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Global Warming: The Enhanced Greenhouse Gas Effect

To understand the Enhanced Greenhouse Gas Effect, you must know the major greenhouse gases and the factors that determine how much influence they have on global warming.

Greenhouse Gases

Greenhouse Gases (GHGs) are gases that "trap heat in the atmosphere and warm the planet."[49] "The main gases responsible for the greenhouse effect include carbon dioxide [CO_2], methane [CH_4], nitrous oxide (N_2O), and water vapor (which all occur naturally), and fluorinated gases [FGs] (which are synthetic)."[50] Three factors determine how much each gas affects global warming:

1. It's concentration in the atmosphere,
2. How long it remains in the atmosphere, and
3. It's warming potential in terms of "the total energy that a gas absorbs over a given period of time (usually 100 years) relative to the emissions of 1 ton of carbon dioxide."[51]

Gas	Concentration (2017)[52]	Warming Potential[53]	Atmospheric Life[54]
CO_2	405.5 $\pm$ 0.1 ppm	1	See Note below
CH_4	1859 $\pm$ 2 ppb	25	~10 yrs
N_2O	329.9 $\pm$ 0.1 ppb	300	~100 yrs
FGs	Up to 550 ppt	1,000s up to 10s of 1,000s	10s of 1,000s yrs

Note: CO_2 is a long-lived GHG: up to 40% remains after 100 years, up to 20% remains after 1,000 years and up to 10% remains after 10,000 years

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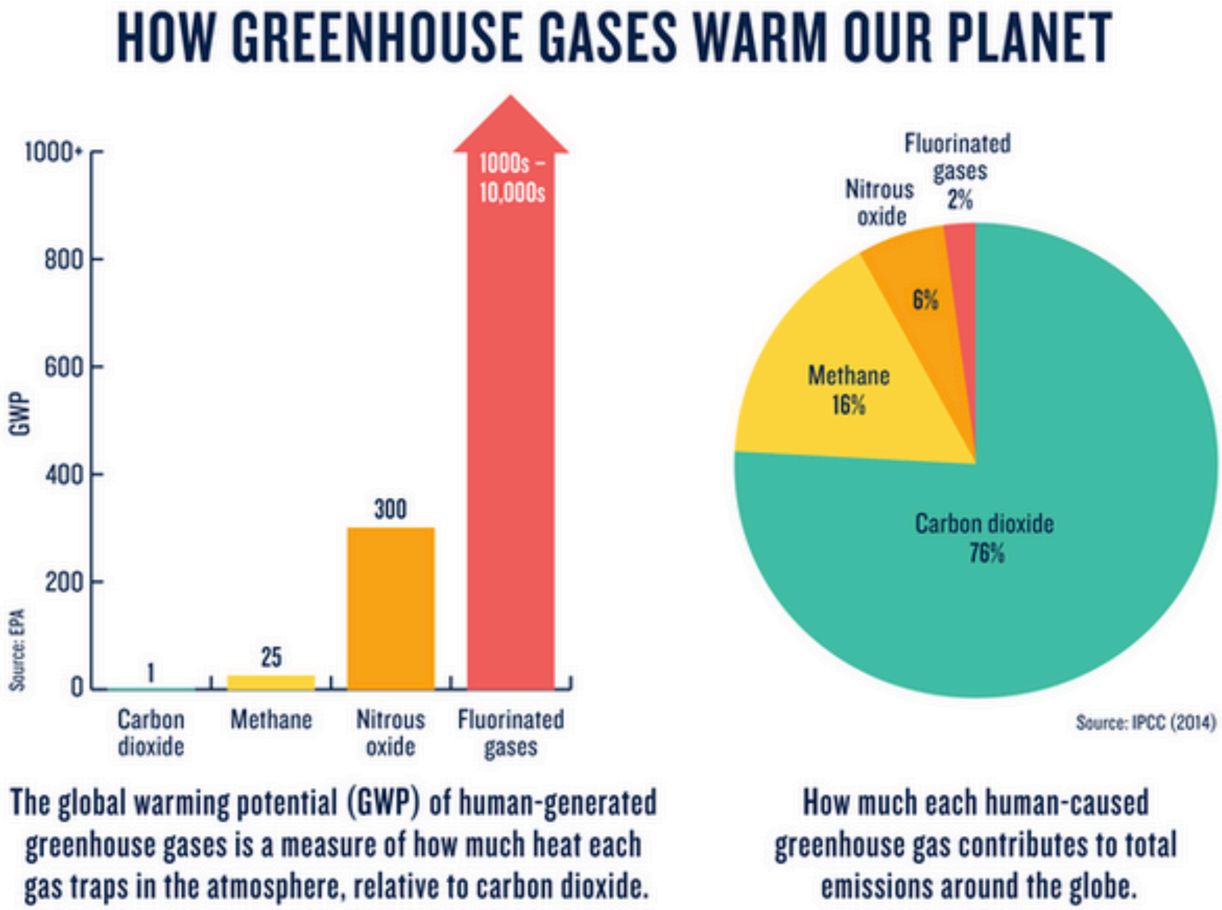
Figure Showing Warming Potential and % of GHG Emissions[55]



Radiative/Climate Forcing & the AGGI

"In accordance with the basic laws of thermodynamics, as Earth absorbs energy from the sun, it must eventually emit an equal amount of energy to space. The difference between incoming and outgoing radiation is known as a planet's radiative forcing (RF)."[56] "[RF] forcing is . . . calculated in units of watts per square meter (W m^{-2})"[57] "When forcings result in incoming energy being greater than outgoing energy, the planet will warm (positive RF). Conversely, if outgoing energy is greater than incoming energy, the planet will cool."[58] Positive and negative RFs are known as climate forcings, and the phenomena that cause climate forcing are known as climate drivers.[59] "Thus climate forcing is a 'change' in the status quo. The Intergovernmental Panel on Climate Change (IPCC) takes the pre-industrial era (chosen as the year 1750) as the baseline."[43]

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"Natural climate drivers include changes in the sun's energy output, regular changes in Earth's orbital cycle, and large volcanic eruptions that put light-reflecting particles into the upper atmosphere. Human-caused, or anthropogenic climate drivers include . . . greenhouse gases . . .. Since 1750, human-caused climate drivers have been increasing, and their effect dominates all natural climate drivers."[61]

The RF "that has the largest magnitude and the least scientific uncertainty is the forcing related to changes in the atmospheric global abundance of long-lived, well mixed greenhouse gases, in particular carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and halogenated compounds (mainly CFCs). Measured global atmospheric abundances of greenhouse gases are used to calculate changes in radiative forcing beginning in 1979 when NOAA's global air sampling network expanded significantly."[62]

In 2006, NOAA introduced the NOAA Annual Greenhouse Gas Index [AGGI] as an alternative way of calculating the warming effects of well mixed greenhouse gases.[63] "The index was designed to enhance the connection between scientists and society by providing a normalized standard that can be easily understood and followed. [It] . . . is defined as the ratio of total direct radiative forcing due to long-lived greenhouse gases for any year for which adequate global measurements exist, to that which was present in 1990 (1990 was chosen because it is the baseline year for the Kyoto Protocol and the publication year of the first IPCC Scientific Assessment of Climate Change)."[64] Below are a graphic and a table that document the increases in the RF's and AGGI's of the well mixed greenhouse gases.

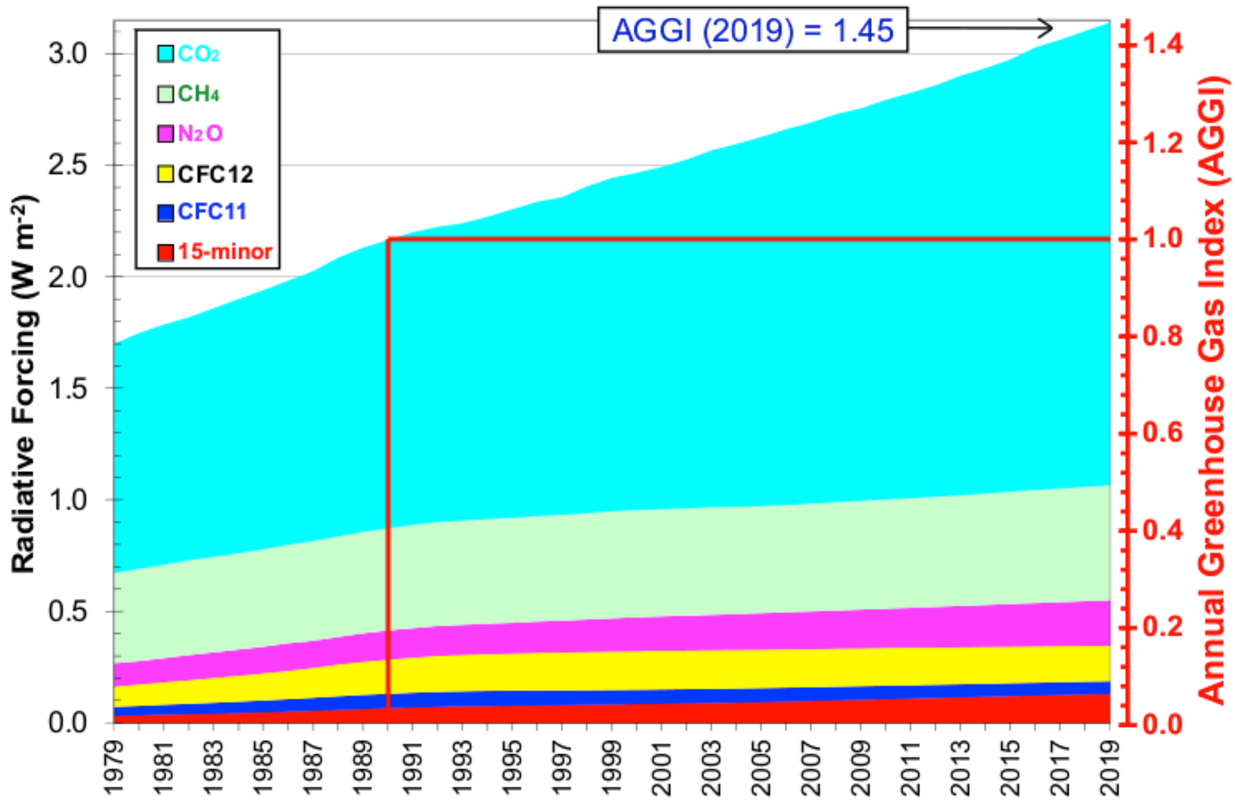

Figure 4. Radiative forcing, relative to 1750, of all the long-lived greenhouse gases. The NOAA Annual Greenhouse Gas Index (AGGI), which is indexed to 1 for the year 1990, is shown on the right axis.[65]

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Table 2. Global Radiative Forcing and the AGGI 1979-2019[66]

Table 2. Global Radiative Forcing, CO2-eq mixing ratio, and the AGGI 1979-2019										
Global Radiative Forcing W m-2								CO2-eq (ppm)	AGGI	
Year	CO2	CH4	N2O	CFC12	CFC11	15-minor	Total	Total	1990 = 1	% change *
1979	1.03	0.406	0.104	0.092	0.04	0.031	1.699	382	0.79	
1980	1.06	0.413	0.104	0.097	0.042	0.034	1.748	385	0.81	2.2
1981	1.08	0.42	0.107	0.102	0.044	0.036	1.786	388	0.83	1.8
1982	1.09	0.426	0.111	0.107	0.046	0.038	1.818	391	0.84	1.5
1983	1.12	0.429	0.113	0.113	0.048	0.041	1.859	394	0.86	1.9
1984	1.14	0.432	0.116	0.118	0.05	0.044	1.9	397	0.88	1.9
1985	1.16	0.437	0.118	0.123	0.053	0.047	1.94	399	0.9	1.9
1986	1.18	0.442	0.121	0.129	0.056	0.049	1.982	403	0.92	1.9
1987	1.21	0.447	0.12	0.135	0.058	0.053	2.025	406	0.94	2
1988	1.25	0.451	0.122	0.143	0.061	0.057	2.085	410	0.96	2.8
1989	1.28	0.455	0.126	0.149	0.063	0.061	2.13	414	0.98	2.1
1990	1.29	0.459	0.129	0.154	0.065	0.065	2.165	417	1	1.6
1991	1.31	0.463	0.131	0.158	0.066	0.069	2.199	419	1.02	1.6
1992	1.32	0.467	0.133	0.162	0.067	0.072	2.224	421	1.03	1.1
1993	1.33	0.467	0.134	0.164	0.067	0.074	2.239	422	1.03	0.7
1994	1.36	0.47	0.135	0.165	0.067	0.076	2.269	425	1.05	1.4
1995	1.38	0.472	0.136	0.168	0.067	0.077	2.303	428	1.06	1.6
1996	1.41	0.473	0.139	0.17	0.066	0.078	2.336	430	1.08	1.5
1997	1.43	0.474	0.142	0.171	0.066	0.079	2.357	432	1.09	1
1998	1.46	0.478	0.144	0.172	0.066	0.08	2.404	436	1.11	2.2
1999	1.5	0.481	0.148	0.173	0.065	0.082	2.443	439	1.13	1.8
2000	1.51	0.481	0.151	0.173	0.065	0.083	2.466	441	1.14	1.1
2001	1.54	0.48	0.153	0.174	0.064	0.085	2.492	443	1.15	1.2
2002	1.56	0.481	0.155	0.174	0.064	0.087	2.525	446	1.17	1.5
2003	1.6	0.483	0.157	0.174	0.063	0.089	2.566	449	1.19	1.9
2004	1.63	0.483	0.159	0.174	0.063	0.09	2.596	452	1.2	1.4
2005	1.66	0.482	0.162	0.173	0.062	0.092	2.626	454	1.21	1.4
2006	1.69	0.482	0.165	0.173	0.062	0.095	2.661	457	1.23	1.6
2007	1.71	0.484	0.167	0.172	0.061	0.098	2.692	460	1.24	1.4
2008	1.74	0.486	0.17	0.171	0.061	0.1	2.728	463	1.26	1.7
2009	1.76	0.489	0.172	0.171	0.06	0.103	2.755	465	1.27	1.2
2010	1.79	0.491	0.175	0.169	0.06	0.106	2.792	469	1.29	1.7
2011	1.82	0.492	0.178	0.169	0.059	0.109	2.824	471	1.31	1.5
2012	1.85	0.494	0.181	0.168	0.059	0.112	2.858	474	1.32	1.5
2013	1.88	0.496	0.183	0.167	0.058	0.114	2.901	478	1.34	2
2014	1.91	0.499	0.187	0.166	0.058	0.117	2.935	481	1.36	1.6
2015	1.94	0.504	0.19	0.165	0.058	0.119	2.974	485	1.37	1.8
2016	1.99	0.507	0.193	0.164	0.057	0.122	3.028	490	1.4	2.5
2017	2.01	0.509	0.195	0.163	0.057	0.124	3.062	493	1.42	1.6
2018	2.04	0.512	0.199	0.162	0.057	0.127	3.101	496	1.43	1.8
2019	2.08	0.516	0.202	0.161	0.057	0.129	3.14	500	1.45	1.8

CO_2 accounts for ~ 2/3rds of total 2019 RF. Since 1979, the total RF has increased ~ 84.8%, the total atmospheric concentration has increased ~30.9%, and the AGGI has increased ~ 83.5%.