities of even larger regional effects continue to be studied by various researchers.

Even if the globally averaged temperature fluctuations reflect improper measurements or natural periodic variations, it seems impossible to attribute local and possibly regional temperature fluctuations to anything other than man-made influences. We have yet to see a report that denies the existence of the "heat-island" effect. There is also sufficient evidence to suggest that the atmospheric levels of water vapor are rising and may be responsible for local and regional changes in temperature and in weather patterns. This analysis of human created thermal warming and water vapor emissions has enormous implications for proposed alternative energy solutions. The analysis given above suggest that a hydrogen economy - one that is solely based on hydrogen or fuel cells where water vapor emissions are the only output (but in greater quantities than most fossil fuels) - is likely to leave us with similar or even worse local and regional climatic effects than we have at present. Nuclear power, which also produces greater water emissions in the cooling towers than fossil fuels do for the same energy output, are equally problematic and offer no real solution to the situation

There are many other aspects of the Climate Change issue that could be discussed that go beyond the initial intention of this paper. For example, the question of sea-levels rising is an often cited example. Here one should read the works of scientists such as Dr. Nils-Axel Morner, a respected scientist who used to contribute his research to the IPCC reports until he found that his understanding that sea levels are NOT rising was ignored. His credentials are as important as his research. Polar ice data from both the Arctic and Antarctic, as well as glacial melting, also have their own experts and data. For example, the often cited melting of the snows of Mt. Kilimanjaro is accepted in the scientific community as NOT being the result of a rise in temperature, but instead as a result of a decrease in precipitation as a result of local deforestation.

If there is a moral to the story, it is that prolonged scientific debate and confusion can sometimes result from a failure to step back and look at all aspects of a problem. And a second moral is that out-of-context technological fixes aimed at a single aspect of a complex whole may prove destructive. Much of the research on alternative fuels today is premised on the belief that water vapor is a benign emission. But if we have learned anything over the past decade, it is that a life-giving element can become destructive if it is removed from a balanced context. The faith being placed in hydrogen and fuel cell technologies (which emit nothing but water) may need more thorough study.

While rarely spoken about, the potential market for Caron Trading Futures is incredibly large. On June 25th, 2008 the Financial times ran a story entitled, “Carbon Trading set to Dominate Commodities”. In this story, the Financial Times reports estimates of the potential size of the carbon trading emissions market as high as 2-3 trillion dollars. This would make carbon emissions trading the largest commodity market in the world! One year earlier on April 27th, 2007 the Financial Times ran another series of articles describing many of the problems and misuses that were already being experienced in carbon trading schemes. If you believe that there are already problems in our present system of energy and its costs, the potential for making money in carbon trading is even greater. The potential for making and losing money here is perhaps only rivaled by our present financial crisis.

Of course any activity or plan that conserves energy or uses it more efficiently is to be encouraged. However, recall that significant levels of reduction are needed for all human beings to live a healthy life and do so in harmony with the natural world. For example, there have been some improvement in the efficiency of both the output of solar panels and a reduction in the energy needed to produce them. However, the biggest reductions come when a person reconfigures their life not to use a different energy source, but instead, when they simply use significantly less energy.

The only solutions that will truly decrease the destabilization of the environment are those that work in conjunction with the entire natural process found in any given ecosystem. A greater study and understanding of the complex interactions found within natural ecosystems may indeed yield important details in this regard and point to real solutions to these problems.

www.sensri.org

Michael D'Aleo (michael@sensri.org), who is trained both as engineer and educator, has spent a number of years working in industry, receiving several patents along the way. His main interest has been to solve technical problems artistically, based on processes found in the natural world. He currently teaches physical science and mathematics at the Waldorf School of

Saratoga Springs in Saratoga Springs, New York and lectures internationally on science education and environmental issues. He co-authored the book, *Sensible Physics Teaching*, with Stephen Edelglass. D'Aleo is also a principal researcher at SENSRI, a 501-c-3 organization in Saratoga Springs, New York, devoted to phenomena-centered research.

Dr. Stephen Edelglass was for many years on the faculty of the Cooper Union for the Advancement of Science and Art in New York City. He then taught high school mathematics and physics at the Green Meadow Waldorf School in Spring Valley, New York, until his death in November 2000. In addition to *Sensible Physics Teaching*, he co-authored *The Marriage of Sense and Thought: Imaginative Participation in Science*. He was also a founder of SENSRI.

To find out more about SENSRI's research efforts, or to read the original paper with the full set of calculations, please visit our website. To learn more about how phenomena centered approach to science might solve the root of our environmental challenges, you are encouraged to read the essay, The New Environmental Aesthetic at the address above. We welcome inquiries about our research and offers of support.

References

1. Brown and Lemay, *Chemistry, the Central Science* (Englewood Cliffs N.J.: Prentice-Hall, Inc, 1977), p. 302.

2. National Oceanic and Atmospheric Administration, "Global Warming Frequently Asked Questions," Dec. 10, 1999. http://www.ncdc.noaa.gov/ol/climate/globalwarming.html

3. Christy, John and Spencer, Roy, "Using Satellites to Monitor Global Climate Change," 1999. http://www.atmos.uah.edu/essl/msu/background.html

4. Quattrochi, D. and Luvall, J., "Here Comes Urban Heat," *Science @ NASA* March 16, 2000. http://science.msfc.nasa.gov/headlines/y2000/essd16mar_1m.htm

5. Quattrochi, D. and Luvall, J., "NASA Studies Mother Nature's Air Conditioners," *ENN News Archive*, May 15, 1997. http://www.enn.com/enn-news-archive/1997/05/051597/05159718.asp

6. Zahoor, A., "Trees, Cities, and Global Warming Based on Effect of Trees in Ameliorating Air Temperature in Urban Settings in Pakistan, *ENN News Archive*. Doctoral dissertation in Range Resources at the Univ. of Idaho, 1997. http://www.enn.com/enn-news-archive/1997/08/081997/08199713.asp

6b. Datasets and Images, GISS Surface Temperature Analysis

http://data.giss.nasa.gov/gistemp/station_data/

7. Graetz, D. "Fire's Role in Global Warming Studied," *ENN News Archive*, Sept. 27, 1999. http://www.enn.com/enn-news-archive/1999/09/092799/csirofire_5847.asp

8. Fisher, H., Whalen, M., Smith, J., Mastroianni, D., and Deck, B. "Ice Core Records of Atmospheric CO2 around the Last Three Glacial Terminations," *Science*, 1999, 283:1712-1714.

9. Parlange, M. and Brutsaert, W., "Hydrological Cycle Explains the Evaporation Paradox," *Nature*, Nov. 5, 1998.

10. Incropera, F. and DeWitt, D., *Fundementals of Heat Transfer* (New York: John Wiley & Sons, 1981), Appendix A.

11. U.S. Department of Energy, EIA Annual Energy Review, Report #:DOE/EIA-0383(2009). http://www.eia.doe.gov/oiaf/aeo/overview.html

12. U.S. Census Bureau, National and State Population Estimates, 2008 – 2008. http://www.census.gov/popest/states/NST-ann-est.html

13. U.S. Census Bureau. http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=Search&_lang=en&_sse=on&geo_id=05000US36081&_county=Queens+County

14. Watson, Donald, *Designing and Building a Solar Home* (Charlotte, Vt.: Garden Way Publishing, 1977), pg. 12.

15. U.S. Department of Energy, EIA, *Annual Energy Review (ibid #11 above)*

16. Heywood, J.B., *Internal Combustion Engine Fundamentals* (New York: McGraw Hill, 1988), p. 915.

17. *The World Almanac and Book of Facts* (Mahwah, N.J.: Funk and Wagnalls, 1993), pg. 166.

18. Jones, P., T. Osborn, T. Wigley, P. Kelly, and B. Santer (1997), Comparisons between the microwave sounding unit temperature record and the surface temperature record from 1979 to 1996: Real differences or potential discontinuities?, J. Geophys. Res., 102(D25), 30135-30145.

19. American Geophysical Union, *Water Vapor in the Climate System* (Washington, D.C., 1995). http://www.agu.org/sci_soc/mockler.html.

20. Burian, Stephen J. and Shephard, J. Marshall, Effect of urbanization on the diurnal rainfall pattern in Houston, Published in Hydrological Processes, **Volume 19 Issue 5**, Pages 1089 – 1103, March 2005.