Two Prominent Publications Address Global Warming

(***Editor's Note***: Al Gore is not the only one calling attention to the problems of global warming. In September 2006 two prominent publications devoted entire issues or special sections to this issue. The 9-15 September issue of ***The Economist*** devoted a 24-page insert to the topic, and the special topic of the September issue of ***Scientific American*** was "Energy's Future: Beyond Carbon."

The Economist: "The Heat is On"

In a special section titled "The Heat is On," *The Economist* for 9-15 September 2006 reported that global temperatures have been rising above those predicted by climate models since 1970, and in 2001 the IPCC (Intergovernmental Panel on Climate Change) predicted global temperature increases ranging from 1.4^{o}C to 5.8^{o}C by the end of the (21st) century. Of particular concern is the effect on the Gulf Stream and rise in sea level. "If all of Greenland's ice were to melt," *The Economist* reports, "sea levels would rise by around 7 metres; if West Antarctica's were to go, that would add another 6 metres; and if East Antarctica's ice melted -- which nobody thinks likely for the foreseeable future --sea levels would go up by a devastating further 70 metres. Even a 1-metre rise would flood 17% of Bangladesh's land mass and cause serious problems for coastal cities such as London and New York."

The hypothesized link between global climate change and more severe hurricanes is seen as linked to an Atlantic Multidecadal Oscillation (AMO). Global climate change has already advanced the dates many species breed, migrate, or emerge from hibernation. It has also led some species to migrate poleward, but this leaves no viable option for the polar bear.

The minimum carbon dioxide concentration which many scientists feel can be realistically stabilized is 550 ppm, and "the prospect of anything much above 550 ppm makes scientists nervous." At this concentration some parts of the world will "gain," while others will "lose." Hence mitigation efforts will be in order, and their cost will depend on how quickly energy efficiency measures can be instituted to lower energy demand, how quickly the cost of renewable energy will fall, and how quickly greenhouse gas emissions can be reduced.

Reducing carbon dioxide emissions was the goal of the Kyoto Protocol, but Canadian and Japanese emissions, currently more than 20% higher than 1990 levels, are unlikely to reach their target of a 6% reduction below 1990 levels by 2012. The European Union, with its European Emissions Trading Scheme, has taken the Kyoto Protocol most seriously. Much of the emissions reduction is being achieved by investing in carbon dioxide emission reduction projects in China, which China also taxes at 65%.

Although Senator Environment and Public Works Committee Chairman James Inhofe (R-OK) has characterized the threat of global warming as the "greatest hoax ever perpetrated on the American people," *The Economist* notes that many American companies, anticipating a future in which carbon dioxide emissions will be controlled, are already engaging in practices to reduce them. While many might expect transportation to be the largest source of carbon dioxide emissions, it accounts for only 13.5%. A much larger share, 24.5%, comes from electric power generation, chiefly because of its extensive use of coal; and deforestation, at 18% provides the second largest amount.

Scientific American: "Energy's Future: Beyond Carbon"

In his "Climate Repair Manual," which introduces the *Scientific American* special topic issue, "Energy's Future: Beyond Carbon," Gary Stix boldly states, "The debate on global warming is over." He goes on to point out that a concentration of most of the 20 hottest years in recent history has resulted from buildup of atmospheric carbon dioxide concentration to 400 ppm, and an increase beyond 500 ppm -- which could be attained by 2050 -- is a risk that "no climatologist wants to test." Stix portrays the control of global warming as a project that dwarfs building the atomic bomb or landing men on t he Moon. Regardless of a peak in world oil production, fossil fuels "become a liability if a global carbon budget has to be set." Stix is concerned that economic pressures from expanding economies like those of China and India may jeopardize renewing the Kyoto Protocol when it expires in 2012. Yet, he expresses hope in the strategy of Socolow and Pacala (see below) and hopes that ideas expressed in other articles in this issue will produce a more sustainable future.

"A Plan to Keep Carbon in Check"

"Faster and faster, year after year for two centuries, human beings have been transferring carbon to the atmosphere from below the surface of the earth," Robert H. Socolow and Stephen W. Pacala write, in building their case for holding the rate of carbon emissions constant for the next 50 years rather than allow it to double under a business-as-usual scenario. This, they point out, means avoiding the emission of 175 billion tons of carbon over the next half century, which can be done through seven "wedges" in a graph, each representing 25 billion tons of carbon, as Socolow and Pacala first presented in their landmark article in the 13 Aug 2004 issue of ***Science*** (reported in our Fall 2004 issue). Socolow and Pacala describe 15 different ways to produce a "wedge," more than twice the number needed -- five related to alternative energy sources, three each from more efficient or reduced end uses and carbon capture, two each from power generation and agriculture. They estimate that jump-starting this program requires incentives between $100 and $200 per ton of carbon, equivalent to 25¢ to 50¢ per gallon of gas, and 2¢ to 4¢ per kWh of electricity.

"Fueling Our Transportation Future"

John B. Heywood points out that a quarter of global greenhouse gas emissions are attributable to transportation, and over half of that is for land transport of people. Options he considers to reduce these greenhjouse gas emissions include reduced vehicle weight, improved vehicle technology, changed vehicle use, and different fuels, including hydrogen fuel cells. He notes that already Brazil derives 40% of its transport fuel from sugar cane, and 20% of the U.S. corn crop is converted to ethanol fuel. Heywood cautions, though, that relying on nonconventional petroleum sources such as oil shale and tar sands would ***increase*** greenhouse gas emissions.

"An Efficient Solution"

"Developing a comprehensive efficiency strategy is the fastest and cheapest thing we can do to reduce carbon emissions," and the European Union member nations and Japan have taken the lead in doing this, notes Eberhard K. Jochem. Buildings in the developed world and megacities of the emerging world account for "more than one third of total energy-related greenhouse gas emissions," he goes on, and only one third of the energy from original sources is useful to the end user. Yet new refrigerators use only a quarter as much energy as their predecessors, and the same is true of compact fluorescent bulbs relative to their incandescent cousins. Jochem adds that European manufacturers are now offering prefabricated zero-net-energy houses.

"What to Do About Coal?"

Any attempt to consider an energy future beyond carbon must confront the question of coal, which continues to loom large. David G. Hawkins, Daniel A. Lashof, and Robert H. Williams observe that the 280 500 megawatt electric power plants expected to be constructed in the U.S. between 2003 and 2030 could, over their lifetime, produce as much carbon dioxide as was released by all of the coal burned since the Industrial Revolution. Add to this the equivalent of one large coal-burning power plant that China is building every week. The IPCC (Intergovernmental Panel on Climate Change) estimates that there is geologic ability to store all the carbon dioxide generated by 21st century fossil fuel-burning plants. While carbon dioxide injection has been used to increase oil output, it has yet to be used to limit the carbon dioxide concentration in the atmosphere (the goal is to stay below 450 ppm to avoid dangerous climate consequences).

Although the IGCC (Integrated Gasification Combined Cycle) method of generating electricity from burning coal is more expensive than from the simpler burning of coal, the IGCC is more cost effective for adding CCS (Carbon dioxide Capture and Storage) -- 20% more coal will be required to retrofit IGCC as opposed to 30% to retrofit conventional coal-burning plants with the same electrical output. If the IGCC plant is within 100 km of an oil field, the added cost of CCS can be offset by the value of the carbon dioxide for oil recovery.

Because the more expensive technology for generating electricity from coal is less costly to adopt to CCS, the authors write that "delaying CCS at coal power plants until economy-wide carbon dioxide control costs are greater than CCS costs is shortsighted." They feel that CCS will not be adopted unless "the cost of emitting CO_2 were at least $25 to $30 per metric ton." Installing CCS equipment in new coal-burning plants will give us an earlier start to develop facility with the technology, will be cost-effective in the long run, and will enable more electricity to be generated by coal in the near term. To foster development of CCS, they advocate a system of carbon dioxide permit trading like the system that has already proved successful for controlling sulfur dioxide emissions.

"The Nuclear Option"

John M. Deutch and Ernest J. Moniz describe the four generations of nuclear power plants:

I: earliest prototype reactors (1950s-early 1960s)
II. light water reactors (late 1960s-early 1990s)
III. current reactors (*e.g.*, Japan, 1996)
IV. "new. . . designs. . . currently being researched" (*e.g.,* pebble-bed, can be built in 100 megawatt modules)

Although nuclear energy avoids carbon emissions, its present estimated cost of 6.7¢ per kWh is far greater than the 4.2¢ cost of a kWh from burning coal. Adding the current European cost of $50 for a permit to emit a tonne of carbon increases the cost of coal-fired electricity to 5.4¢ per kWh. Scaling global nuclear energy up to a terawatt (ten times the present U.S. nuclear capacity) would provide one to two of Socolow and Pacala's carbon avoidance wedges and generate enough nuclear waste to fill Yucca Mountain in 3.5 years. So far only Finland has managed to solve its nuclear waste problems -- by building a permanent waste storage site at Olkiluoto.

"The Rise of Renewable Energy"

"Because economic growth continues to boost the demand for energy -- more coal for powering more factories, more oil for fueling new cars, more natural gas for heating new homes -- carbon emissions will keep climbing despite the introduction of more energy-efficient vehicles, buildings and appliances," writes Daniel M. Kammen, well-known for his introduction of solar energy -- in both thermal and photovoltaic forms -- to Africa. Although interest in alternative energy technologies spawned by the energy crises of the 1970s lasted no longer than the crises themselves, Kammen writes that "dramatic improvements in the performance and affordability of solar cells, wind turbines and biofuels . . . have paved the way for mass commercialization." Moreover, rising oil and natural gas prices have made alternative energy technologies even more competitive.

Solar. A 45% increase in photovoltaic cells in 2005 brought the total world photovoltaic electricity generation capacity up to 5000 megawatts – 833 megawatts made in Japan, 353 in Germany, 153 in the US (and 50 of that in California). Although commercial photovoltaic cell efficiencies are now up to 15-20%, solar photovoltiaic electricity still costs 20-25¢ per kWh, compared with 4-6¢ for coal, 5-7¢ for natural gas, 6-9¢ for biomass, and 2-12¢ for nuclear. But solar thermal electricity, though less widely implemented, is less expensive – 5-13¢ per kWh.

Wind. At 4-7¢ per kWh, "wind power is the cheapest form of new electricity," and worldwide generating capacity is now 60,000 megawatts (18,000 in Germany, 10,000 in Spain, 3000 in Denmark, and 9100 in the U.S.). On an economic basis alone, wind power makes more sense than power plants burning natural gas.

Biomass. Although accounting for the energy content of by-products made along with ethanol from corn shows a positive net energy of 5 MJ/L, the role of fossil fuels in ethanol production could increase the emission of greenhouse gases by as much as 29% or decrease it as much as 36%. But because "producers of cellulose ethanol burn lignin," replacing gasoline by cellulosic ethanol would reduce greenhouse gas emissions by 90%. Moreover, Plug-in Hybrid Electric Vehicles (PHEVs) promise 80-160 miles per gallon of fuel, a 70% reduction in consumption that would eliminate the need for oil imports.

Kammen cautions that accelerating progress toward greater alternative energy use requires greater research and development, comparable to that for the Manhattan Project and Project Apollo. Along with this, Kammen also calls for education, contests for the public to participate in, and permit trading for greenhouse gas emissions.

"High Hopes for Hydrogen"

Given an expected tripling of vehicles by 2050, Joan Ogden notes that increased fuel efficiency will not obviate the need for more fuel sources, and she expects that either electricity or hydrogen will play an important role in energizing transportation. While electricity would be feasible if there were a more effective way to store it, hydrogen in fuel cells could be a source of distributed electricity as well as a transportation energy source. The following hurdles to producing hydrogen fuel still need to be overcome: 1) lengthening the life of the Proton Exchange Membrane (PEM) -- presently limited to 2000 hours of a car's 5000 hour lifetime; 2) lowering cost -- even mass-production would leave a cost of $125 per kilowatt of engine power, compared with $30 per kW for an internal combustion engine; 3) storing enough hydrogen on board for a 300-mile trip -- gaseous hydrogen requires large high-pressure containers, liquid low temperatures, and hydrides large weight; 4) safety -- hydrogen has a higher ignition temperature than gasoline but is flammable over a wider range of concentrations.

Committing all the world's present hydrogen production today to fuel cells would energize 20% of the world's 750 million vehicles. Because fuel cells are more efficient than the internal combustion engine, producing hydrogen from natural gas leads to lower carbon dioxide emissions per kilometer (100 g/km ***vs.*** 150 g/km for a hybrid vehicle ***vs.*** 195 g/km for an internal combustion engine). (One kg of molecular hydrogen has the same energy content as a gallon of gasoline, but in a fuel cell it can make a car go further.)

Although producing hydrogen without carbon dioxide emissions (from electrolysis, biomass, or with carbon dioxide sequestration) is presently not competitive with gasoline, its competitiveness is expected to increase in the future. The larger problem is distributing the hydrogen once it is produced, and building a distribution system awaits a market for it. A basic network of 12,000 hydrogen fuel stations is projected as the minimum needed, at a $1 million cost for each. This $12 billion cost, though, pales in comparison with the 1.3 trillion cost projected for "maintaining and expanding the North American gasoline economy over the next 30 years." Concludes Ogden, "Building a hydrogen economy is costly, but so is business as usual."

"Plan B for Energy"

In closing this special issue, W. Wait Gibbs contrasts the scenario of Socolow and Pacala, requiring seven "wedges" to stabilize carbon dioxide emissions over the next 50 years, with the scenario of Martin Hoffert, requiring up to 18 wedges, because of the expectation that the energy needs of economically-expanding China and India will be met mostly by coal. After that comes the need to *reduce* carbon dioxide emissions, and this is where Plan B is needed. Gibbs offers the following components of Plan B (and their reality factors on a 1-5 scale, with higher numbers being more likely):

1) fusion (3) -- which Hoffert feels should also use product neutrons to convert thorium to uranium to provide further fission fuel.
2) high-altitude wind (4) -- since only 0.5% of incident sunlight is transformed to wind energy, wind energy is far less concentrated than solar. A bus-sized high-altitude wind system is designed to produce 4 kW; a 1.6 megawatt unit spans the size of a football field.
3) cold fusion and sonofusion (1) -- currently both discredited.
4) matter-antimatter reactor (1) -- impeded by lack of a cost-effective source of antimatter.
5) space-based solar (3) -- NASA is no longer interested, due to cost and change in emphasis. But the solar intensity on a satellite is eight times than on a ground-based solar cell, and it shines 24-7. Yet the power to payload ratio is too low to produce electrical energy competitively.
6) nanotech solar cells (4) -- quantum dots would greatly exceed the 22% efficiency with which conventional silicon cells convert solar energy to electrical energy.
7) a global supergrid (2) -- to transport both electricity and hydrogen all over the world.
8) waves and tides (5) -- here Great Britain is currently leading the way.
9) designer microbes (5) -- that will convert carbon dioxide generated in various energy conversion processes into raw material for biofuels.