Chapter 8
Review of Current Scientific Literature on Causes and Impacts of Global Warming

The Supreme Court in *Massachusetts* v. *Environmental Protection Agency*, 127 S.Ct. 1438 (2007), stated:

> A well-documented rise in global temperatures has coincided with a significant increase in the concentration of carbon dioxide in the atmosphere. Respected scientists believe the two trends are related. For when carbon dioxide is released into the atmosphere, it acts like the ceiling of a greenhouse, trapping solar energy and retarding the escape of reflected heat. It is therefore a species—the most important species—of a "greenhouse gas."

Consistent with the findings of the Supreme Court, there is a broad scientific consensus that, over the last two centuries, there is a 90%–95% probability that human activities have increased amounts of important greenhouse gases (GHGs, primarily carbon dioxide, methane, nitrous oxide, and fluorocarbons)[1] in the atmosphere to levels not seen in all of prior human experience, and likely not seen for 3 million years. This consensus has been reflected in *Climate Change 2007: The Physical Science Basis. Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC 2007), and in at least three reports of the National Research Council of the National Academy of Sciences (NAS/NRC): *Climate Change Science: An Analysis of Some Key Questions* (2001), *Abrupt Climate Change: Inevitable Surprises* (2002), and *Surface Temperature Reconstructions for the Last 2,000 Years* (2006). These findings are also reflected in the summary of science prepared by the U.S. Environmental Protection Agency in the Advance Notice of Proposed Rulemaking: *Regulating Greenhouse Gas Emissions Under the Clean Air Act* (July 30, 2008).

As reflected in these reports, it is likely or very likely that human-induced increases in these GHGs are already causing global climate to warm. Human activities likely caused most of the approximately 0.6 ^{o}C (1.1 ^{o}F) rise over the 20th century.[2] The mean ocean temperature has risen by 0.05 ^{o}C (0.09 ^{o}F), global average sea level has risen by 0.1–0.2 meters (1/3–2/3 feet) over the 20th century, and snow cover and Arctic ice have decreased by about 10% and 10%–15%, respectively, since the late 1960s (when data first became available for this measurement).[3] Various other climate factors are changing consistent with warming induced by GHGs. By contrast, we know of no measures of climate on the global scale that indicate cooling. It is virtually certain that what has been observed so far is only the beginning, and that continued

[1] Water vapor is a GHG and is an important amplifier of climate change because its atmospheric concentrations tend to increase when the atmosphere and surface waters warm up. Anthropogenic emissions of water vapor to the atmosphere by automobiles and other combustion sources do not significantly affect global atmospheric concentrations of water vapor relative to the natural evaporation and condensation processes.

[2] NAS/NRC, *Climate Change Science,* p. 1.

[3] *Id.*, p. 16.

GHG emissions along current trajectories will cause additional warming of the Earth system as a whole. The average time for removal from the atmosphere of added carbon dioxide is measured in centuries. It is very likely that such perturbation would cause the rate of surface warming and sea level rise in the 21st century to be substantially larger and faster than that experienced in the 20th century, without precedent in the past 10,000 years.

The evidence that anthropogenic emissions of GHGs have already affected the climate includes the following observations:

- Ocean temperature has increased to depths of at least 3,000 meters.
- Global sea levels rose by 1.7 millimeters per year (mm/yr) during the 20th century and by 3.1 mm/yr during 1993–2003. There is high scientific confidence that the rate of rise increased during the 20th century.
- The average Arctic temperature has increased at twice the global average.
- Summer Arctic sea ice has shrunk at 7.4% per decade since 1978.
- Mountain glaciers have declined in both hemispheres.
- There is a trend toward less snow at low altitudes.
- Atmospheric water vapor content has increased (consistent with the effect of increased air temperature).
- There has been an increase in precipitation over many large regions (the Northern Hemisphere, in general, and eastern North America).
- There have been more intense, longer droughts in many regions.
- There has been less rainfall in African Sahel, southern Africa, and southern Asia.
- The frequency of heavy rainfall events has increased over most land areas.
- There have been widespread increases in hot days and nights, and heat waves.
- Various ecological changes have been observed, including impacts on nesting behavior, insect and disease outbreaks, and species distribution.

On the other hand, to date, there have been no observed effects upon:

- Global average diurnal temperature range.
- Antarctic sea ice extent.
- Tornadoes, hail, lightning, and dust storms.
- Meridional overturning circulation in the global ocean, which would lead to cooling of Europe.

A variety of impacts will affect Arkansas and the southeastern United States, particularly if emissions of GHGs are not limited. These impacts include the following:

- There will be increased storminess, with increases in floods, windstorms, and, in some places, ice storms.
- Floodplains will likely increase in extent as larger floods increase in frequency. Ground-level ozone pollution will be exacerbated. Tropical and insect-borne diseases will move north.
- There will be increased heat-related deaths and decreased cold-related deaths.
- Although less likely to impact Arkansas directly, there will be adverse impacts on winter sports that will reduce the snow season in resorts.
- There will be strains on water supplies, particularly in western states, which will witness a decreased snowpack.
- There will be increased drought stress, because there will be less precipitation during summer months and more during winter months, putting further stress on water supplies.
- The increases in drought stress and storminess are likely to have an adverse impact upon agriculture and forestry.
- Sea levels will rise, putting stress on coastal areas and causing salt-water intrusion into coastal aquifers. Sea levels are expected to rise by 1–2 feet by 2100 due to thermal expansion, alone. However, the sea level rise could be much greater due to melting of the Greenland or Antarctic glaciers.
- Rising sea levels, increased drought stress, and impacts on agriculture will also become "a [national security] threat multiplier for instability in some of the most volatile regions of the world."[4] This insecurity may affect Arkansas.
- Cold-water fisheries will decline.
- Coral reefs and related fisheries will be adversely affected by ocean acidification caused by increased carbon dioxide levels.
- Climatic hardiness zones will move north and the distribution of vegetation and wildlife will change. This will likely put stress upon vulnerable species.

There is also a danger of severe and sudden impacts whose likelihood cannot be assessed, as reflected in the NAS/NRC report *Abrupt Climate Change: Inevitable Surprises* (2002). The glaciers in the Antarctic and Greenland provide a 100,000-year history that show that climate was far more variable before the beginning of human civilization. This history raises the concern that there may be more extreme results as a result of increasing atmospheric GHG levels. Over the last 5,000 years, climate has been very stable, but the norm is rapid and wild fluctuation. If a forcing element, such as levels of GHGs in the atmosphere, changes considerably, it is possible that we could pass a threshold and flip a switch that would cause the climate to undergo rapid change that could include dramatically warmer or colder temperatures or rapid changes in sea level. We cannot predict when continental glaciers will collapse and how fast this will occur. The fossil record shows that there have been 5-meter rises in sea level in the shortest interval that can

[4] CNA. *National Security and the Threat of Climate Change*. Available at: http://securityandclimate.cna.org/.

be read (10 years). A recent study has found that melting of continental glaciers could cause a rise of as much as 3–6 feet by 2100, in addition to the 1–2-foot rise predicted as a result of thermal expansion. In light of recent evidence, James Hansen has expressed the following concern:

> Crystallizing scientific data and analysis reveal that the Earth is close to dangerous climate change, to tipping points of the system with the potential for irreversible deleterious effects.[5]

Several individuals have pointed to publications and speeches by "climate skeptics" that appear to present contrary views. However, these publications have not been peer reviewed. Peer-reviewed scientific literature has unanimously endorsed the views in the IPCC and NAC/NRC reports described above.[6] In fact, the individuals who raise "questions" about the consensus view are not disagreeing about the science, but are confusing science and policy, disagreeing with the default position dictated by applicable law for addressing residual face of uncertainty, and quite frequently basing their view on largely unsupported and sometimes unstated assumptions regarding the relative environmental and economic risks of error.

Moreover, there is no disagreement that there are some uncertainties regarding the degree of risk from GHG atmospheric increases, the timing of impacts and, in some cases, even the nature of some risks. The critics suggest that economic concerns regarding response suggest that we should not take action unless it is virtually certain that very bad things will happen. However, applicable law, including the United Nations Framework Convention on Climate Change and the federal Clean Air Act, require that actions be taken to limit emissions if there is a risk of serious harm, rather than a certainty. Thus, the United Nations Framework Convention on Climate Change, which has been ratified by the United States, provides:

> The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost.[7]

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[5] James E. Hansen."Dangerous Human-Made Interference with Climate." Testimony to Select Committee on Energy Independence and Global Warming, United States House of Representatives. April 26, 2007. Available at: http://www.columbia.edu/~jeh1/2007/Testimony_20070426.pdf.

[6] Naomi Oreskes. "Beyond the Ivory Tower: The Scientific Consensus on Climate Change." *Science* December 3, 2004;306(5702):1686. Available at: http://www.sciencemag.org/cgi/content/full/306/5702/1686. Some publications are miscited. For example, some cite the work of Bjørn Lomborg, *Cool It: The Skeptical Environmentalist's Guide to Global Warming* (September 2007), as evidence against taking action. In *Cool It*, he writes: "Global warming is real and man-made. It will have a serious impact on humans and the environment toward the end of this century." *Id.* at 8. He also agrees that action should be taken to address climate change. (*See* http://www.lomborg.com/faq/.) Dr. Lomborg is an economist, not a climate scientist, and his work expresses his opinion on solutions.

[7] United Nations Framework Convention on Climate Change. Article 3, section 3. Available at: http://unfccc.int/2860.php.

A similar or identical precautionary standard appears in many sections of the federal Clean Air Act. Thus, section 202(a)(1), which was construed by the United States Supreme Court in *Massachusetts* v. *Environmental Protection Agency* provides as follows:

> The Administrator shall by regulation prescribe . . . standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare.

The applicable science meets this standard, and no skeptic says that there is a reasonable scientific certainty that there will not be adverse impacts from rising GHG levels.