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EDITORIAL

Global climate change: impacts and policy options

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With this issue, we celebrate a milestone in the life of this journal: we have just completed 10 years of uninterrupted publication of scientific work in the areas of cleaner production and scientific sustainability. When we began this journal, the dominant concern was avoidance of pollution in industrial and municipal processes. Sustainability, though it was being discussed in sociopolitical circles, it did not gain much steam in scientific and industrial endeavors. That however has changed completely, and practitioners of all walks of society are very much concerned about sustainability of our products, processes, services, and life styles. Of all the crucial issues, and there are many, climate change has overshadowed all others in importance, because of its global nature.

Global climate change has become a significant national and international issue. Scientists, engineers, policy makers, and the public at-large have genuine concerns about it; views, however, continue to vary widely about the nature and extent of the problem and possible solutions. Discussed here are impacts to include *nature and extent of the problem* and policy options to include: *developing country perspectives, agreements and disagreements, suggestions for moving forward, and International implications*.

Swedish Nobelist Svante Arrhenius (1896) coined the term *greenhouse effect* at the turn of the century. He postulated that increasing concentrations of certain gases, such as carbon dioxide, in the atmosphere would allow sunlight to penetrate, but retain outgoing infrared radiation, in a manner analogous to a greenhouse. This phenomenon would cause global warming.

In the natural functioning of the earth's climate, atmospheric gases—most importantly water vapor and carbon dioxide, and less importantly methane, nitrous oxide, and ozone—trap solar heat reflected from the earth's surface and prevent it from escaping into space. Without this natural greenhouse effect, the earth would be 33°C cooler and could not support life as we know it.

The IPCC reports, as cited in the following discussions, represent conclusions drawn by the scientists based upon historical data and field evaluations. It is important to note that many IPCC publications are based upon complex models, which naturally have many uncertainties.

The IPCC report, *Climate Change* 2007—*The Physical Science Basis* (IPCC 2007) has stated that, "Global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years."

In the previous IPCC reports the likelihood of warming was viewed as very likely. But now, in the recent report the IPCC has concluded that, "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007).

There has always been some concern as to the role anthropogenic activities play in global climate change. For the first time, the IPCC study has claimed that, "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations" (IPCC 2007). The term "very likely" in the IPCC reports

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means that it has a probability of over 90%—a significant assertion supported by over 2,500 IPCC scientists representing over 130 countries.

It is now becoming clear that observed average global temperature rise resulted from accumulating greenhouse gases (GHG) in the atmosphere. IPCC has used various global climate models to infer potential impacts down the road, and what they have concluded is a disturbing picture. Scientific data, with physical and discernable evidence of climate change and its effects, is presented in numerous scientific journals. Dramatic physical evidence is also presented in many video recordings shown in the popular media. Some examples are:

- Arctic sea ice decline (NASA 2005, showing satellite images of shrinking ice caps.)
- Jakobshavn Glacier retreat (From 1997 to 2004, Greenland's Jakobshavn Glacier nearly doubled the speed at which it discharges ice to the ocean, NASA 2004.)
- Larsen B Ice Shelf (In 2002, a gigantic section of this shelf in the Arctic Peninsula shattered and crashed into the ocean; loosing 1,255 mi^2 of ice shelf, which disintegrated in a mere 35 days, demonstrating dramatic changes resulting from climate change, NASA.)

In spite of all of this evidence, intuitively, some people continue to feel that climate change is natural, not necessarily anthropogenic. Some reasons relate to political and economic considerations and some are based upon observed phenomena. For example:

- Local temperature can easily rise or fall by 10–40°F from just one day to the next.
- Major storms could come and change the climate locally in a matter of hours.
- Many extreme weather events, for example the heat wave of 1936 in the US, have happened before the greenhouse effects had really increased.
- Information Council on the Environment (ICE), representing industry groups, continues to argue that climate change is a theory rather than a fact—much the same way cigarette manufacturers had done for years about health effects of smoking. ICE ads asked, "If the earth is getting warmer, why is Minneapolis…getting colder?" (*Newsweek*, August 13, 2007). Clearly, such ads can potentially affect public opinion, at least in the short-run.

Many Americans, especially industry representatives, continue to question global climate change research findings. Incredible as it may seem, polls find that 64% of Americans think there is a lot of disagreement on climate change issue and only 1/3 think global warming is caused by things people do. In contrast, majorities in Europe and Japan recognize anthropogenic activities as being the main cause for global climate change (*Newsweek*, August 13, 2007).

Nature and extent of the problem

Due to increases in industrial activities and use of fossil fuels, GHG emissions have increased markedly. Looking forward, IPCC model calculations project Earth's global temperature to increase by 1.1–6.4°C during the twenty-first century with further rise in atmospheric concentrations of CO_2 and minor contributions by CH_4, NOX, and HC. Some of the serious model predictions of climate change include the following (IPCC 2007):

- In coastal areas, sea level is expected to rise 0.3–2.9 ft during the next century. This could amount to a land loss of up to 5,000 mi^2. This will further increase vulnerability of coastal areas to flooding, increased saltwater intrusion, erosion of beaches, and destruction of wetlands. The impacts are expected to go beyond coastal areas to include impacts on surface and groundwater resources.
- Agricultural economy is likely to be impacted severely due to increased soil evaporation rates; increased frequency of severe droughts; increased intensity of rainfall events; and increased ozone concentration that could limit growth of crops. Some benefits of increased CO_2 levels, which can act as a fertilizer and enhance some crop growth, are possible but of no real positive significance.
- Effects on forests are likely to include changes in forest health and productivity. There would also be an increase in nature and extent of severe disturbances such as fires and insect infestation.
- Serious human health effects will be of concern to segments of populations such as the very young, elderly, and people with special ailments, for example asthma, heart problems, etc. Global climate change is likely to increase risk of infectious diseases such as malaria, dengue fever, yellow fever, encephalitis, and cholera; naturally, this is likely to affect developing countries more than industrialized countries.
- There will be displacement of populations from coastal regions causing major economic, social, and human health related impacts, which will be felt more severely be developing countries than the industrialized countries.

There will also be some serious international, economic, political, and humanitarian implications that are discussed later.

Developing country perspectives

Clearly, since industrialized and developing countries share the same environmental commons (atmosphere, oceans, water resources, forests, and other natural resources) overuse of resources by any group is likely to affect the rest. Consequently, impacts on developing countries, representing a large segment of the world population, can be significant as well. As reported in the *New York Times* (December 16, 2007), if the established industrial countries turn off every power plant and car right now, the concentration of carbon dioxide in the atmosphere, unless there are changes in policy in developing countries, could still reach 450 ppm by 2070: a level deemed unacceptably dangerous by many scientists. Thus, active involvement of emerging economies like China and India is crucial.

Some argue that once the developing countries get rich, much like the industrialized countries, they are likely to take the climate change more seriously and do the right thing (*New York Times*, December 16, 2007). Critics also point out the fact that carbon dioxide has a long life and sources like coal burning plants, which China is building at an unprecedented rate of one per week, means that waiting is likely to compound the problem and the solutions will become even more challenging (*New York Times*, December 16, 2007).

Some of the developing country issues and perspectives, so important to address this global problem, are summarized here (Agarwal 2002):

- Any limit on carbon emissions for developing countries amounts to a limit on economic growth. This is simply because there is a clear correlation between gross domestic product and the level of development of a country with the amount of carbon emitted per capita. The developing countries think that the developed countries are the major source of the problem because of their higher per capita carbon dioxide emission.
- If the developing countries continue to grow by making huge energy investments by producing high levels of carbon dioxide in the coming decades, this will lock them into a carbon-energy economy like industrialized countries. Making changes later will be expensive and difficult.
- From developing countries' perspective, all countries must agree to share atmospheric space in an equitable manner. After all, the natural atmosphere is a property of the commons. If per capita emission entitlement was set at a number, say 0.38 tons carbon per year, then all countries could develop their policies and technologies and work on tradable emission approaches among countries, thus allowing developing countries some room to grow as well. This of course is not likely to be acceptable to industrialized countries because of the implied reduction of their standard of living and because this argument totally ignores the energy efficiency of advanced economies (energy consumed per unit GDP).

Since developing countries do not have a well-established power distribution grid, they have a unique opportunity to take a lead in creating distributed technologies that are based upon renewable energy (for example solar and wind). This, however, will require considerable investment that developing countries do not have. This will also require technologies so that the cost of producing renewable energy is reduced and it becomes within the reach of the consumers. Support from industrialized countries in this area could be mutually beneficial because this will provide huge markets for these technologies.

Developing countries are less able to adapt to climate change, hence they are likely to be more adversely affected. This means the social and economic burden of climate change is likely to be heavier for the developing countries, thus collaboratively working with industrialized countries could be mutually beneficial.

Agreements and disagreements

There is a *general agreement* on most aspects of climate change. There is an agreement that the scientific data on climate change is credible, impacts are real, serious, understandable, and of major concern to people. There are also long-term implications of climate change and some impacts will clearly be irreversible. Most people globally agree that human activities are a major contributor to climate change, thus, we need to find ways to collectively address this serious challenge.

Disagreements continue to center around the issue as to *what degree* climate change effects are anthropogenic or based upon natural cycles. Even if most people agree that the effects are anthropogenic, then the concern is as to who should pay to address the problem. When one deals with such problems of the commons and related public policy issues, there are questions such as: who pays and who gains? Which industry is affected most? What are the impacts on the economy of a country? These are political implications of enormous nature.

It is always convenient to say that we should wait to act so that we fully understand the problem because all of the scientific evidence is not in: a strategy commonly used by those who are opposed to an issue. Thus, suggesting that unequivocal scientific evidence needs to be present before

moving forward. One really needs to understand the processes of scientific discovery and aim of science.

While the aim of science is to discover "truth," Popper's thesis states "utter inaccessibility of truth;" the goal of science is then to achieve a better approximation to truth or a higher degree of verisimilitude. Scientific evidence, thus, can provide a high degree of reliability but never "an absolute truth" (Jain and Triandis 1997). In support of Popper's thesis, presented here are some examples where scientific discoveries seemed logical, but further investigations required some readjustments.

Is there a medium (luminiferous aether) through which light propagates? Physics theories have postulated that just as water waves must have a medium to move across (water), and audible waves require a medium to move through (air), so also, light waves must require a medium, the *luminiferous aether*. The Michelson–Morley experiment, one of the most important and famous experiments in the history of physics, years later, proved that no medium is needed and there is no such *luminiferous aether*.

Does life originate spontaneously? From the time of the ancient Romans, through the Middle Ages, and until the late nineteenth century, it was generally accepted that some life forms arose spontaneously from non-living matter. Such *spontaneous generation* appeared to occur primarily in decaying matter. Earlier experiments by Needham supported the *spontaneous generation*. Later, Louis Pasteur used a variation of Needham's methods and demonstrated that life arises from other life, and not spontaneously.

What does this all mean? Science can provide unbiased information; the level of complete certainty (or absolute truth) is not possible. Organized skepticism of scientific findings by scientists and others who have no vested interest in the outcomes is healthy. Science can provide information that can form a sound basis for decision-making related to complex and crucial issues such as climate change, which is what science has done. There is clear evidence that global climate change is real and is mostly anthropogenic. Suggesting that scientific evidence is not absolute and complete regarding global warming is either missing the point or is an attempt to ignore the problem for other reasons: economic, political.

Controversies about global climate change continue since there can be no absolute evidence for such complex temporal-dependent issues. As Bertrand Russell has stated, "The most savage controversies are those about matters as to which there is no good evidence either way." Causes of disagreements and controversy continue to be due to: economic considerations; who pays and who gains; problem of the commons.

Suggestions for moving forward

Recognizing uncertainties, controversies, and disagreements, suggested here are some ways to move forward and make progress towards addressing crucial climate change issues:

- Expenditures on GHG control are acceptable as long as contributions by nations are commensurate with their contributions to the problem, and with their relative wealth—ability to pay.
- A carbon tax on polluters is advisable.
- Externalities of markets are hardly ever fully accounted for in the market exchange of goods and services; a combination of a market mechanism and regulatory framework can assist in internalizing these costs.
- Pollution rights, marketable permits, carbon taxes, and so on, are the right mechanisms for addressing some climate change issues.
- A combination of market mechanism and command-and-control regulations will be necessary.
- Most knowledgeable people agree that some expenditure by all nations to limit GHGs is a prudent course of action. Modest investments would provide valuable experience if major efforts were later needed.
- Regarding cost-benefit analysis, we should consider opportunity costs, marginal costs, and benefits in determining the level of investment in reducing GHGs.
- Most people seem to agree that, regardless of uncertainties that may exist, significant investment should be made to reduce GHGs for the purpose of accruing other related environmental and economic benefits.
- At the international level, efforts to develop an institutional framework for global accords on this topic with a focus on partnerships, appropriate technology development, and technology leap-frogging need to continue.
- Major investments in science, technology, and innovation (research and development) could make renewable and alternate energy technologies such as: geothermal, solar, wind, and biofuels (preferably from agricultural waste rather than corn) economically viable. This, in turn, will attract venture-capital investments to commercialize these technologies. It is important to note that during the first three quarters of 2007, US venture capital firms invested $2.6 billion in alternate-energy start-up companies (*USA Today*, December 26, 2007).
- Reducing GHG emissions will further enhance "sustainability" concept—generally accepted internationally; this can also further international cooperation in other areas as well.

International implications

There are some sobering international implications of climate change that should be of concern to industrialized and developing countries as well. Some of these are:

- Volatile regions are likely to become more unstable.
- Already weakened states will be more vulnerable to extreme weather events such as droughts, flooding, and sea level rise.
- International trade is likely to be affected markedly due to major disruptions caused by climate change.
- Access to critical resources, such as oil, gas, minerals, and water, could create major disruptions and further cause global conflicts.
- Clearly, developing countries have very little adaptability capacity, economic resources, and technical capabilities to adapt to major disruptions caused by climate change; thus they will experience increased tension and instability.

Much of the social and economic burden will be borne by large groups of most vulnerable populations causing considerable political instability.

Scientists and engineers, like they have done in the past, can play a positive and a significant role in continuing to: define the problem, develop technologies to economically and effectively address complex issues related to global climate change, and also provide a scientific basis for decision-making and sound policy development. Global climate change challenge provides a unique opportunity to increase international collaboration since this problem can only be addressed by thoughtful international negotiations and diplomacy.

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