Climate Science for Lawyers

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In an era where addressing the impacts of climate change may become one of humanity's greatest challenges, we as citizens should all have a basic understanding of the science. As environmental and energy lawyers, however, this is even more important. Every day we are called upon to advise individuals, companies, NGOs, and policy makers. Issues related to climate change are increasingly touching our practices.

Scientists have a solid, long-tested understanding of how heat flows into and out of Earth's atmosphere and how greenhouse gases (GHGs), such as carbon dioxide, methane, and fluorinated gases, trap heat. Adding more long-lived GHGs to the atmosphere is causing a warming of the climate that will persist long after GHG emissions stop. However, less well understood are how feedbacks to the climate system may amplify or ameliorate the speed and magnitude of that warming, and where geographically the most dramatic changes may take place. Learning what the science can and cannot tell us is fundamental to defending our clients' interests and assuring that laws and policies related to climate change are well-grounded. Science also will drive policy changes, and well-informed lawyers can provide guidance to help navigate the direction of those changes.

Although facts are objective, the choice of which policies to pursue in response to those facts is inevitably subjective and reflects differences in human values and preferences. It is well documented that people (both liberal and conservative) tend to be selectively skeptical of science if they believe the policy implications of that science will conflict with their cultural or political values. This has been one of the greatest challenges to universal acceptance of climate change science, despite the overwhelming consensus among climate scientists as to its validity. For this reason, approaches that separate science and policy may be most effective. As 376 of the nation's top scientists wrote, "[h]uman-caused climate change is not a belief, a hoax, or a conspiracy. It is a physical reality." *See* Open Letter Regarding Climate Change from Concerned Members of the National Academy of Sciences, ResponsibleScientists.org, Sept. 20, 2016, *available at* www.evokinnovations.com/2016/09/20/open-letter-climate-change-us-national-academy-of-sciences/. By recognizing our biases and remaining curious about the natural processes that make Earth habitable, lawyers can take positive and meaningful action on behalf of their clients to address these issues from a policy perspective.

The science of climate change is elegantly simple in some ways and more complex in others, but the fundamentals are accessible to any interested person. The key to a stable average temperature on Earth is that the heat coming into the planet must equal the heat that escapes to space. Most people know that the primary source of heat coming into Earth is sunlight. However, fewer people stop to consider how that heat leaves Earth to achieve a stable average temperature despite the fact that heat from the sun has been hitting the earth every day for eons.

The answer lies in the flow of electromagnetic radiation ("radiation" or "light"), which for all practical purposes is the only way heat enters or leaves Earth. Radiation is visible light but also invisible radio waves, microwaves, infrared, ultraviolet, and even gamma and X-rays. The only difference between these forms of radiation is the wavelength, or frequency.

Matter can both absorb and emit radiation. We intuitively know that Earth absorbs the sun's radiation when we feel a hot rock or hot sand under our feet. Fundamental laws of thermodynamics cause objects to move toward a state of thermal equilibrium where the heat being absorbed is equal to the heat emitted. The intensity of the radiation an object emits depends on the object's temperature: hotter objects emit more intense radiation at shorter (even visible) wavelengths (e.g., hot orange coals or sunlight). Cooler objects (room temperature) radiate primarily at longer wavelengths, usually in the invisible infrared spectrum. Although infrared light is invisible to the human eye, every object around you (a chair, the carpet, the wall) is constantly emitting infrared radiation.

Earth achieves its energy balance by releasing longwave infrared light to space at the same rate that it absorbs heat from shortwave sunlight. Satellite pictures of Earth taken in the infrared or microwave spectrum reveal a bright planet, because Earth emits a lot of light to space at these wavelengths.

Temperature adjustments are key to achieving an energy balance because hotter objects emit more intense light and, therefore, more total energy. If incoming energy increases, Earth heats up to radiate more infrared light and offset that initial increase. A hotter temperature effectively allows a planet to "push" more heat out to space.

The Greenhouse Effect

Earth's atmosphere is made up of a variety of gases held in place by Earth's gravity. Unlike most solid or liquid matter that can absorb and emit radiation at all wavelengths, gases are very selective about what wavelengths they can absorb and emit, and it is this property that allows some gases to trap heat on earth. A GHG is any gas that can absorb and emit longwave infrared light but does not absorb shortwave sunlight. Accordingly, sunlight passes through GHGs to Earth's surface, but infrared radiation emitted from Earth cannot get out to space as easily. Indeed, without GHGs, Earth would be too cold for human life.

At Earth's surface, GHG molecules absorb infrared radiation coming off the earth, and then re-emit it in all directions. The radiation emitted upward is absorbed by other nearby

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GHG molecules and re-emitted again. This chain of absorption and re-emission continues as the infrared light moves to GHG molecules higher in the atmosphere until the air is so thin that there are too few GHG molecules overhead to absorb it, allowing the infrared light to escape finally to space. At this higher altitude, however, the GHG molecules are colder, so they emit much less intense infrared light than at the surface.

GHGs are mixed through the entire atmosphere, so adding more GHGs means more molecules everywhere, including at the higher altitudes where the GHGs were previously too thin to absorb. With more GHGs, the infrared light now has to move even higher—where the atmosphere is colder—before escaping to space, resulting in even less energy leaving the atmosphere. Earth's energy budget must balance, so the earth and its atmosphere heat up, increasing the intensity of the infrared radiation until the energy books are again in balance.

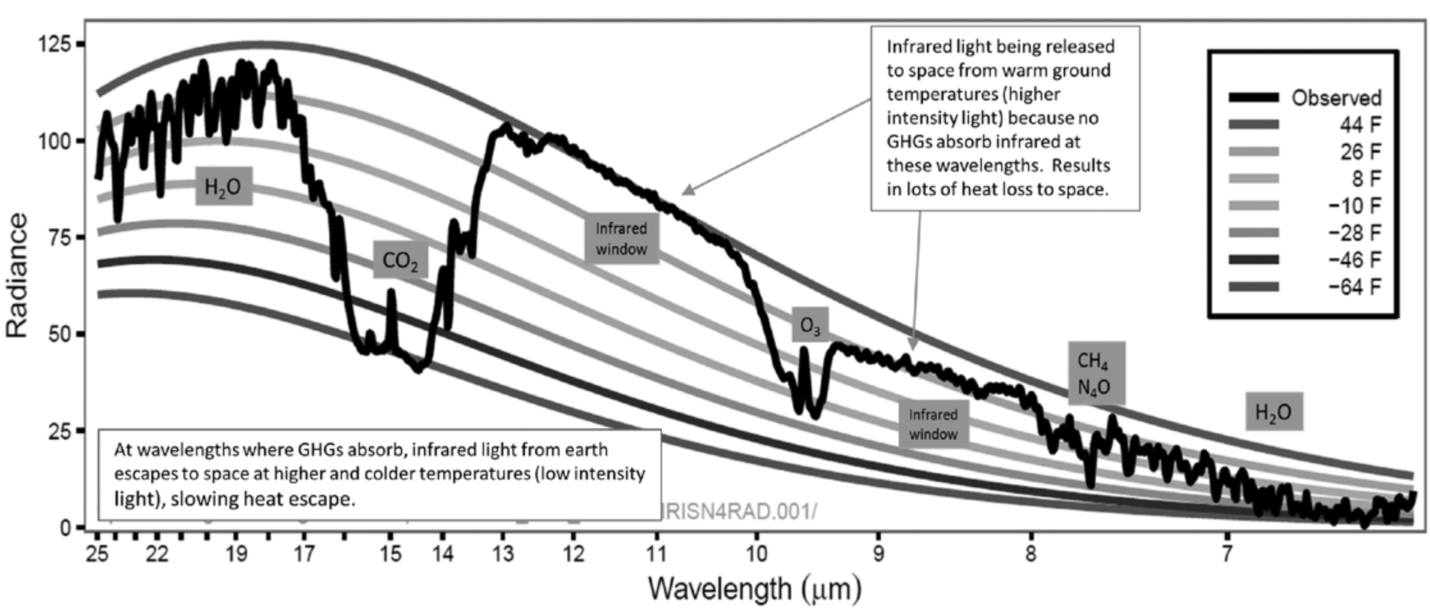
The figure below provides an illustration of how GHGs slow heat escape. The black jagged line is a plot of the intensity of Earth's infrared emissions—how much heat escapes to space—in watts per square meter (labeled "radiance") measured from NASA's Nimbus 4 satellite. The satellite only "sees" the infrared light where it escapes to space, not where absorption and re-emission are occurring. The area below the black jagged line is the total energy emitted by Earth over the infrared spectrum. The shaded lines represent the infrared emissions of a theoretical object at a range of temperatures that perfectly absorbs and emits all wavelengths.

Along the wavelengths where major GHGs absorb well, there is a dip in the black line, which corresponds to lower "radiance" numbers and less energy being emitted to space—an effective "bite" out of the total energy leaving Earth in the infrared spectrum. The dip is especially significant for CO_2, where infrared does not escape to space until high altitudes and cold temperatures, about – 64°F, which is why the intensity of the light is so reduced at those wavelengths, trapping a lot of heat in Earth's atmosphere. The infrared light with wavelengths 8–9 and 10–13 micrometers escapes from warm surface temperatures (around 44°F), which means higher intensity radiation (more heat) is leaving Earth because no GHGs absorb at those frequencies. This is known as the "infrared window." Molecule per molecule, adding a GHG that absorbs in the infrared window or that is not yet plentiful enough to reach the peak of its potential "bite" of energy will lead to a greater drop in the outgoing energy than adding more CO_2, which is already well saturated to the coldest layers of the atmosphere. Adding more CO_2 will cause increased warming, but at a slower rate than some other GHGs. This is why GHGs such as methane and fluorinated gases are of increased concern despite their lower concentrations.

Carbon dioxide only makes up .04% (400 ppm) of Earth's atmosphere, but it is considered the most important GHG (pre-industrial levels were at about 280 ppm). The importance of CO_2 stems from its long persistence in the atmosphere. Although there are carbon "sinks" that are good at taking CO_2 out of the air relatively quickly (such as vegetated areas of land and surface layers of the ocean), adding large amounts of CO_2 will saturate those sinks so they cannot remove any more, and then excess CO_2 in the atmosphere will be controlled by much slower processes. Deep ocean water is rich in carbonate ions that react with and remove atmospheric CO_2, but the currents that mix deep ocean water with surface water take around 1000 years to do so.

As CO_2 levels rise, they can deplete even the deep ocean carbonate, and then the only way to remove extra CO_2 is an even slower chemical process called weathering, which can take tens of thousands to hundreds of thousands of years. Much of the CO_2 that humans add to the atmosphere now will remain in the atmosphere for many millennia.

Infrared radiance observed by satellite
(Sahara Desert in April)



Feedbacks in the Climate System: The Major Unknowns

Scientists know with high confidence that adding more GHGs to the atmosphere will cause a continued warming of the planet. However, other processes "feedback" on the climate system and can amplify or ameliorate the intensity or speed of the warming. An example of such a feedback is ice and snow. Snow reflects about 90% of incoming solar radiation, ice reflects 50–70%, but the oceans absorb over 90% of solar radiation. If temperatures increase, snow and ice melt, less solar energy is reflected to space, and more is absorbed by the oceans. This creates further warming that melts even more ice and snow, further decreasing reflectivity and increasing heat absorption in a feedback loop. Other major feedbacks scientists study include water vapor (a warmer Earth means more water vapor in the air, intensifying the greenhouse effect) and clouds (clouds absorb infrared and reflect sunlight, so they have a mixture of warming and cooling effects). Measurements of these feedbacks in real time, as well as research on ancient climates showing that strong amplifying feedbacks were responsible for most of the temperature changes during the ice ages of the last 800,000 years, give scientists great confidence that feedbacks generally amplify the effects of an initial warming or cooling. Despite broad agreement that feedbacks are likely to amplify human-caused warming, there is still uncertainty as to the degree of amplification.

Extreme Weather and Climate Change

Weather and climate are not the same. Weather is not very predictable and can change quickly. Climate, by contrast, consists of long-term averages of weather events, usually over at least three decades. Global average temperatures are expected to increase, but how that will manifest in changes to some extreme weather patterns is less clear.

The best consensus science on climate change is documented in the reports of the Intergovernmental Panel on Climate Change (IPCC), an institution established to assess climate change set up by the United Nations and the World Meteorological Organization in 1988. The IPCC does not conduct original research, but assesses and summarizes tens of thousands of published research reports from scientists around the world, most of which have been subjected to rigorous peer review. IPCC reports tend to be conservative assessments because they represent the agreement of many hundreds of scientists around the globe. Indeed, IPCC reports must be unanimously approved by all the participating national governments, any of which can veto the report if it disapproves of the final wording. While individual scientists and research groups may have more up-to-date data, for purposes of law and policy, the strong international scientific consensus is an important reason to rely on IPCC reports; however, lawyers should also understand where the scientific consensus is headed because science evolves rapidly between IPCC assessments.

The most recent IPCC Fifth Assessment Report (AR5) documents a number of extreme weather events, evidence of observed and projected changes in those events, and the strength of the evidence linking any changes to anthropogenic (human-caused) climate change. *See* Intergovernmental Panel on Climate Change, *Climate Change 2013: The Physical Science Basis, Contribution of Working Group 1 to the AR5 of the IPCC*, 7 (Thomas F. Stocker et al., ed., Cambridge Univ. Press 2013). Increases in heat waves, temperature extremes, the number of warm days and nights, and sea level have all been observed, can be linked to anthropogenic climate change, and are projected to continue to increase. *Id.* at 110. With respect to most other types of extreme weather events (e.g., floods and droughts) the evidence is generally not sufficient to draw strong conclusions, raising important implications for a range of laws and policies. *Id.* at 112.

Even with respect to extreme events that we know are likely to increase, global climate models and their projections are most accurate on a global or hemispheric scale. As one "downscales" the data to more local areas, the reliability of climate projections become increasingly suspect. From the perspective of a company trying to better understand potential impacts from climate change on its operations, a municipality trying to determine whether adaptation investments are warranted, or lawmakers trying to determine policy outcomes, this presents a significant challenge.

The Evidence of Human-Induced Climate Change

Scientists who dedicate their careers to the study of the climate system are in overwhelming agreement that the earth is warming because of human additions of GHGs to the atmosphere, primarily from the burning of fossil fuels but also from deforestation (burning of tropical forests releases CO_2), and that continued burning of fossil fuels will increase warming. The evidence for these conclusions continues to mount: scientists can calculate with reasonable accuracy the quantities of GHGs added through fossil fuel combustion and deforestation; air bubbles trapped in ice cores recording the composition of the atmosphere reveal that CO_2 concentrations since the industrial revolution are nearly 40% higher than at any time during the last 800,000 years; average temperatures since the 1800s have increased; most of this warming has occurred in the last 30 years, despite *decreasing* solar intensity over this time period caused by 11-year cycles in the number of sun-spots; surface ocean temperatures have increased; Arctic ice sheets are retreating; the ocean's acidity has increased 30% since the industrial revolution (as oceans absorb excess atmospheric CO_2); satellites show decreasing spring snow in the northern hemisphere and snow is melting earlier; carbon isotope analysis can differentiate between atmospheric CO_2 that originated from fossil fuel burning versus volcanic eruptions or burning of forests, supporting the conclusion that increased atmospheric CO_2 is human-caused, not from natural phenomena; and climate models can accurately reproduce observed temperature increases only if human-added GHGs are included.

So what would it take to be wrong? As one noted scientist put it:

> Is it possible, or does it seem likely, that humans could put as much CO_2 in the air as we like without changing the earth's climate . . . . ? There are two obstacles to this possibility. First, there would have to be some other mechanism to explain the recent warming . . . , some large perterbation to the energy budget of the earth that no one has measured or conceived of yet. It takes a lot of energy to warm up the [earth and oceans] and it cannot happen just by random chaos. Certainly there will always

> be things about the natural world that are not perfectly understood, maybe even things about which we have no clue yet. But so far . . . no one has come up with an alternative source of energy to account for all that warming . . . . Second, there would have to be a reason to throw out the greenhouse effect theory . . . . Overcoming either of these obstacles seems like a long shot, given how much intense, motivated searching has been done. Overcoming both obstacles together seems extremely unlikely . . . .

David Archer, *Global Warming*: *Understanding the Forecast*, 144 (2d ed. 2011).

Science does not tell us what to do or seek the "truth;" it is about the strength of the evidence. Considering the weight of the evidence, arguments attacking the science are not likely to be productive when addressing potential policy responses. Using the science, however, provides potential for creative and better arguments in the policy debates.

Law, Science, and Climate Change

Climate change is increasingly impacting the practice of law. After two decades of failed efforts to reach broad international agreement, in December 2015, 197 countries agreed to a framework for reducing GHG emissions. U.N. Framework Convention on Climate Change (UNFCCC), *Adoption of the Paris Agreement*, Dec. 12, 2016, U.N. Doc. FCCC/CP/2015/10/Add.1, (Paris Agreement). For the first time, virtually all of the world's emitters, developing and developed countries alike, agreed to take voluntary steps to reduce GHG emissions.

The Paris Agreement requires parties to identify their GHG emission reduction commitments in nationally determined contributions (NDCs), which are reported on and strengthened every five years, but are otherwise voluntary commitments. As of this writing, 163 countries have submitted NDCs, including all major emitters. During the recent 22nd Conference of the Parties to the UNFCCC (COP22), the international community demonstrated a continued commitment to implementing the Paris Agreement.

Virtually all countries will need lawyers to assist with integrating NDCs into domestic and international law, to develop legal frameworks enabling the flow of finance, and to develop standards around measurement and reporting on a variety of factors that lawyers are particularly well-equipped to address.

In the United States, a series of executive orders now requires all federal agencies to consider certain climate change related risks and reduce GHG emissions. *E.g.,* Exec. Order No. 13,653, 78 Fed. Reg. 66,819 (Nov. 6, 2013); Exec. Order No. 13,693, 80 Fed. Reg. 15871 (Mar. 25, 2015). Federal reviews under the National Environmental Policy Act (NEPA) should now include climate change considerations. *See* Council on Environmental Quality Final Guidance for Federal Departments and Agencies on Consideration of Climate Change in NEPA Reviews, 81 Fed. Reg. 51,866 (Aug. 5, 2016). Understanding the science, such as which extreme weather events are likely to increase and for which we do not have sufficient information can inform where agency resources aimed at reducing risk and increasing resilience may be better spent, or, in a NEPA review, how likely are particular climate change related impacts.

Even if these executive orders and guidance are reversed in the new administration, it is the states, local governments, the private sector, and market mechanisms that have driven emission reductions in the United States. Regional partnerships between states such as the Regional Greenhouse Gas Initiative, California's vehicle emissions standards, or the recent historic industry-supported agreement to reduce emissions in international aviation are just some examples. Indeed, the United States is currently in the first sustained period where economic growth increased while CO_2 emissions decreased (known as "decoupling"), a result stemming primarily from non-federal actions.

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Courts are also playing a role. Several cases have held that agencies must consider climate change impacts in NEPA reviews, and a recent historic decision allowed a complaint to proceed alleging constitutional and public trust violations against the federal government for its failure to take aggressive action on climate change. *See Juliana v. United States,* No. 6:15-cv-01517-TC, 2016 WL 6661146 (D. Or. Nov. 10, 2016). There is likely to be an ongoing need for science-informed legal advice as more local, state, and international policy initiatives develop, as the private sector continues investments in low-carbon technologies, as more private and public agreements (mandatory and voluntary) continue to emerge, and as courts are called upon to adjudicate climate change issues.

One of the hottest topics in climate change law concerns identification and public reporting of climate change risks by companies. In 2010, the U.S. Securities and Exchange Commission (SEC) issued climate change risk disclosure guidance and advised companies to evaluate, among other things, the "physical impacts" they may face from climate change, including extreme weather events such as "floods or hurricanes." *See* SEC Commission Guidance Regarding Disclosure Related to Climate Change, 75 Fed. Reg. 6,290, 6,296–97 (Feb. 8, 2010). With respect to some weather events, the SEC is getting ahead of what the science can tell us.

The SEC is now considering whether to revise climate risk reporting rules. SEC Concept Release, 81 Fed. Reg. 23,916 (Apr. 22, 2016). Attorneys that advise policy makers and the regulated community alike can use science to become better advocates, whether to provide a solid foundation for proposed rules or to advocate for better rules through the public comment process.

Lawyers with a solid understanding of climate science will better understand where and how to best advocate for their clients. Although not flawless, science is ultimately the best approach humans have to better understand many problems and should inform debates around potential policy solutions.