SCR 28 WORKGROUP PAPER FOR FEB. 6, 2008

AN ENVIRONMENTAL AND CLIMATE SCIENCE PERSPECTIVE ON AUCTION OF EMISSION ALLOWANCES AND USE OF FUNDS UNDER THE REGIONAL GREENHOUSE GAS INITIATIVE (RGGI)

by C.A. Tolman

SUMMARY

Because several of the legislative members of the SCR 28 Workgroup were not able to hear my presentation on December 7, I decided to put my thoughts into writing for their benefit, and for the benefit of those who may not have thought about the very serious environmental impacts that the Workgroup's legislative recommendations can have on Delaware's future.

Because Delaware is a coastal state with most of its land area not far above sea level, rising sea levels resulting from global warming and climate change pose an extremely serious threat to the future welfare of our citizens and to the continued existence of the state itself. It is thus incumbent upon us to reduce carbon dioxide emissions produced by the burning of fossil fuels as rapidly and completely as possible, and to seek opportunities to become a national leader in dealing with the growing threat. We must use every means at our disposal to reduce greenhouse gas (GHG) emissions from all sectors of society, including major improvements in energy efficiency and ambitious development of renewable energy resources. This is a powerful argument for a 100% auction of Delaware's 7.5 million emission allowances under RGGI. We will need all the resources we can get in order to transform our state into one that is sustainable.

Improvements in energy efficiency are extremely important because they can often reduce GHG emissions at low cost, and can in fact often save money. They are however insufficient by themselves to achieve the kind of emissions reductions that are needed. Therefore a substantial fraction of the money raised by the auction should be for the promotion of renewable energy sources.

In order to mobilize citizen action and support for the changes needed, we will need to expand public education in energy and climate change for people of all ages from grade school to senior citizens. Many people are aware that there is a serious and growing problem, but don't know what they can do to address it.

Costs of energy from fossil fuels are going to rise as a result of increasing global competition for limited supplies, and because of increasing costs of carbon emissions--as a result of cap-and-trade programs like RGGI or direct taxes on carbon emissions. These costs can be expected to rise as the damage caused by climate change increases and as people demand that the polluters pay. Rising energy costs fall particularly heavily on the poor, for whom these costs may eat up a large fraction of their income. Thus social justice requires that some of the money raised in the auction be used to assist those who already are pressed to pay their energy bills.

Reasons for this Paper

Several of our workgroup members--especially legislators--were not at our meeting on December 7, when I first presented an environmental and climate science perspective on the main issues facing the SCR 28 (RGGI) Workgroup: 1) What percentage of Delaware's emission allowances should be auctioned? and 2) How should the funds generated be used? So I decided to put my thoughts into writing. (Some of the information here was not presented earlier.)

Global Warming and the Percentage Auction

Global warming (climate change) is expected to have a variety of impacts, mostly negative, which increase in severity as the global average temperature increases, as shown in **Figure** 1. Of all the impacts on Delaware, the one most likely to have the most negative consequences--because of our coastal location and low average elevation--is sea level rise. This threat provides a powerful argument for reducing emissions of carbon dioxide (CO2) and other greenhouse gases as rapidly as possible. The Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report, published last year, concluded with a high degree of certainty that the Earth's climate is changing as a result of human activities—especially the emissions of CO2 from burning fossil fuels.[1] Increasing atmospheric concentrations of CO2 disturb the energy balance between the incoming solar radiation and radiation going back into space--causing Earth's average surface temperature to increase. **Figure** 2 shows the dependence of global average equilibrium[2] surface temperature on CO2 concentration, expressed in ppm (parts per million by volume) from 450 to 750. The current concentration is about 385 ppm and is increasing at over 3 ppm per year.[3] Leading climate scientists warn that CO2 should not be allowed to rise above about 450 ppm if we are to avoid dangerous and irreversible damage.[4]

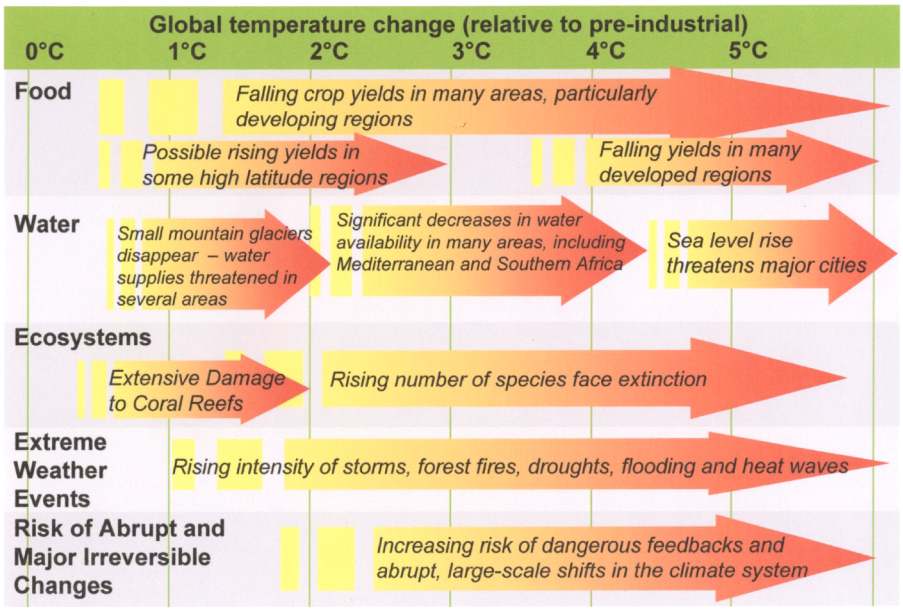

Figure 1. Impacts of temperature changes, from Sir David King.[5]

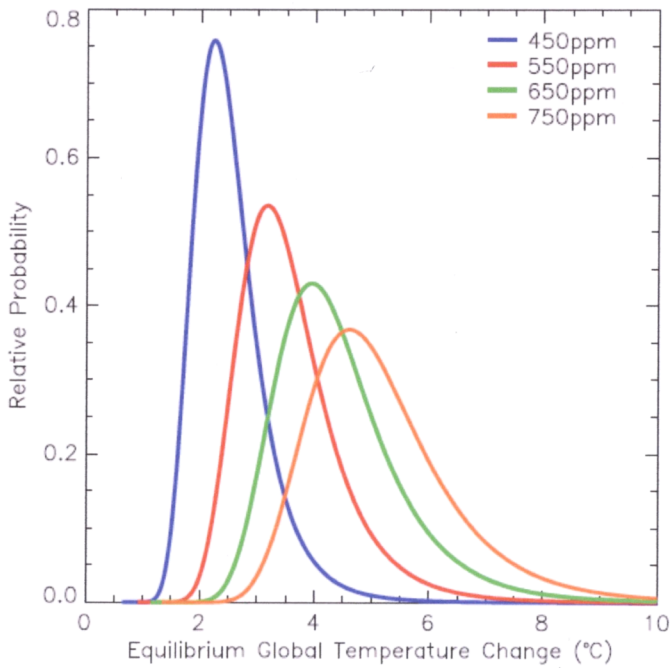

Figure 2. Sensitivity of temperature change to CO2, shown as probability distributions of temperature change for various CO2 concentrations, from Sir David King.[6]

The area to the right of any particular temperature change (for a given CO2 concentration) in Figure 2 is the probability that the equilibrium temperature will exceed that value.[7] For example, in the case of 450 ppm (the tall blue curve at the left) the probability that the global average temperature will exceed 2.2ºC (4.0ºF) is a little over 50%; there is some chance that it could even be above 4.4ºC (8.0ºF).

It is easy enough to calculate how the atmospheric CO2 concentration will change with time for any given emission scenario.[8] Suppose we continue a business as usual (BAU) scenario, increasing the global emission rate by a constant 3% each year, starting at 8.8 GtC per year in 2005.[9] **Figure** 3 shows how the emission rate under that scenario would increase over the 100-year period from 2005 to 2105. **Figure** 4 shows how the CO2 concentration would increase with time.

It should be pointed out that Figure 4 is conservative and probably underestimates the future rate of increase of CO2 for three reasons: 1) For the past few years the global emission rate has been increasing each year by more than 3%, fueled by the rapid growth of the Chinese economy;[3] 2) The model used to generate Figure 4 assumes that the current 57% fraction of CO2 emitted to the atmosphere remains there,[10] while the 43% of the CO2 now taken up by oceans and land is expected to decrease as water temperatures increase, CO2 becomes less soluble, and forests are destroyed; and 3) Figure 4 does not take into account the increasing rates of carbon emissions from carbon reservoirs in soils, permafrost, and sea beds as temperatures increase, *i.e.* it ignores positive feedback effects on emission rates.

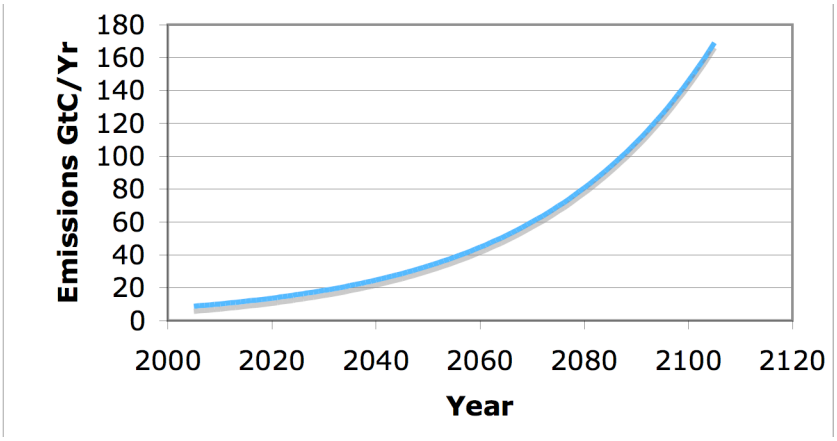

Figure 3. A BAU carbon emission scenario, starting at 8.8 GtC/yr in 2005, and increasing at a compound rate of 3.0% per year.

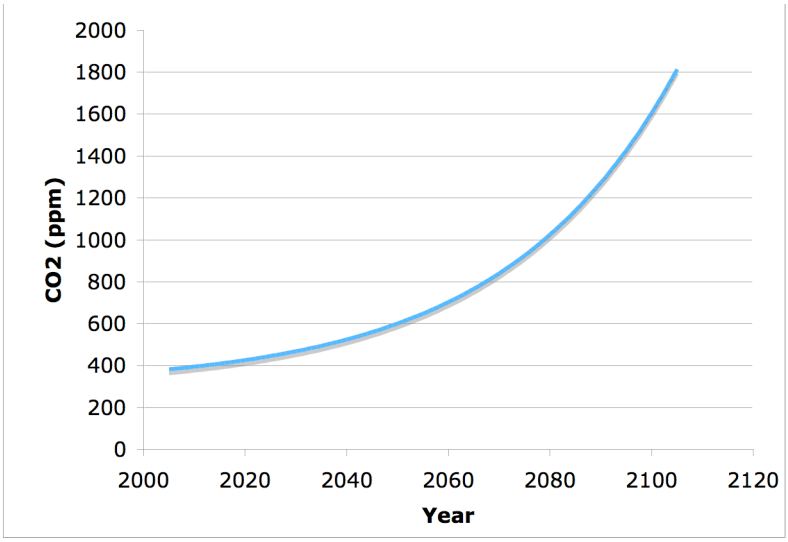

Figure 4. CO2 concentrations for the business as usual (BAU) emission scenario shown in Figure 3.

Table 1 shows the years when various concentrations are reached in Figure 4, and the most probable global equilibrium temperature increases (ΔT), from Figure 2.

Table 1. BAU Increases in CO2 and Temperature with Time

Year	CO2 Conc. (ppm)	Prob. ΔT (°C)
2005	380	~1.5*
2026	450	2.2
2044	550	3.1
2055	650	3.9
2064	750	4.6
2071	850	~5.2*

* Estimated by extrapolation from other values.

So what does increasing temperature mean for sea level in Delaware? Sea level rose by 12 inches at Lewes during the last century, according to an EPA report.[11] Estimates for the next century vary from a probable 23 inches in the same 1997 report to 64 inches (1.6 m) in a very recently published study.[12] The latter was based on geological evidence of sea level rise about 120,000 years ago, when the earth was coming out of an ice age, and the temperature was about 1ºC higher than it is now. The paleoclimate record can also provide guidance on how the equilibrium sea level depends of global mean temperature.

Figure 5 shows paleoclimate data over a wide range of global average temperatures--from 6ºC lower than now at the last glacial maximum, 20,000 years ago, when sea level was about 120 m (about 400 ft) lower, to 4ºC higher 40 million years ago, when sea level was about 80 m (about 265 ft) higher, and there was no ice in Greenland or Antarctica. These data indicate that the equilibrium sea level increases about 20 m (about 65 ft) for each 1ºC temperature increase (36 ft per ºF) over the range shown. Global average temperature has increased 0.8ºC since 1750, at the beginning of the Industrial Revolution, but temperature and sea levels would continue to rise ***even if we could stop CO2 emissions now***. The global average temperature involves the surfaces of sea and land, and atmosphere near the Earth's surface. Because of its huge heat capacity and slow turnover, hundreds of years are required for complete warming and mixing of the oceans, the average sea surface temperature lags the average land temperature, and a long time is required to reach equilibrium. The open point labeled 'Projection for 2100' in Figure 5 is based on about a 3°C temperature increase from today and a small enough change in sea level (+1 m) that the point is hardly above the horizontal line on this scale.

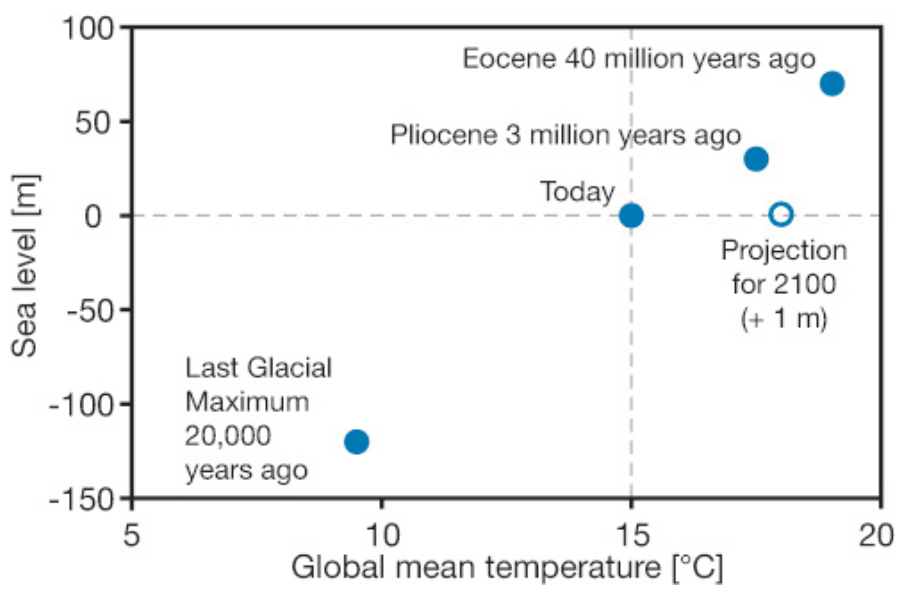

Figure 5. Equilibrium sea level change (in meters) from the present value, at various global average temperatures.

Figure 6 schematically shows possible trajectories of CO2 emissions and atmospheric concentrations, global average temperatures, and contributions to sea level from thermal expansion and melting of land-based ice. The point where the last two curves cross (when thermal expansion and melting of glaciers make equal contributions to sea level rise), shown at about 1000 years, was unknown when this figure was drawn.

A recent IPCC report gives the measured rate of sea level rise during the period 1993-2003, based on satellite measurements, as 0.31±0.07 m/century compared to 0.16±0.07 m/century calculated for thermal expansion during the same period.[13] In other words, the rate of sea level rise from melting of ice is already as great as the rate from thermal expansion. The two curves have already crossed, and the rate of ice loss is rapidly increasing in both Greenland[14] and Antarctica.[15]

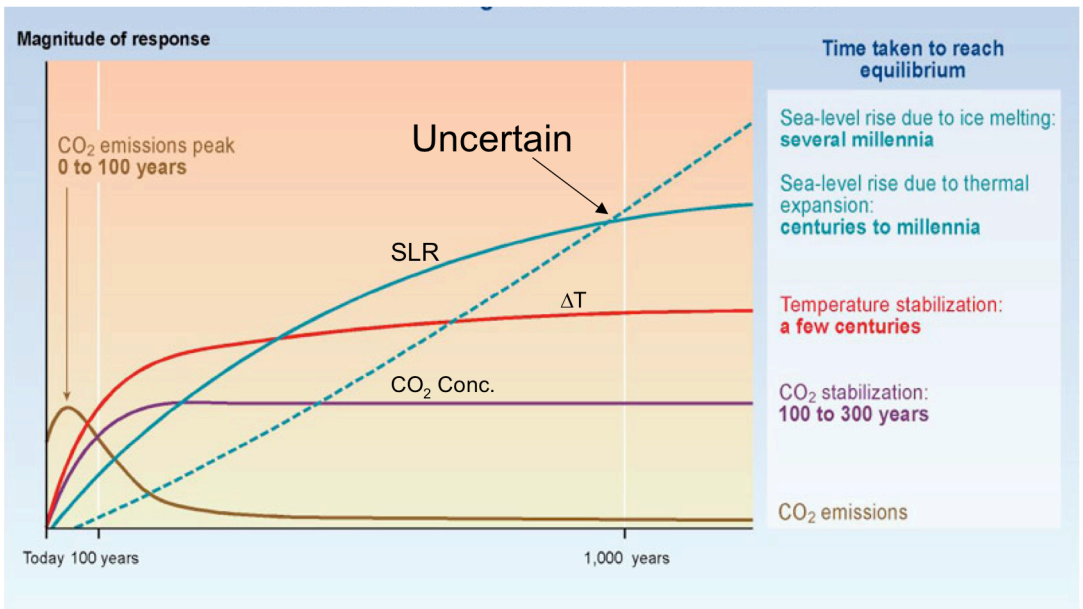

Figure 6. A schematic plot vs. time of global CO2 emission rate and concentration, temperature change (ΔT), and sea level rise (SLR) due to thermal expansion (solid line) and glacial melt (dashed line).

Figure 7 shows a topographical map, developed by the UD College of Marine and Earth Studies, which shows how the Delaware coastline would look with various increases in sea level. With even an 0.6 m (2 ft) rise, the state would lose about half of its coastal wetlands. With an 80 m (262 ft) rise, corresponding to the complete loss of ice from both Greenland and Antarctica, all that would remain of Delaware above water is the dark green area In Figure 7 in the northernmost part of the state; the Delmarva Peninsula would be gone.

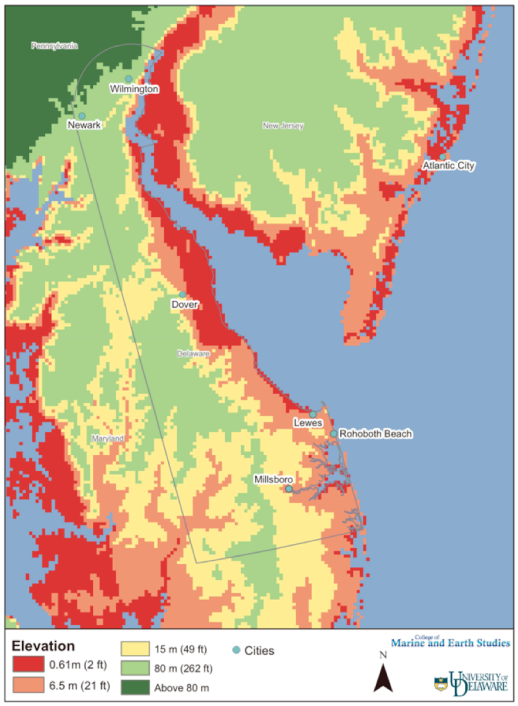

Figure 7. Impact on Delaware of various heights of sea level rise.[16]

The consequences of sea level rise provide a powerful reason for Delaware to move as fast as it can to reduce its CO2 emissions. That means auctioning 100% of its RGGI emission allowances, in order to raise as much money as possible to deal with the twin threats of global warming and rising energy costs. These costs, which fall hardest on the poor, are expected to rise because of increasing global competition for natural gas and other fossil fuels, and increasing prices of carbon emission allowances.

How the Funds Raised at Auction Should be Used

Figure 8 shows an assessment by the American Solar Energy Society (ASES) of how future U.S. carbon emissions from all sectors of the economy could be reduced by a variety of technologies. Starting from the top they are: improved energy efficiency (EE), wind, biofuels, biomass, solar photovoltaic (PV), concentrating solar power (CSP), and geothermal. The 1,640 MtC/yr (1.64GtC/yr) shown in 2005 corresponds to 6.5 GtCO2/yr. Wind is the largest renewable energy resource shown. The Figure indicates that wind could reduce annual U.S. carbon emissions by about 175 million tons or CO2 by about 700 million tons, but does not include offshore wind. Recent studies at UD show that complete development of the U.S. offshore wind resource along the East Coast from MA to NC could produce an average of 184 GW,[17] reducing CO2 emissions by 1,600 million tons per year[18] (24% of total 2005 U.S. CO2 emissions), if offshore wind power replaced coal burning power plants.

The orange and blue-green dashed lines in Figure 8 are the emissions trajectories that decrease U.S. carbon emissions by 60% and 80% by 2050, respectively. Prime Minister Gordon Brown has already committed the UK to reducing its emissions 60% by 2050.[19] Henry Waxman of California has introduced a bill into Congress calling on the U.S. to reduce its CO2 emissions 80% below their 1990 values by 2050 in order to keep

atmospheric CO2 concentration from going above 450 ppm--so as to have a reasonable chance of keeping temperatures from rising more than 2ºC (3.6ºF).[20] Lester Brown, the respected Director of the Earth Policy Institute, has recommended decreasing U.S. emissions by 80% by 2020,[21] as shown in the lower green dashed line in Figure 8.

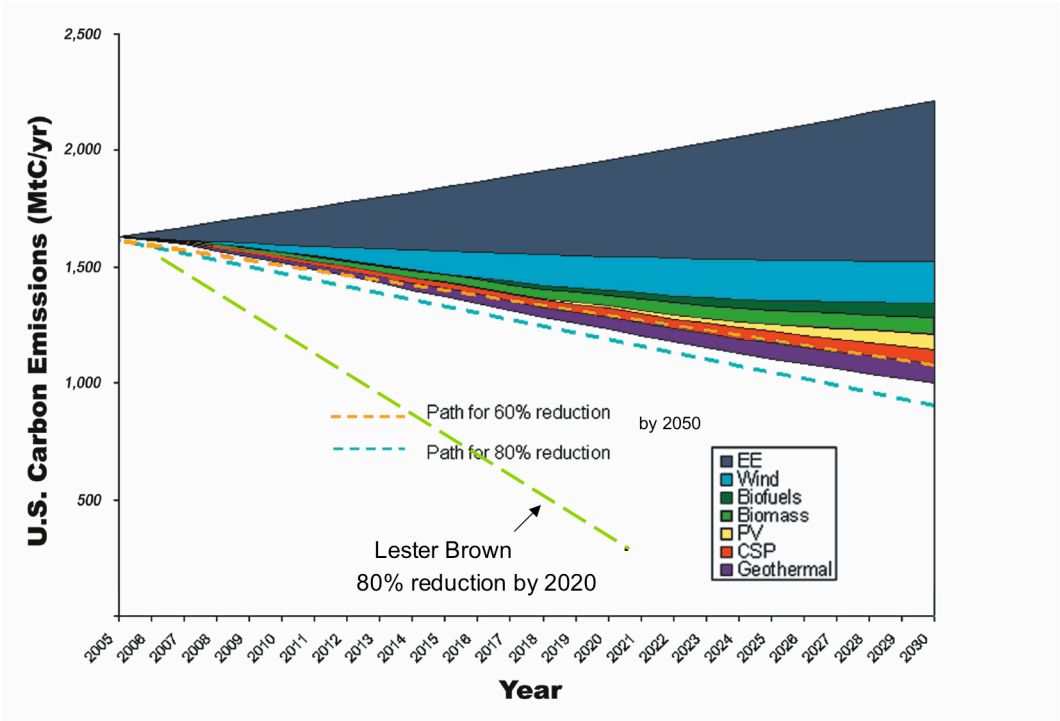

Figure 8. U.S. carbon emission reduction wedges proposed by the American Solar Energy Society (ASES).[22]

What Figure 8 shows quite clearly is that, though energy efficiency is essential for significantly reducing CO2 emissions, several different renewable energy resources will also be needed. Solar PV will have a growing role, but wind is our best renewable energy source.

Figure 9 shows a global emission scenario capable of reducing CO2 emissions by 80% from their 2005 level by 2050, and limiting CO2 concentration to 450 ppm.

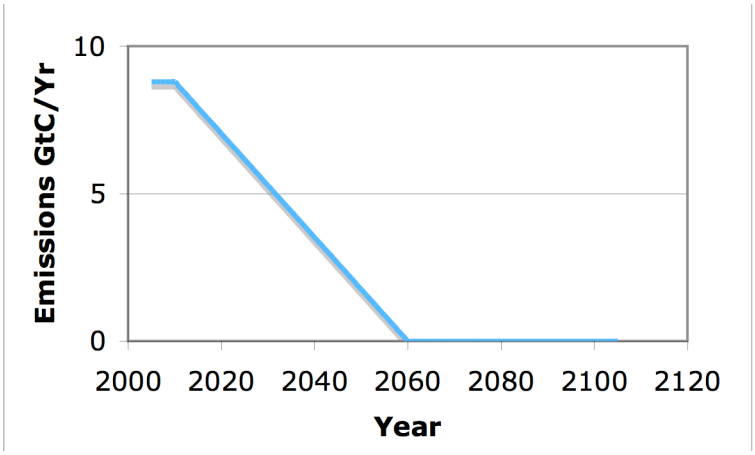

Figure 9. The '2% Solution' - a scenario with global emissions decreasing linearly by 2%/yr, starting at 8.8 GtC/yr in 2010 and going to zero in 2060.

Figure 10 shows how the CO2 concentration would increase under that scenario, reaching 450 ppm in 2060, and not increasing beyond that.

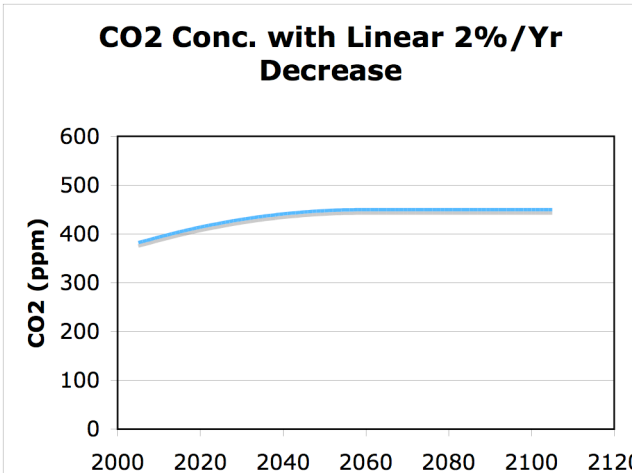

Figure 10. Concentrations of CO2 with the emission scenario shown in Figure 9.

The conclusions to be reached are:

- Climate change is a real and growing threat.
- DE is especially vulnerable to sea level rise.
- GHG emissions need to be cut by at least 80% by 2050 to avoid serious damage.
- Energy efficiency is necessary but not sufficient.

I propose the following for Delaware's RGGI legislation:

- 100% auction of emission allowances.

- Distribution of net funds from the auction (after administrative expenses) approximately as follows:
    - 40% energy efficiency improvements
    - 35% renewable energy development
      (e.g., funding support for offshore power lines to promote future offshore wind power development)
    - 15% to reduce the energy cost burden for the poor
    - 10% to educate the public

- Distribution of the net funds – in terms of management:
  25% to the SEU
  75% to the Citizens Energy Council proposed by Nick Dipasquale

Respectfully submitted,
Chad A. Tolman
Energy Chair
DE Chapter, Sierra Club 2/5/08

REFERENCES

[1] IPCC, **Fourth Assessment Report (AR4), Climate Change 2007**. At: http://www.ipcc.ch/

[2] Equilibrium temperature means the temperature reached after the CO2 concentration is constant (no more emissions), and enough time is allowed to pass so that all the ice that is going to melt does, Earth's land surface is no longer changing, and the extra heat resulting from the radiative imbalance has been well-mixed into the world's oceans.

[3] M.R. Raupach et al., **Global and Regional Drivers of Accelerating CO2 Emissions**, ***Proceedings of the National Academy of Sciences***, Vol. 104, pp. 10288-10293, 2007. At: http://www.pnas.org/cgi/content/full/104/24/10288

[4] J.E. Hansen, **Dangerous Human-Made Interference with Climate**, Testimony before the Select Committee on Energy Independence and Global Warming U.S. House of Representatives, April 26, 2007. At: http://www.columbia.edu/~jeh1/testimony_26april2007.pdf

[5] Sir David King, Chief Scientific Advisor to the UK Government, **Climate Change: State of Urgency: the Science, the Impacts and Maintaining a Growing Economy**, AAAS lecture of 7/12/07, Slide 9, at: http://www.aaas.org/news/press_room/climate_change/media/20070712_king/king_presentation_20070712.pdf

[6] Sir David King, *op. cit.*, Slide 8.

[7] This is similar for example to the bell shaped curve describing the heights of adult American males.

[8] Calculations can be done readily with an Excel spreadsheet, available on request from C. Tolman at ChadTolman@comcast.net.

[9] 8.8 GtC means 8.8 billion metric tons of carbon, corresponding to about 35 billion short tons of CO2. (The conversion factor from metric tons of carbon to short tons of CO2 is 4.03 short tons of CO2 per metric ton of carbon.) 8.8 GtC per year is the estimated global rate of emissions of carbon as CO2 in 2005, with 7.2 from both the burning of fossil fuels and 1.6 from land use changes, especially deforestation, as reported by the IPCC in **Climate Change 2007: The Physical Basis, Summary for Policy Makers**, p. 3. At: http://www.ipcc.ch/ipccreports/ar4-wg1.htm

[10] The 57% fraction of CO2 that currently remains in the atmosphere is shown in Fig. 6 of a letter from Dr. James Hansen to British Prime Minister Gordon Brown, dated December 19, 2007. . On the web at: http://www.columbia.edu/~jeh1/mailings/20071219_DearPrimeMinister.pdf

[11] EPA, **Climate Change and Delaware**, Washington, D.C., National Technical Information Service, Pamphlet 2230-F-97-008h, 1997. At: http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BPQKV/$File/de_impct.pdf

[12] Reuters, ***Environmental Network News***, **Seas Could Rise Twice as High as Expected: Study**, December 16, 2007. At: http://www.enn.com/wildlife/article/27485

[13] Table SPM-0 the IPCC report **Climate Change 2007: The Physical Basis, Summary for Policy Makers**. At: http://www.ipcc.ch/ipccreports/ar4-wg1.htm

[14] Alister Doyle, ***Environmental Network News***, **Greenland thaw seen biggest in 50 years**, January 15, 2008. At: http://www.enn.com/top_stories/article/29343

[15] Steve Connor, **Antarctic's ice vanishing faster than expected, scientists discover**, ***The New Zealand Herald***, Jan. 15, 2008. At: http://www.nzherald.co.nz/feature/story.cfm?c_id=26&objectid=10486791

[16] This figure was kindly supplied by Dr. Willett Kempton of the UD College of Marine and Earth Studies.

[17] Table 1 in W. Kempton et al., **Large CO reductions via offshore wind power matched to inherent storage in energy end-uses**, ***Geophysical Research Letters***, Vol. 34, 2007. At: http://www.ocean.udel.edu/windpower/docs/KemptonEtAl-MAB-PROOF.pdf

[18] An average power of 184 GW produces 1.6 billion MWh per year. Coal plants emit about one ton of CO2 per MWh. See Table 12 in A. Dhanju et al., **Assessment of Delaware Offshore Wind Power**, UD College of Marine Studies, 2005. At: http://www.ocean.udel.edu/windpower/docs/BurDhanWhit05-MAST667-FINAL.pdf

[19] BBC News, **Climate Bill's 60% Emission Cut**, November 6, 2007. At: http://news.bbc.co.uk/2/hi/uk_news/politics/7080580.stm

[20] Henry Waxman, **The Safe Climate Act of 2007** (H.R. 1590). At: http://www.house.gov/waxman/safeclimate/index.htm

[21] Lester Brown, **Plan B 3.0, Mobilizing to Save Civilization**, Earth Policy Institute, W.W. Norton & Co., New York, 2007.

An audio interview with Lester Brown on NPR is available at: http://www.time.com/time/health/article/0,8599,1700189,00.html

[22] American Solar Energy Society (ASES), **Tackling Climate Change in the U.S. – Potential U.S. Carbon Emissions Reductions from Renewable Energy and Energy Efficiency by 2030**. At: http://www.ases.org/climatechange/