3 Potential Impacts of Global Climate Change

The prospect of global warming caused by an increase in greenhouse gases became a major policy issue during the past decade. For some time, scientists and policymakers throughout the world have been seeking answers to a number of questions—is global climate change partly linked to human activity? How much warming? How soon? Should we worry? What kind of policy responses, if any, are appropriate now or in the future?

The Intergovernmental Panel on Climate Change (IPCC) was organized in November 1988 under the auspices of the United Nations to address these questions. The IPCC, comprised of more than 300 scientists and climatologists from around the world, drew upon the work of over 2,500 scientists worldwide. The signatories of the *Framework Convention of Climate Change* (*FCCC*) agreed on July 1996 to formally accept the IPCC's *Second Assessment Report on Climate Change*. For this reason, the IPCC reports are at the center of the debate about the possibility, sources, and extent of climate change due to human activities.

The potential impacts of climate change are difficult to describe with any confidence. Scientists largely disagree about the extent of a future global-temperature increase, even among scientists who believe global warming will occur. Temperature increase may, in turn, cause secondary impacts such as sea level rise, global hydrological patterns change, and general human health degradation. However, the likelihood and severity of such impacts depend on the extent of global temperature increase.

Potential impacts are usually discussed at a wide-ranging, global level for at least two reasons. First, global-climate models and computer simulations do not claim to predict with precision the extent and location of a particular type of impact from climate change. The magnitude and location of future global warming will depend, in part, on how geophysical and biological feedback enhance or reduce the warming. Second, many governments are undertaking activities that are expected to affect the extent of climate change, and, therefore, the type and scope of impacts.

3.1 Potential Global Temperature Increases

The US Environmental Protection Agency (EPA) estimated in 1990 that a doubling of CO_2 would increase average temperature by 1.2 to 1.3ºC, causing an increase in atmospheric levels of water vapor, which in turn would increase the extent of warming to approximately 2 to 4ºC. EPA noted that a variety of geophysical and biogenic feedback widen the range of potential warming to between 1.5 and 5.5ºC for an initial doubling of CO_2.[1]

More recent estimates predict a lesser degree of warming. The IPCC's 1995 report predicted an increase of about 2 to 3.5ºC between 1990 and 2100, depending on whether climate sensitivity was "moderate" or "high."[2] These figures are approximately one-third lower than the IPCC estimated in 1990. According to the IPCC, the drop is due primarily to lower emission scenarios, inclusion of the cooling effects of sulfate aerosols, and modeling improvements in the treatment of the carbon cycle.[3]

Global warming could have direct impacts on transportation. Some of these potential impacts could be beneficial, such as a decrease in snow-removal costs or a longer ocean transport season in northern regions. Other potential impacts may be less desirable. Urban areas may experience a greater number of summer days that fail to meet air quality standards, with implications for the transportation community. Highways may experience more wear and tear from longer- and higher-temperature summer heat waves. In Alaska, highways and railroads built on permafrost could recede if higher temperatures cause thawing.[4]

3.2 Potential Secondary Impacts from Temperature Increases

While scientists disagree as to the likelihood, extent, and causes of global warming, they seem to agree that global warming of the predicted 2 to 3.5°C would represent an enormous change in climate. For example, Chicago and Atlanta have very different climates with a difference in mean annual temperature of 6.7ºC. The total global warming since the peak of the last ice age, 18,000 years ago, was only about 5ºC. The range of predicted temperature increases, therefore, could result in significant secondary impacts.

Scientific debate in the literature tends to focus on the extent of global warming that might result from increases in greenhouse gas concentrations. The IPCC and other scientists who predict significant warming often discuss secondary impacts such as sea level rise, hydrologic cycle alteration, and human health degradation. In contrast, scientists who believe future temperature increases from greenhouse gases will be negligible appear to discuss secondary impacts less frequently. The result is a body of literature on potential secondary impacts that typically assumes a significant level of global warming. The discussion below should be viewed in such a light.

3.2.1 Sea Level Rise

If significant global warming occurs, average sea level is expected to rise as a result of thermal expansion of the oceans and melting of glaciers and ice-sheets. Available data show that global sea level has risen by between 10 and 25 cm over the past 100 years.[5] IPCC models project a global average increase in sea level during the next hundred years of between 20 and 86 cm by 2100, with 50 cm considered as most likely.[6] EPA recently estimated the potential sea level rise, using models that assume somewhat lower concentrations of CO_2 than the IPCC considered when discussing potential impacts of global warming.[i] EPA predicts a median estimate for global sea level rise of 45 cm by 2100.[7] Under both the IPCC and EPA estimates, regional sea level changes may differ from the global mean value due to land movement and ocean current changes.[8]

A significant rise in sea level would inundate wetlands and lowlands, accelerate coastal erosion, worsen coastal flooding, threaten coastal structures, raise water tables, and increase salinity of rivers, bays, and aquifers.[9]

Sea level rise would be a problem especially in the US along the Atlantic coast's low-lying barrier island system, and along the Gulf Coast. In both areas, small vertical rises in sea level would cause large, horizontal movements in the shorelines, where the full effects of storm surges, winds, waves, and tides are felt. The cost of these disturbances is potentially large, because of extensive development and high population density in most coastal areas in the US.[10] US EPA estimates that a 50 cm sea level rise would inundate more than 5000 square miles of dry land and 4000 square miles of wetlands in the US.[11] Total losses from a one-meter rise are estimated to be between $270 billion and $475 billion, ignoring future development.[12]

[i] The EPA study also incorporated the cooling effects of sulfate emissions, stratospheric ozone depletion, and possible declines in ocean circulation, and phaseout of chlorofluorocarbons (CFCs) under the Montreal Protocol.

Potential impacts of sea level rise on transportation include erosion of coastal highways and bridges as well as infrastructure damage from an increased frequency or intensity of storm events. Sea walls may be needed to keep flooding and storms from damaging roads and causeways.[13] If sea level rise causes shifts in population density, the resulting change in consumption patterns might require changes to transportation networks handling personal travel and freight. In addition, sea level rise would probably create a need for improvements in existing harbor and port facilities to handle higher tides.[14] Airports might also require sea walls and other additional protection because many have been built on once-swampy coastal areas and may not be high enough to withstand tides and storm surges.[15]

3.2.2 Changing Hydrologic Patterns

The hydrologic cycle traces the movement of water among the oceans, atmosphere, land and vegetation, and ice caps and glaciers. Scientists from the IPCC, US EPA, and the US Congress Office of Technology Assessment agree that significant global warming would intensify the global hydrologic cycle and have major impacts on regional water resources.[16] The increase in temperature that these organizations predict could increase average global precipitation from 7 to 15 percent, but models are unable to predict impacts on water supply for specific regions.[17] Climate modelers generally agree that, with an increase in global temperature, precipitation would increase at high latitudes and decrease at low to middle latitudes. The potential for more-intense or longer-lasting drought could increase. The 1990s have experienced an unusually high incidence of intense droughts and flooding.

Changing hydrologic patterns can have great significance. Some densely populated areas of the US currently experience water scarcity and lie in areas predicted to receive even less precipitation in the future. Global climate change might, therefore, result in a changed population distribution. Similarly, water-dependent activities such as agriculture are likely to be greatly affected by a change in hydrologic patterns.[18] Studies predict that agricultural productivity will increase in some areas and decrease in others, especially the tropics and subtropics.[19] In summary, then, hydrologic changes are likely to cause changes in production and consumption patterns. Transportation systems, particularly for freight, may have to adapt to these changes.[20]

Transportation may have to adapt to other changes in hydrologic patterns, as well. While ocean levels would rise globally by a uniform amount, inland rivers and lakes would rise or fall as a function of changes in precipitation, runoff, and evaporation. For example, if the level of warming predicted by the IPCC does occur, the Great Lakes could lose 15 percent of their net water supply and water levels could fall by 30 to 80 cm. While warmer temperatures could result in a longer shipping season, increased shipping costs would result from lower water tables.[21] Vulnerability of some river systems to drought has been demonstrated in the past. For example, commercial shipping was all but stopped in 1988 when drought decreased water levels in the Mississippi River.

3.2.3 Impacts on Human Health

Scientists affiliated with the IPCC believe that climate change could have wide-ranging and mostly adverse impacts on human health.[22] Health effects might include increases in mortality and illness due to a predicted increase in the intensity and duration of heat waves. Warming would result in increased levels of airborne pollen and spores, which would worsen respiratory disease.[23] The most significant, albeit indirect, effect could be an increase in the potential transmission of vector-borne infectious diseases, such as malaria, resulting from extensions of the geographical range and season for vector organisms. Limitations on freshwater supplies and nutritious food would also have human health consequences. Positive health benefits of temperature increases might include a reduction in cold-related deaths in colder regions.

The World Health Organization (WHO) has identified the health ramifications of global warming to be among the most pressing problems for the next century.[24] A 1990 report observed that several vector-borne diseases might be influenced by climate change, including malaria, lymphatic filariasis, dengue and yellow fever. Initial impacts would likely be at the margins of the diseases' current distributions, with expanding distributions as warmer temperatures expand toward the poles. WHO also predicted that climate change might affect the altitude at which vector-borne diseases are found. The IPCC predicts 50 to 80 million additional annual cases of malaria around the world.[25] On the positive side, climate change may cause the elimination of some disease vectors and pathogens as the result of very hot, dry conditions.

3.3 Extent of Scientific Certainty about Climate Change

It is difficult to prove the global climate change effect because of normal temporal and spatial variations in temperature. Information on historic concentrations show that CO_2 and methane are currently at levels not reached for prolonged periods in the last 160,000 years.[26] However, scientists have not firmly established links between such greenhouse gas concentrations and the record-setting warmth of the 1980s and 1990s or severe flooding and storms of the 1990s.

Predicting the future is even more difficult because of the need to rely on models, assumptions, and incomplete data. The general circulation models (GCMs) used to assess climate change tend to suggest that increasing concentrations of greenhouse gases will produce a change in the average temperature of the Earth, and predict that concentrations will continue to increase without specific actions. The IPCC reports and those scientists concerned about global climate change typically rely on the predictions of GCMs, or at least the general outcomes implied by the models. But even the IPCC acknowledges that some uncertainties exist. For example, differing GCM predictions typically give average global temperature increases ranging from 1.5 to 4.5ºC.[27]

In the past, a major difficulty in developing an appropriate US global climate change policy has been scientific uncertainty about the likely extent of change, and its specific regional effects. A small number of scientists argue that global warming is not fully supported by empirical evidence, mostly as a result of an inadequate understanding of atmospheric and weather patterns and that the US should reach a better scientific understanding before taking measures to reduce greenhouse gases. Another, much larger, group of scientists asserts that human activity is altering the chemical makeup of the Earth's atmosphere. These scientists also assert that the time lag between emissions of greenhouse gases and their full impact is on the order of decades to centuries, as is the time needed to reverse any effects. Finally, these scientists, including those of the IPCC, feel that the potential risks are so great that some action is warranted.

The IPCC's *First Assessment Report on Climate Change* (1990) was cautious. It found that there is a natural greenhouse effect that already keeps the Earth warmer than it otherwise would be and that human activities are substantially increasing the atmospheric concentration of greenhouse gases. The IPCC's 1990 report did not explicitly conclude that human activities were causing the greenhouse effect. The IPCC noted that all predictions are subject to many uncertainties regarding the timing, magnitude, and regional patterns of climate change due to an incomplete understanding of greenhouse gas sources, clouds, oceans, and polar ice sheets.

The IPCC released its *Second Assessment Report on Global Climate* in December 1995. The *Second Assessment* sought to determine what concentrations of greenhouse gases might be regarded as a "dangerous anthropogenic interference with the climate system," and to highlight options that were sustainable.[ii] The IPCC report concluded that "the balance of evidence suggests that there is a discernible human influence on global climate." The IPCC identified several potentially serious repercussions for the well-being of human populations, including regional shifts in agricultural activity, changes in water-supply availability, sea level rise, and increased incidence of human illness and death. The IPCC report also referenced the *FCCC* principle that lack of full scientific certainty should not be used as a reason for postponing actions where there are threats of serious or irreversible damage.

- The IPCC and other scientists who believe global climate change is occurring have circumscribed what they assert as scientifically defensible. These assertions appear in the IPCC 1995 report, and peer-reviewed journals and studies: Greenhouse gas concentrations currently are increasing at a much faster rate than before the twentieth century.
- The rate of increase in greenhouse gases is partly caused by human activity.[28]
- An increased concentration of greenhouse gases in the atmosphere causes an increase in average global temperature level.

The 1995 IPCC report cites data indicating that global mean surface temperature has increased since the late nineteenth century by between about 0.3 and 0.6ºC, a "change that is unlikely to be entirely natural in origin" and that corresponds to increases in greenhouse gas concentrations.[29] Many scientists also assert that global temperatures will continue to increase unless measures are taken to reduce greenhouse gas concentrations; the "no action" scenario in the IPCC report predicts a temperature increase could be as high as 3.5ºC by 2100.[30]

Scientists are less confident about predicting the actual temperature increase that will result from current trends in greenhouse gas concentration, or providing a specific time frame.[31] Many are also reluctant to causally link recent weather extremes to global climate change. Most will not predict regional patterns of climate change because of the difficulty of modeling or simulating complex global climate impacts on relatively small areas. Even proponents of global warming theories agree that there is an incomplete understanding of biogenic and anthropogenic sources of greenhouse gases and do not fully comprehend the influence of clouds, oceans, and polar ice sheets on global climate. As the IPCC recently noted, "many uncertainties…arise from the non-linear nature of the climate system."[32]

As with any large-scale, complex issue, there are some scientists that disagree with one or more of the IPCC conclusions on global climate change. For example, scientists from the George C. Marshall Institute recently concluded that natural climate change is the most probable link to moderate temperature increases. It asserted that "as the climate models improve, the predictions get closer to a small, gradual warming indistinguishable from the natural warming we have been experiencing for the last several hundred years."[33] Others at the Marshall Institute and elsewhere concede that the magnitude of the rise in temperature predicted by GCMs seems to agree with the observed temperature increase, but argue that the predictions are inconsistent with the time frame of the warming.[34]

[ii] The IPCC, comprised of more than 300 scientists, drew on the work of 2,500 scientists from around the world, including peer-reviewed studies of empirical observations, statistical models, and climate models.

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[1] US Environmental Protection Agency, *Policy Options for Stabilizing Global Climate: Report to Congress* (EPA 21P-2003.1, Dec. 1990), pp. 8-9.

[2] Intergovernmental Panel on Climate Change, Second Scientific Assessment of Climate Change, Summary and Report, World Meteorological Organization/UN Environment Program (Cambridge, UK: Cambridge University Press, 1995), p. 23.

[3] *Ibid.*

[4] Black, William, "Global Warming: Impacts on the Transportation Structure," in *TR News,* Vol. 150, (September-October 1990) pp. 2-8.

[5] Intergovernmental Panel on Climate Change, Second Scientific Assessment of Climate Change, Summary and Report, p. 22.

[6] *Ibid*., p. 5.

[7] US EPA, *The Probability of Sea Level Rise*. (EPA 230-R-008, Oct. 1995), p. iii.

[8] *Ibid.*

[9] Titus, J., *et. al.*, "Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea," in *Coastal Management* Vol. 19, (1991) pp. 171-204; for a general discussion, *see also* US Congress Office of Technology Assessment, *Preparing for an Uncertain Climate, Vol. I* (Washington, DC: US Government Printing Office, 1993), pp. 153-207.

[10] Titus, J., US Environmental Protection Agency, "An Overview of the Nationwide Impacts of Rising Sea Level," peer review draft 1993.

[11] Gardiner, David, "Global Climate Change Negotiations." (Testimony Before the House Commerce Committee, Subcommittee on Energy and Power, June 19, 1996).

[12] Titus, J., *et. al.*, "Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea," in *Coastal Management* Vol. 19, (1991) pp. 171-204.

[13] Black, William, "Global Warming: Impacts on the Transportation Structure," in *TR News*, Vol. 150, (September-October 1990), pp. 2-8.

[14] *Ibid.*

[15] *Ibid.*

[16] Intergovernmental Panel on Climate Change, Response Strategies Working Group, Strategies for Adaptation to Sea Level Rise (The Hague, the Netherlands: Ministry of Transport and Public Works, 1990); US EPA, "Policy Options for Stabilizing Global Climate: Report to Congress." (21P-2003.1, December 1990).

[17] *See* US Congress Office of Technology Assessment, *Preparing for an Uncertain Climate Vol. I*, (Washington, DC: US Government Printing Office, 1993), p. 212.

[18] *See, e.g.,* Innes, Robert, and Kane, Sally, "Agricultural Impacts of Global Warming: Discussion." in *American Journal of Agricultural Economics*, Vol. 77, (August 1995), pp. 747-750.

[19] *See, e.g.,* US Congress Office of Technology Assessment, *Preparing for an Uncertain Climate Vol. I*, Washington, DC: US Government Printing Office, 1993).

[20] Black, William, "Global Warming: Impacts on the Transportation Structure," in *TR News,* Vol. 150, (September-October 1990), pp. 2-8.

[21] Environment Canada, "Impacts of Global Warming" at http://www.ns.doe.ca/uco/warm-3.html.

[22] Intergovernmental Panel on Climate Change, Second Scientific Assessment of Climate Change, Summary and Report, p. 35.

[23] *See, e.g.,* McMichael, Antony, "Global Health Watch: Monitoring Impacts of Environmental Change," in *The Lancet*, Vol. 342, (December 1993) p. 1464.

[24] World Health Organization Task Group, "Potential Health Effects of Climate Change." (Geneva: World Health Organization, 1990).

[25] IPCC, 1995, p. 12.

[26] Barnola, J.M. *et. al*., "Vostok Ice Core Provides 160,000-year Record of Atmospheric CO_2," *Journal of Geophysical Research 92:* 14722-14780 (1987).

[27] For discussions of the uncertainties in modeling atmospheric and climate change, see "Shaky Science Behind the Greenhouse Effect" and "The Scientific Myth Behind the Global Climate Treaty," both by S. John Singer at the University of Virginia's Science & Environmental Policy Project.

[28] *See, e.g.*, US Congress Office of Technology Assessment, *Changing By Degrees: Steps to Reduce Greenhouse Gases* , Washington, DC: US Government Printing Office, 1991; Intergovernmental Panel on Climate Change, *Second Scientific Assessment of Climate Change*, Summary and Report, World Meteorological Organization/UN Environment Program (Cambridge, UK: Cambridge University Press, 1995).

[29] Intergovernmental Panel on Climate Change, *Second Scientific Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change*, World Meteorological Organization/UN Environment Program (Cambridge, UK: Cambridge University Press, 1995).

[30] *Ibid.*

[31] *See, e.g.*, Baliunas, Sallie, "Uncertainties in Climate Modeling: Solar Variability and Other Factors," testimony before the Senate Committee on Energy and Natural Resources, September 17, 1996.

[32] *Ibid.*

[33] George C. Marshall Institute. *Are Human Activities Causing Global Warming?* (April 1996).

[34] *See* "Uncertainties in Climate Modeling: Solar Variability and Other Factors." Sallie Baliunas' Testimony to the Senate Committee on Energy and Natural Resources on September 17, 1996.