Greenhouse Gases

In order to start measuring carbon footprints, it is important to understand the underlying principles behind greenhouse gases (GHGs) and the concepts associated with them, such as radiative forcing (RF), global warming potential (GWP) and carbon dioxide equivalent (CO2e). Dictionary.com defines a carbon footprint as, “the amount of carbon dioxide or other carbon compounds emitted into the atmosphere by the activities of an individual, company, country” (Dictionary.com 2017), or more generally in another definition, “The total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO2)” (Time for Change 2017). Thus, a carbon footprint is essentially the total combined GHGs emitted directly or indirectly as a result of a process or thing. GHGs are gases that insulate and warm the earth by absorbing energy from the sun, more specifically infrared radiation, trapping it in the Earth’s atmosphere (EPA 2017). Different GHGs have different radiative efficiencies, their ability to absorb energy, and lifetimes, the time period that they will remain in the atmosphere. The impact of GHGs on the Earth can be described with RF.

Radiative forcing is defined as, “the change in the net vertical irradiance (expressed in Wm-2) at the tropopause due to an internal change or a change in the external forcing of the climate system, such as, for example, a change in the concentration of carbon dioxide or the output of the sun” (IPCC 2017). It can be calculated with the formula: (IPCC 2001). In simpler terms, RF is the difference in amount of energy absorbed and lost by Earth. In the context of GHGs, RF refers to the amount of radiative energy absorbed by a gas, and hence its impact towards the Earth. RF can be positive, which happens when GHGs absorb infrared radiation, causing an increase in the Earth’s energy bucket, resulting in a warming effect. Conversely, negative RF occurs when aerosol particles reflect solar radiation, causing a decrease in the Earth’s energy bucket, leading to a cooling effect. In addition, the RF of a certain gas is determined by different four factors, one of which is atmospheric concentration, which refers to the quantity of the GHG emitted that remains in the atmosphere (CORE 2017). The next factor is the warming/cooling capacity, defined as the strength of the gas in trapping or reflecting heat. (CORE 2017) Another factor is a gas’s residence time in the atmosphere, which describes its lifetime (CORE 2017). The last factor is spatial distribution which refers to how far a GHG spreads geographically (CORE 2017). However, RF is instantaneous and does not account for the impacts of GHGs in the long-term (CORE 2017).

While radiative forcing is used to determine the additional net-difference of energy absorbed by the Earth as a result of GHGs, the global warming potential of a gas is an estimate of how much that given gas contributes to the Earth’s RF. GWP is defined:

An index, describing the radiative characteristics of well-mixed greenhouse gases, that represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation. This index approximates the time-integrated warming effect of a unit mass of a given greenhouse gas in today’s atmosphere, relative to that of carbon dioxide. (ICPP 2017)

Essentially, the GWP of various GHGs are ratios that compare the amount of infrared energy absorbed by 1 ton of a given gas over a period of time (usually 100 years) compared to 1 ton of CO2 (which has a GWP of 1 because it is used as a reference). For example, a GHG with a GWP of 100 would increase the RF by 100 times more than CO2 would (Chamberlin 2008). The key factors that account for GWP include the capacity of a gas to absorb infrared radiation, at what wavelengths does the gas absorbs radiation and how long the gas will remain in the atmosphere (GHG Management Institute 2010). As a result, the GWP of gases may differ depending on how long the gas has been in the atmosphere. For instance, methane (CH4) has a GWP of 56 over 20 years, but drops to 21 when looking at a time span of a 100 years and then to 6.5 at 500 years (UNFCCC 2017). The shift in GWP over time is attributed to the lifetimes of different GHGs and how long they remain in the atmosphere. Overall, GWPs of numerous GHGs are critical to creating a fixed unit of measurement when measuring the carbon footprint of a process or item.

In connection to the GWP, the carbon dioxide equivalent is a standard unit of measuring GHGs based on the GWP. The concept behind CO2e is to express the RF all GHGs as a common unit in terms of CO2 so as to be able to effectively measure the carbon footprint of an item or process within a single number. The formula for finding the CO2e of a given gas is: (GHG Management Institute 2010). To summarize, GHGs result in positive RF, leading to an increase in the Earth’s temperature. The GWP of different GHGs are used to create a standard unit expressed in CO2e, which is used in measuring the carbon footprint of any item or process.

References

"Carbon footprint." Dictionary.com. Accessed April 17, 2017. http://www.dictionary.com/browse/carbon-footprint?s=t.

Climate change 2001 IPCC third assessment report. Geneva: IPCC, 2001.

"GLOSSARY." IPCC - Intergovernmental Panel on Climate Change. Accessed April 17, 2017. https://www.ipcc.ch/publications\_and\_data/publications\_and\_data\_glossary.shtml.

"Radiative Forcing." CORE: Radiative Forcing. Accessed April 17, 2017. http://www.co2offsetresearch.org/aviation/RF.html.

Shaun@darkoptimism.org, Shaun Chamberlin -. "DarkOptimism." Dark Optimism RSS. September 3, 2008. Accessed April 17, 2017. http://www.darkoptimism.org/2008/09/03/the-climate-science-translation-guide/.

"Understanding Global Warming Potentials." EPA. February 14, 2017. Accessed April 17, 2017. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

United Nations Framework Convention on Climate Change. Global Warming Potentials. December 03, 2007. Accessed April 17, 2017. http://unfccc.int/ghg\_data/items/3825.php.

"What is a carbon footprint." Time for change. Accessed April 17, 2017. http://timeforchange.org/what-is-a-carbon-footprint-definition.

"What is a Global Warming Potential? And which one do I use?" GHG and Carbon Accounting, Auditing, Management & Training | Greenhouse Gas Management Institute. June 28, 2010. Accessed April 17, 2017.   
 https://ghginstitute.org/2010/06/28/what-is-a-global-warming-potential/.