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Emerging global issues . . .

Climate Change

Clear Trajectory—Haze in the Details

by Charles J. Bennett, Senior Research Associate, Global Corporate Citizenship, The Conference Board

"We're in the middle of a large uncontrolled experiment on the only planet we have."

Donald Kennedy, Editor in Chief, *Science*

Climate Change and the Impact on Business

Whether it is the threat of public policy changes and increased regulation, market competitiveness challenges or opportunities, potentially increased costs of risk insurance, or investor interest and concern, climate change is a fact of life for business in the 21st century. Its significance for different businesses and sectors will vary, but given the increasing costs of, and uncertainties surrounding, the reliability of traditional energy sources; and growing pressures for higher standards of citizenship and contributions to global sustainability, businesses that ignore the debate over climate change do so at their peril.

One of the greatest impacts is likely to be in the area of energy planning. Recent developments point to four realities of climate change that will affect most businesses' energy planning:

- Science is unlikely to provide unequivocal answers. However, scientific consensus that the climate is changing is growing steadily stronger over time.
- Governments and markets are likely to act on their perception of the science. Increasingly, this perception is swinging toward a belief that climate change is an urgent priority that must be addressed through a variety of measures.
- Corporate boards will be increasingly expected to evaluate potential risks associated with climate change. The frequently cited "Enron effect" will likely result in increased pressure on boards to evaluate potential costs and risks associated with mitigation either of carbon emissions or of the effects of actual climate changes.
- The global economy will become less carbon-intensive over time. The carbon-based energy mix will change and alternatives will increase. The real questions are what the pace of the transition will be and who will be the winners and losers.

Editor's Note: Climate change, frequently referred to as "global warming," continues to be an issue of significant concern for business. To help expand understanding of the key scientific issues involved, The Conference Board recently joined with the American Association for the Advancement of Science (AAAS) in a conference where leading climate scientists in the United States shared their perspectives on this complex and often controversial area. The purpose of this report is to help the business executive understand the science behind the climate change debate.

Even if the Kyoto Treaty does not become a reality, the debate on climate change over the last 15 years has already set into motion many forces that can result in reduced emissions over time. Business has been broadly—if not yet deeply— involved in the process, whether engaging in energy efficiency improvements, emissions trading, the development of new technologies, or other initiatives.

Kyoto and the Energy Emissions Dilemma

Seven years since its inception, the Kyoto Treaty is not yet in effect (and, if Russia does not ratify, may never be). During the lengthy debate over the Kyoto agreements, two factors have become clear. First, demand for and use of energy is and will continue to grow rapidly, especially in emerging economies. Second, if dramatic changes in the control or offset of emissions from fossil fuel energy sources are not achieved, the likelihood of ongoing climate change and environmental quality degradation will continue to be growing concerns for many in all sectors–government, business, and the public–around the world. Thus initiatives to manage and reduce the environmental effects of energy use are gaining momentum widely, whether guided by specific Kyoto commitments or not. This will likely continue whatever the outcome of the Kyoto process. In essence, the often contentious "Kyoto Process" is taking the world "beyond Kyoto."

Concerns about Reaction to Climate Change

Despite growing concern about its threat, there are many in government, business, and the scientific community who are concerned about possible overreactions to climate change. Overreaction, or the wrong reaction, could waste resources and potentially weaken the sustained resolve that many believe is essential for ultimate success. They argue that it is important to understand the cause(s) behind current increases in temperature and increasingly unstable weather patterns before deciding whether or not human action can alter the course of these changes. An additional concern is whether or not the cost of attempting to control greenhouse gases emissions will result in sufficient benefits to justify the effort, or whether a better course may be to focus resources on adaptation

The scientists participating in the AAAS/Conference Board meeting believe strongly that reduction in anthropogenic (human-caused) emissions is an essential step in any overall strategy for dealing with climate change.

What the Science Says

The Climate *is* Changing

While scientists may disagree on details and exact causes, there is a widespread consensus that climate (defined as average weather conditions over time and area) change is occurring. This is most clearly manifested in a relatively rapid rise in average global temperature over the past 150 years and especially in the past 100 years when temperature has increased approximately 1° F on average (from 57° to 58° F). There has also been a steady increase in dramatic weather events (e.g., intense rain storms) in the recent decades, which scientists believe are the result of the increasing atmospheric instability that grows concurrent with warming. Thus, in the words of several of the scientists attending The AAAS /Conference Board meeting, the "trajectory is set."

History of Climate Change: Past Evidence and Future Predictions

Recent warming is an anomaly

According to Thomas Crowley of Duke University, "studies of past climate can be used to place present warming trends in a longer-term perspective." Much of the knowledge of climate history is derived from tree rings, ice cores, coral formations, and, more recently, historical records dating back about 150 years. Furthermore, global climate models have been developed to a point where they "backcast" climate patterns quite accurately, adding to scientists' confidence in their understanding of the historical record. According to Professor Crowley, "Climate change projections suggest that by the mid-21st century global temperatures will approach levels as high as any in the last two million years."

We could "flip the canoe" and experience abrupt climate change

Professor Richard Alley of Penn State University believes that anticipating smooth future changes is "optimistic." There is abundant evidence in the record of abrupt changes in the past (up to 10° C in about a decade, although most changes are less dramatic). While many of these abrupt changes have been associated with periods of glaciation– the process of covering the earth with glaciers or masses of ice–others have occurred during warm periods, often associated with changes in North Atlantic Ocean circulation. As an example, he cites evidence in North American climate history of droughts that would make the "Dust Bowl" of the 1930's appear minor. Professor Alley believes that human activity is causing the recent relatively rapid warming and likens this to "rocking the boat." Because there are so many uncertainties–both about "how the world works" and "what people will do"–it is difficult to predict what changes might occur. But, he adds, climate history suggests that "the real world never changes smoothly" and that the possibility of abrupt change–"flipping the canoe"–is very real, often bringing unaticipated outcomes.

We could be approaching the warmest period since the Eocene epoch (55–36 million years ago)

Professor Daniel Schrag of Harvard states that historical evidence indicates that the present atmospheric CO^2 level (380 PPM) is higher than it has been for over 400,000 years. Furthermore, projections suggest that it could reach 800–1000 PPM by 2100, levels not seen since the Eocene. It is not anticipated that Eocene temperature conditions (pine forests in Antarctica or palm trees in Wyoming) will be replicated because we are moving from a cool earth toward a warmer one rather than from a warm earth to a hotter one as was the case then. The implication is that significant, but slower than in the past, warming could occur, which would be accompanied by melting ice caps and rising sea level. Dr. Schrag also points out, as did other participants, that models may be conservative and actually underpredict future temperatures.

The Outcome is Uncertain

Climate models developed by the Intergovernmental Panel on Climate Change (IPCC) project a range of potential temperature increases between 1990 and 2100 from a low of about 1.4° C (2.5° F) to a high of about 5.9° C (10.4° F), depending on assumptions about human activity and natural forces. Global climate models are extremely complex to develop and operate, and certain factors such as cloud cover and the effects of small particulates (e.g., aerosols) are difficult to incorporate. Furthermore, regional patterns are difficult to break out from the larger models, which complicates projections for smaller areas. Nevertheless, scientists at the conference were consistent in their belief in the direction of the change, if less certain about the slope of the curve and its pace.

Climate Change Can Have Many Causes

This is the issue around which much public policy debate has swirled. It is difficult to define the causes of change because of the complexity of the climate. A number of key factors can contribute to changes over time, including:

- Land use changes can have an impact. Clearing of land for agriculture or forestry and urban development can contribute to warming. Forest growth helps with cooling.
- Volcanic activity can lead to cooling, as was witnessed in 1816 after the eruption of Mt. Tambora in present day Indonesia. The dust from Mt. Tambora contributed to the "year without summer," most pronounced in the northeastern United States and eastern Canada.
- Ocean circulation and the balance between ocean and atmospheric CO^2. Scientists are concerned that warming may affect ocean circulation patterns, which in turn affect adjacent landmasses, especially in the North Atlantic.
- Aerosols. Extremely small suspended particles varying from black combustion soot to white evaporated sea salt are believed to contribute both to warming and cooling, depending on what type they are (e.g., black absorbs heat; white reflects heat). Unlike greenhouse gases (water vapor, CO^2, methane and other gases are collectively known as GHG), aerosols are unevenly distributed around the globe.
- Solar intensity variation has been important historically but is not believed to be a factor in warming in recent decades, although sun spot activity may have short-term effects.
- Variations in the earth's orbit are believed to occur over very long periods of time (23,000 – 100,000 years) and are not believed to be a factor in recent warming.
- CO^2 and other GHG are thought to be the key contributors to recent warming. CO^2 has increased from 280 to 380 PPB in the atmosphere in the past 100 years, and other gases such as methane have increased as well. GHG are quite evenly distributed around the earth.

In addition to these causes, there are "feedback factors" that can intensify changes. Two examples that further underscore the complexity of interpreting climate change are:

- Water vapor feedback. Clouds contribute to the greenhouse effect. Warmer air results in higher humidity and more clouds, which results in increased greenhouse effect, and so on.
- Ice reflectivity feedback. Ice reflects short-wave-length solar radiation back through the atmosphere. When glaciers melt, darker land absorbs radiation and gives off longer wavelength heat that is subject to being trapped by GHG.

The "Greenhouse Effect" is Real and Intensifying

The 11 scientists participating in the AAAS /Conference Board event collectively believe that recent increases in GHG and global temperature correlate too closely with the industrial era for there not to be a causal relationship between those increases and human activities, especially fossil fuel combustion. While past climate changes appear to correlate with variations in other causal factors such as volcanic activity or changes in solar intensity, comparable increases in CO^2 and other gases have not been seen over the past 400,000 years, despite many changes in climate during that period.

Professor F. Sherwood Rowland of the University of California at Irvine says that were it not for the "natural greenhouse effect"—the "greenhouse effect" is the result of the ability of GHG to intercept some of the heat that is radiated from the earth back toward space—the earth's average temperature would be 0° F rather than the actual average temperature of 58° F.

In the past century this average has increased by 0.6° C (1° F), and humankind's influence on climate is exemplified by the increase in the number of cities with populations over one million, which has jumped from 13 in 1900 to 350 in 2000. During this period the atmospheric concentration of CO^2 has increased by 100 PPB from 280 to 380. Per capita emissions currently average 1 ton/person per year, with the U.S. average highest at 5 tons/person/year. It is anticipated that by 2100 this concentration could increase by two to three times that of the 1900 level. This explains why there is, in certain scientific circles, a great interest in slowing, and ultimately reversing, the increase of CO^2 in the atmosphere. This, they argue, would avoid the anticipated corollary increase in global average temperature and associated changes in climate, weather, and sea level.

The Future: Prediction and Complexities

On the evolving role and reliability of models in climate research, Gerald Meehl from the National Center for Atmospheric Research (NCAR) notes that global models are highly complex. This complexity is derived both from their global scale and from the variety of data needed (including atmospheric information, ocean currents, sea ice and land surface conditions) to formulate a model. Meehl says the myth and the reality regarding climate models can be broken down as follows:

Myth: "Models can't simulate what we've already observed."

Reality: "Models are doing quite well simulating the 20th century and up to 1000 years previously."

He emphasizes that models must include anthropogenic GHG and aerosols to accurately reflect recent changes– "'natural' forcing factors don't get us there."

Regional models are being developed to provide more local insights. Important measures for understanding potential impacts of climate change include changes in frost dates and heat wave projections. Dr. Meehl cites an example of a model of North America that indicates greater decreases in frost days in the West and more intense heat waves in the South, Southwest, and Northwest. These reflect projected alterations in atmospheric circulation patterns. The expectation is that such models will continue to be refined to reduce uncertainties and increase their utility for projecting and planning for anticipated changes.

The coupling between ocean and atmosphere

Underscoring the uncertainties that are the result of the complexity of climate, Professor David Battisti, University of Washington, provides alternate scenarios of the future of ice in the Arctic. One hypothesis states that sea ice will retreat toward the north pole as a result of warming, which could result in the disappearance of Arctic ice in summertime within 100 years. An alternate hypothesis is that changes in ocean circulation could occur that would result in an expansion of polar ice and contribute to cooling in Europe and beyond, even though the average temperature of the globe will increase. The relationship between the oceans and the atmosphere is very complex, increasing the uncertainty about what will happen–and how fast. What is not in question is that something will happen, and possibly relatively quickly.

The aerosol conundrum

Dr. Joyce Penner of the University of Michigan, one of the leading scientists on the topic of aerosols, notes that aerosols contribute both to warming and to cooling depending on a given form's characteristics. Aerosols also affect the presence and depth of clouds by providing condensation nuclei. The dual effects of aerosols, combined with regional variations in both types of aerosols and their concentrations, make their inclusion in models challenging and their climatic effects difficult to pin down. When aerosols are incorporated into models, they often offset observed temperature increases of the past century. Penner concludes that "in the long run, GHG win." The accumulation of CO^2 and other GHG will overwhelm the confounding effects of aerosols.

The Key Message

Climate is Changing—Right Now

Sea Level is Rising

Sea level rises are a result of ocean warming, physical expansion of the water, and melting glaciers. According to Professor Michael Oppenheimer of Princeton, two frequently cited myths regarding Arctic and Antarctic ice sheet melting are:

- Ice caps are too cold to be affected by global warming.
- There is a threat of imminent collapse of one of the major ice sheets.

Both of these assertions, says Oppenheimer, are false.

He notes that mean global sea level has risen 10–20 cm (3.9–7.8 inches) over the past century. This trend is expected to continue, but both the rate and the amount of sea level rises are, as with most other climate change patterns, subject to uncertainty.

The rate of melting in West Antarctica and Greenland appears to be increasing, although the latter is somewhat offset by increasing ice volume in central Greenland. There have been some relatively dramatic recent collapses at the edges of these ice sheets. Records from ice cores indicate that major changes in the Greenland ice occurred in the past and there is concern among scientists that relatively modest climate change could result in substantial changes in ice caps.

Oppenheimer emphasizes a theme shared by others at the conference—the process is underway. The issue: What is the rate over which changes are likely to occur—decades or millennia? If over millennia, the adaptation challenge will be much less difficult to meet than if it occurs over decades. To maintain the greatest number of options in meeting the climate change challenge, the world must maximize its efforts to minimize the rate of change.

Mountain Glaciers are Melting – "The Canary in the Coal Mine?"

Professor Lonnie Thompson of Ohio State University likens mountain glaciers to "water towers." The metaphor is appropriate because such glaciers account for 10 percent of the world's surface water, and in many parts of the world they are sources of municipal and irrigation water as well as hydroelectric power. Especially in the tropics, glacier melting is well documented. For example, on Mt. Kilimanjaro in Tanzania, the ice pack has decreased from 4.3 square miles to less than one since 1912 and is expected to disappear within 15–20 years if the current rate of melting continues. Thompson notes that if all of the mountain glaciers melted, sea level would rise 0.5 meters (1.6 feet). He states that "the large spatial scale and accelerating rate of mountain glacier retreat both north and south of the equator as we begin the 21st century are astonishing."

Of special concern with the retreat of tropical glaciers is that this indicates an abrupt climate change underway in a region that is noted for quite uniform climate over very long periods. Approximately 70 percent of the world's population lives in the tropics. These facts suggest the potential for widespread effects in areas of the globe that may lack adequate resources to adapt well to change.

An additional irony of the mountain glaciers' retreat is that they yield excellent historical records of climate change through ice coring—records that, because of a lack of resources, are increasingly being lost at a time when the world needs these cores to better understand the influences on climate history.

Spring is Starting Earlier Now

According to Dr. Chris Field of the Department of Global Ecology, Carnegie Institution of Washington, and Stanford University, over the past 100 years, the start of spring in the northern hemisphere has averaged 2.5 days

per decade earlier—or about a month overall. That rate may be increasing based on a recent synthesis of a broad range of studies of plants and animals. Species ranges are expanding pole-ward—and upward on mountain slopes—further underscoring the effects of changing temperature. The role of climate change in the world's recent ecological problems (e.g., expanding wildfires, increases in invasive plant and animal species) is not clear, but there appears to be solid evidence that warming can exacerbate negative impacts of human actions such as forest clearing.

Dr. Field says there appears to be an inverse relationship between warming and some agricultural yields. Corn and soybean production in the United States increases in cooler years and is depressed in warm years associated with a rise in nighttime minimum temperatures. The issue of anticipating precipitation changes—one of the most challenging aspects of climate change forecasting—is critical. Dr. Field emphasizes the importance of "net precipitation," or the balance between precipitation and evaporation. The latter will increase as a result of warming, potentially reducing the net effect. One possibility is a decrease in the snow pack in California of between 70 percent and 100 percent. This could result in a decrease in irrigation potential of 50 percent. Competition for water will increase, leading to unknown effects for the agricultural, industrial, and municipal sectors. While such scenarios are not yet certain, the earth is on a path that could lead to them.

The key challenge is to get on a trajectory of climate change that can be managed. While the earth will be warmer, the rate of change is potentially manageable, which in turn enhances our chances of controlling effects.

Summing Up: Is There Anything To Be Done?

Don Kennedy, editor-in-chief of *Science*, asks the question: How can we end our current warm period? History indicates repeated climate, especially temperature, cycles. Until recently these were related to natural phenomena. The leading scientists speaking at the conference believe that human activity is now contributing to warming for the first time, especially through GHG that result from human activity (acknowledging the confounding effects of aerosols—especially those that are created or exacerbated by human activity). The earth—for whatever the exact reasons—is on a trajectory toward an ever warmer climate. This cannot be avoided at this point, but the trajectory can be "jiggled" and potential risks associated with warming can be mitigated. Ultimately the trajectory could be reversed.

Climate models are important to our ability to understand what might happen, but they are imperfect because they:

- Understate the future
- Are uncertain
- Don't deal well with surprises or abrupt changes
- Don't predict regional patterns well
- Don't fully account for aerosols

Nevertheless, these imperfections "don't constitute an argument for waiting." There are very real potential risks associated with climate change, many of which are already evident. Melting glaciers, shifting ranges of plant and animal species, changes in biodiversity and ecosystem health and others may be, as Dr. Field suggests, not a "canary" but a "menagerie in the coal mine." Kennedy urges everyone to take the evidence seriously and respond to the challenge by working to reduce the rate of climate change, and the potential for abrupt and unexpected changes, which will increase our ability to adapt to and manage their effects.

A Business Perspective

Concurrently with the preparation of this summary, the challenge—and opportunity—facing business was summed up by John Browne, Group Chief Executive of BP plc:

> Taking small steps never feels entirely satisfactory. Nor does taking action without complete scientific knowledge. But certainty and perfection have never figured strongly in the story of human progress. Business, in particular, is accustomed to making decisions in conditions of considerable uncertainty, applying its experience and skills to areas of activity where much is unknown. That is why it will have a vital role in meeting the challenge of climate change–and why the contribution it is already making is so encouraging. (Beyond Kyoto, *Foreign Affairs*, v. 38 no. 4, July/August 2004, p. 32.)

About the report

The material in this report is based on presentations and discussions at *Q's and AAA's about Global Climate Change*, a conference organized by American Association for the Advancement of Science (AAAS) and held at their headquarters in Washington, D.C., on June 15, 2004. The Hewlett Foundation provided funding for the conference. Participation by The Conference Board was facilitated by Environmental Defense as a part of their commitment to create innovative partnerships to develop and share knowledge about climate change. The Conference Board greatly appreciates financial support from The Turner Foundation for participation in the conference and the preparation of this report.

About the author

Charles J. Bennett, PhD., is a Senior Research Associate at TCB and is associated with the Global Corporate Citizenship Research group and the Townley Global Management Center for Environment, Health and Safety. Prior to joining TCB in 2001, Dr. Bennett was a senior corporate environment and safety executive. He is a graduate of Middlebury College and holds a doctorate from Syracuse University.

The Conference Board, Inc., 845 Third Avenue, New York, NY 10022-6679
Tel 212 759 0900 Fax 212 980 7014 www.conference-board.org