Greenhouse gases and their sources pdf

Water vapor and what expert scientists consider the four other ‘most important’ greenhouse gases comprise the veritable ‘hit parade’ of greenhouse gases that trap heat in Earth’s atmosphere and contribute to overall warming across the globe. There’s a whole family of greenhouse gases (GHGs). But an important thing to remember is that they are not all “created equally.” A particularly important distinction among them is their varying Global Warming Potentials (GWPs). Some are much more “efficient” – and that is decidedly not a compliment in this context – at retaining heat energy in the atmosphere, not allowing it to escape. Some are short-lived, while others can easily last decades or longer in the atmosphere. Some GHGs are emitted in vast quantities but, quite fortunately, may not be so voracious or “efficient” as those emitted in far smaller quantities; others have just the opposite qualities – emitted in only trace amounts, but extremely efficient in blanketing the planet’s atmosphere and keeping heat from escaping beyond it. To bring some understandable reason to the family of GHGs, scientists speak in terms of carbon dioxide equivalent – CO2e. That approach in effect makes carbon dioxide, CO2, the prevailing “currency” of greenhouse gases and global warming. Let’s consider the principal GHGs one at a time, starting with water vapor, the most abundant greenhouse gas in the atmosphere according to NOAA’s National Climatic Data Center (NCDC). Water Vapor NCDC explains that changes in the concentration of water vapor result from climate feedbacks related to the warming of the atmosphere and not from activities related to industrialization. The feedback loop in which water is involved is critically important to projecting future climate change, NCDC continues, “but as yet is still fairly poorly measured and understood.” The agency continues: As the temperature of the atmosphere rises, more water is evaporated from ground storage (rivers, oceans, reservoirs, soil). Because the air is warmer, the absolute humidity can be higher (in essence, the air is able to ‘hold’ more water when it’s warmer), leading to more water vapor in the atmosphere. As a greenhouse gas, the higher concentration of water vapor is then able to absorb more thermal infrared energy radiated from the Earth, thus further warming the atmosphere. The warmer atmosphere can then hold more water vapor and so on and so on. This is referred to as a ‘positive feedback loop’. However, huge scientific uncertainty exists in defining the extent and importance of this feedback loop. As water vapor increases in the atmosphere, more of it will eventually also condense into clouds, which are more able to reflect incoming solar radiation (thus allowing less energy to reach the Earth’s surface and heat it up). The future monitoring of atmospheric processes involving water vapor will be critical to fully understand the feedbacks in the climate system leading to global climate change. As yet, though the basics of the hydrological cycle are fairly well understood, we have very little comprehension of the complexity of the feedback loops. Also, while we have good atmospheric measurements of other key greenhouse gases such as carbon dioxide and methane, we have poor measurements of global water vapor, so it is not certain by how much atmospheric concentrations have risen in recent decades or centuries, though satellite measurements, combined with balloon data and some in-situ ground measurements, indicate generally positive trends in global water vapor. Carbon dioxide (CO2) Let’s now consider what federal agency and academic researchers consider to be the “most important greenhouse gases.” Carbon dioxide (not to be confused with carbon monoxide, CO, associated with vehicle tail pipe emissions or with home CO alerts) occurs both naturally and as a result of human activities. It is an inevitable byproduct of the combustion of fossil fuels, such as coal, gasoline, and natural gas. In 2013, CO2 accounted for about 82 percent of all U.S. greenhouse gas emissions from human activities. Citing data from the National Research Council’s 2011 Advancing the Science of Climate Change, the U.S. Environmental Protection Agency (EPA) website reports that “human activities are altering the carbon cycle—both by adding more CO2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO2 from the atmosphere. While CO2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution.” Concentrations of CO2 in the atmosphere have increased by more than one-third since the beginning of the Industrial Age. Projections over coming years see that trend continuing. Long stable in the range of about 280 parts per million (PPM) in the atmosphere, CO2 concentrations currently are more in the range of 400 PPM. The continuing upward trajectory of CO2 concentrations under what is called a “business as usual” scenario is one of the matters of particular concern to climate scientists. It’s not so much the GWP of carbon dioxide that is concerning, but rather the current and projected continued growth in emissions and atmospheric concentrations, and the fact that CO2 is very long-lived – more than a century – in the atmosphere. What we emit today is going to remain in the atmosphere for a very, very long time. Carbon dioxide is, of course, critical to plant growth and to food production, and it’s emitted each time we humans exhale. In the atmosphere, however, it’s a case of too much of a good thing: The science community has known since the research findings of Swedish scientist and Nobel Laureate Svante Arrhenius more than a century ago that humans’ burning of fossil fuels leads to a greenhouse effect caused by the release of CO2. For the science community, that’s “old hat” and widely accepted. For more information see Understanding the Emphasis on CO2 as a Greenhouse Gas. Methane (CH4) Methane, a hydrocarbon gas resulting from both natural causes and as a result of human activities such as agriculture and farming, is an especially potent (read “efficient,” but not as a compliment) GHG and absorber of radiation. Methane is far less abundant than CO2 in the atmosphere and it has a considerably shorter lifespan of 12 years. The National Research Council says that concentrations of methane in the atmosphere, while increasing sharply throughout the 1980s, have since leveled-off somewhat and now stand about two and one-half times their preindustrial levels. Valued for energy production, methane, like CO2, is odorless and colorless – and it has both beneficial and harmful qualities. EPA figures indicate that human activities account for over 60% of total methane emissions, primarily from industry, agriculture and waste management activities. This chart shows methane contributions by various sources: According to the EPA web site, wetlands are the largest natural source of methane, emitting it from bacteria that decompose organic materials in the absence of oxygen. Smaller sources include termites, oceans, sediments, volcanoes and wildfires. EPA reports that methane emissions in the United States decreased by nearly 11 percent between 1990 and 2012, during which time emissions “increased from sources associated with agricultural activities, while emissions decreased from sources associated with the exploration and production of natural gas and petroleum products.” In recent years, some media reports have focused increased attention on the potential for sudden and massive releases of long-bottled-up methane and methane hydrates currently sequestered by frozen tundra. The concern is that melting of the Arctic tundra could lead to potentially catastrophic and abrupt releases of methane. An excellent resource for further understanding this high-visibility issue is a piece in the widely respected peer-reviewed journal Nature by U.S. Geological Survey\Woods Hole scientist Carolyn Ruppel. Quoting her from that report: …some scientists raised the alarm that large quantities of methane (CH4) might be liberated by widespread destabilization of climate-sensitive gas hydrate deposits trapped in marine and permafrost-associated sediments (Bohannon 2008, Krey et al. 2009, Mascarelli 2009). Even if only a fraction of the liberated CH4 were to reach the atmosphere, the potency of CH4 as a greenhouse gas (GHG) and the persistence of its oxidative product (CO2) heightened concerns that gas hydrate dissociation could represent a slow tipping point (Archer et al. 2009) for Earth’s contemporary period of climate change. Noting that methane is about 20 percent more potent a greenhouse gas than CO2 but oxidizes to CO2 after about a decade in the atmosphere, Ruppel writes that “The susceptibility of gas hydrates to warming climate depends on the duration of the warming event, their depth beneath the seafloor or tundra surface, and the amount of warming required to heat sediments to the point of dissociating gas hydrates.” For those wanting to better understand the significance of methane in the whole global warming/climate change discussion, the Nature piece by Ruppel, chief of USGS’s Gas Hydrates Project, provides useful and practical information.   Nitrous oxide (N2O) Nitrous oxide occurs naturally in Earth’s atmosphere as part of the nitrogen cycle. While it is the product of a wide variety of natural sources, human activities – agriculture, fossil fuel combustion, wastewater management and industrial processes – are increasing the atmospheric concentrations, the EPA says. In addition, nitrous oxide molecules in the atmosphere have long life spans – about 120 years before they are removed in a “sink” or destroyed as a result of chemical reactions. A pound of N2O gas has the equivalent warming effect of 300 times that of one pound of carbon dioxide. Based on 2012 data, nitrous dioxide comprises about 6 percent of all U.S. emissions resulting from human activities. Globally, about two-fifths, 40 percent, of nitrous oxide emissions are attributable to human activities. Agriculture, transportation and industry activities are major sources of nitrous oxide emissions, as indicated on this chart: Fluorinated Gases (HFCs, PFCs, SF6) Fluorinated gases are emitted in smaller quantities than the other greenhouse gases, but what they lack in volume they can make up in potency and long lifespans in the atmosphere, ranging from 1-270 years for HFCs to 800-50,000 years for PFCs and about 3,200 years for SF6. Once emitted into the atmosphere, they disperse widely around the globe; they are removed from the atmosphere only by sunlight in the highest levels of the atmosphere. Being the most potent of the GHGs and having the longest lifespans, these gases often are described as the “high global warming potential (GWP) gases.” Aluminum and semiconductor manufacturing processes are among the principal emitters of the fluorinated gases, as illustrated by this chart: References and Resources The Discovery of Global Warming, Spencer R. Weart, 2008, Harvard University Press. The Rough Guide to Climate Change: The Symptoms, The Science, The Solutions, 2011, Robert Henson, Roughguides.com. The Thinking Person’s Guide to Climate Change, 2014, Robert Henson, AMS Books. 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Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia: Report in Brief, 2010, National Academy of Sciences. Skeptical Science.com About the Author Morris A. (Bud) Ward, editor of Yale Climate Connections, is a proven and widely experienced communicator and educator on environmental, energy and climate change issues. He has an extensive publishing history including hundreds of bylined news and analysis articles and authorship or co-authorship of five professional books. He has conducted numerous first-hand workshops for reporters, editors and policy makers on issues involving journalism/communications, climate change and environmental risk. He writes, speaks and teaches regularly on issues related to climate change and on the changing nature of journalism and mass communications in modern society.

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