THE MATERIALITY OF U.S. CO_2 EMISSIONS ON GLOBAL CLIMATE

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KEY POINTS

- Section 111 of the Clean Air Act requires the EPA to find that emissions of a pollutant from a source category "contributes significantly" to air pollution that endangers the public health.
- Because CO_2 is not directly harmful to humans and only impacts the public health by changing global temperatures, a threshold for significance must be set based on a source category's contribution to global temperature increase.
- The measurement error in the average global surface temperature is approximately ±0.1 °C, so any contribution that is smaller than this "noise" in the data cannot be considered measurable, much less significant.
- At most, future U.S. power plant CO_2 emissions will increase global temperatures by 0.015 °C by 2050, and all U.S. CO_2 emissions will cause a 0.052 °C increase by 2050. Therefore, no source category of U.S. CO_2 emissions currently meets the 0.1 °C threshold to qualify as "contribut[ing] significantly" to global temperatures.

INTRODUCTION

Under Section 111 of the Clean Air Act (42 U.S.C. § 7411), in order for EPA to have the authority to regulate emissions from a category of sources, the agency must find that the emissions of a particular pollutant from that source category "contributes significantly" to air pollution that endangers the public health. This raises the question of what level of air pollution constitutes a significant contribution to dangerous air pollution. Even if the global sum of emissions has an impact, the question of whether any U.S. source category is significantly, or even measurably, contributing to endangerment is what matters within the context of EPA's authority to regulate source categories under Section 111.

Unlike the criteria pollutants regulated under the Clean Air Act, CO_2 is not directly harmful to humans. In fact, it is essential to all life, being an output of the respiration process of all humans and animals and an input to photosynthesis. CO_2 levels would need to reach 20 to 30 times the current concentration in the atmosphere in order to have a negative impact on oxygen levels and respiration. Therefore, the impact of CO_2 on the public health hinges on its effect upon global temperatures and the resulting impacts on global weather and climate.

The question of how the EPA can regulate under the Clean Air Act is a much narrower question than the question of whether the global sum of manmade CO_2 emissions is causing impacts that are endangering the public health. Congress provided in Section 111(b)(1)(A) of the Clean Air Act (42 U.S.C. § 7411) that the emissions from any U.S. source category must "contribute significantly" to air pollution that is causing endangerment in order for EPA to have the authority needed to regulate that source category.

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Under this context, the goal of this white paper is to delineate a sound methodology for assessing whether U.S. power plant emissions are "significantly contributing" to global temperature change. If their contribution to global temperature change is not significant, then their effect on public health cannot be significant, either.

EFFECT OF FUTURE U.S. CO_2 EMISSIONS ON THE WORLDWIDE CO_2 CONCENTRATION AND TEMPERATURE

In 2023, the U.S. contributed 13% to the total worldwide CO_2 emissions from fossil fuels, down from 24% in the year 2000. CO_2 emissions from U.S. fossil fuel-based electricity generation only amounts to about 4% of the worldwide total of CO_2 emissions from fossil fuels, and that proportion is also declining. However, what affects worldwide temperature is not greenhouse gas emissions but the concentration of greenhouse gases in the atmosphere.

Table 1

CO_2 Emissions from Fossil Fuels in the United States and the World in 2023, Million Metric Tons/Year

Territory	CO_2 emissions (million metric tons)	Percentage relative to the worldwide total
United States, electricity	1,421	3.8%
United States, total	4,795	12.7%
World, total	37,819	

Note: Total worldwide CO_2 emissions data from Friedlingstein et al., "Global Carbon Budget 2024," *Earth System Science Data, 17*(3), 965–1039 (https://doi.org/10.5194/essd-2024-519) and *GCB 2024*, Global Carbon Budget, 2025 (https://globalcarbonbudget.org/gcb-2024/). U.S. CO_2 emissions data from *Monthly Energy Review: Carbon Dioxide Emissions From Energy Consumption*, U.S. Energy Information Administration, 2025 https://www.eia.gov/totalenergy/data/monthly/#environment.

To determine the long-term effects of U.S. CO_2 emissions, the Model for the Assessment of Greenhouse Gas Induced Climate Change (Climate Resource, 2021) was used to predict future global CO_2 concentrations and temperatures in a scenario that eliminates U.S. CO_2 emissions. The baseline used in the analysis is the SSP2-4.5 scenario, which is the "middle of the road" scenario among the CO_2 emission scenarios that the Intergovernmental Panel on Climate Change (IPCC) uses in its various assessments.[1] **Table 2** shows the impact of eliminating future U.S. CO_2 emissions and future U.S. power sector CO_2 emissions on the total worldwide CO_2 emissions.

1 The numbers in the table are based on the assumption that the U.S. share of worldwide CO_2 emissions remains constant through the end of the century at about 13%, which is a conservative assumption given that the U.S. share has been declining consistently for the past 25 years.

Table 2

Projected CO_2 Emissions from Fossil Fuels in the United States and the World, Million Metric Tons/Year

CO_2 Emissions (MMT CO_2)	2030	2040	2050	2060	2070	2080	2090	2100
SSP2-4.5	40,595	42,089	42,961	41,736	37,447	30,236	20,642	14,483
Minus U.S. electricity	1,504	1,560	1,592	1,546	1,388	1,120	765	537
New global emissions	39,091	40,529	41,369	40,190	36,059	29,115	19,877	13,946
Minus U.S. emissions	5,076	5,263	5,372	5,219	4,682	3,781	2,581	1,811
New global emissions	35,519	36,826	37,589	36,518	32,764	26,455	18,061	12,672

Note: SSP2-4.5 emissions data and modeling environment from *Model for the Assessment of Greenhouse Gas Induced Climate Change*, Climate Resource, 2021 (https://live.magicc.org). U.S. CO_2 emissions data from *Monthly Energy Review: Carbon Dioxide Emissions From Energy Consumption*, U.S. Energy Information Administration, 2025 https://www.eia.gov/totalenergy/data/monthly/#environment

Taking the values of **Table 2** as inputs, MAGICC then interpolates between the 10-year data points to produce new CO_2 emission profiles. Using these CO_2 emission profiles, MAGICC runs the new CO_2 emission scenarios through a reduced-form climate model to approximate future CO_2 concentrations and worldwide temperatures. **Table 3** shows the model outputs for the worldwide CO_2 concentrations in 2030, 2040, and 2050, and the worldwide temperature change relative to the preindustrial baseline if the U.S. were to eliminate CO_2 emissions by 2030.[2]

Table 3

Predicted CO_2 Concentrations and Change in Worldwide Temperatures in 2030, 2040, 2050, with No U.S. CO_2 Emissions Beginning in 2030

	Net zero CO_2 emissions by 2030	CO_2 concentration (ppm)	Percentage difference	Temperature difference (°C) relative to the 19th century baseline	Temperature difference (°C) relative to SSP2-4.5
2030	SSP2-4.5	440.9		1.435	
	No U.S. Electricity	440.2	0.16%	1.432	0.002
	No U.S. Emissions	438.4	0.55%	1.427	0.008
2040	SSP2-4.5	469.9		1.694	
	No U.S. Electricity	467.8	0.45%	1.685	0.009
	No U.S. Emissions	462.8	1.52%	1.664	0.030
2050	SSP2-4.5	498.8		1.948	
	No U.S. Electricity	495.4	0.68%	1.933	0.015
	No U.S. Emissions	487.4	2.29%	1.896	0.052

Note: Modeling results derived from *Model for the Assessment of Greenhouse Gas Induced Climate Change*, Climate Resource, 2021 (https://live.magicc.org).

Based on the predictions shown in **Table 3**, eliminating U.S. power sector CO_2 emissions by 2030 would reduce the worldwide CO_2 concentrations in 2050 by 3.4 ppm, or 0.7%, and reduce the increase in mean worldwide surface temperature in 2050 by 0.015 °C. On the other hand, eliminating all U.S. CO_2 emissions by 2030 would reduce worldwide CO_2 concentrations in 2050 by 11.4 ppm, or 2.3%, and reduce the increase in mean worldwide

2 Because the model uses decadal data inputs, it is not possible to model the impact of immediately eliminating U.S. CO_2 emissions in 2025. The earliest the model can accommodate is 2030. Because of the long timescale of the model, this 5-year delay does not materially impact the model output in 2050.

temperature in 2050 by 0.052 °C. Note that the measurement error and annual variation in the mean worldwide surface temperature is approximately ±0.1 °C (Morice et al., 2020). Therefore, the modeled temperature increase due to future U.S. CO_2 emissions—which is itself subject to large uncertainties—is not measurable in the worldwide context, as the modeled impact falls within the measurement error for global temperatures.

EFFECTS OF MODEL BIAS ON FUTURE WORLDWIDE TEMPERATURE ESTIMATES

The direct warming impact of CO_2 emissions is a function of the radiative transfer impact of CO_2 molecules in the atmosphere—that is, the amount of infrared radiation that CO_2 molecules "trap" in the atmosphere. Van Wijngaarden and Happer (2019, p. 46) estimate that a doubling of CO_2 concentration from 400 to 800 ppm would result in surface warming of about 1.3 °C in the absence of any climate feedbacks. This estimate of climate sensitivity is less than half of the IPPC's midrange estimate of 3.0 °C (IPCC, p. 94). This discrepancy suggests that assumptions about feedback mechanisms built into the model (most notably the assumed increase in atmospheric water vapor as temperatures increase) are responsible for more than doubling the direct warming effect of CO_2 in models like MAGICC.

Lindzen et al. (2024, p. 5) developed a formula to approximate the impact of reducing CO_2 emissions. More details regarding this formula are provided in **Appendix A**. Based on the formula, the temperature impact of reducing CO_2 emissions scales linearly with the value of the equilibrium climate sensitivity (i.e., the temperature change due to the doubling of the atmospheric CO_2 concentration from 400 to 800 ppm after the climate reaches equilibrium). Therefore, the direct warming impact of any reduction in CO_2 emissions can be approximated by scaling down the climate sensitivity.

The challenge with scaling the MAGICC model output to estimate the "feedback-free" warming is that the model never reaches an equilibrium state as is assumed by the formula from Lindzen et al (2024, p. 5). However, a conservative assumption is that if the modeled warming impact of U.S. power sector CO_2 emissions is only 0.015 °C by 2050 (see **Table 3**), then the direct warming impact of these CO_2 emissions would be less than 0.007 °C. This change is not even measurable in the worldwide context, as it is only 7% of the measurement error of ±0.1 °C and the annual variation in worldwide surface temperature.

CONCLUSION

To determine the impact of a source category of CO_2 emissions on the public health, it is necessary to estimate the impact of those emissions on worldwide temperatures. CO_2 itself, unlike the criteria pollutants covered under the Clean Air Act, is not harmful to human health. Only its warming impact may cause harm. Therefore, devising a measure of significance based on the quantity of emissions from a source category or on the contribution of that source category to global CO_2 concentrations is not sufficient. The only question that matters is, do those emissions "contribute significantly" to global temperature change, and does that change measurably impact the public health?

Within this context, for a source category of CO_2 emissions to be "significant," it must at a minimum be larger than the measurement error and annual variation in the mean worldwide surface temperature, which is approximately ±0.1 °C. Under this criterion, the CO_2 emissions from the U.S. power sector do not "contribute significantly" to worldwide temperature change and to harming public health because the direct warming impact of these CO_2 emissions would be less than 0.007 °C, which is tiny fraction (only 7%) of the referenced measurement error and annual temperature variation of ±0.1 °C. ■

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APPENDIX A: LINEAR FORMULA FOR ESTIMATING TEMPERATURE CHANGE FROM REDUCING CO_2 EMISSIONS

The equation developed by Lindzen et al. (2024, p. 5) to approximate the effects of reducing CO_2 emissions on the temperature for any assumed value of climate sensitivity is:

$$\delta T \approx \frac{S f_0 R(2\Delta t - \Delta t_{US})}{2\ln(2)(C_0 + R\Delta t)}$$

In the equation above, S is the equilibrium climate sensitivity, f_0 is the fraction of worldwide CO_2 emissions being reduced, C_0 is the current worldwide CO_2 concentration, R is the rate of increase in worldwide CO_2 concentration, Δt is number of years from the present to the year of interest (e.g., from 2025 to 2050, which is 25 years), and Δt_{US} is the number of years from the present to the year where zero CO_2 emissions are achieved (e.g., from 2025 to 2030, which is 5 years).

Assuming that f_0 = 12.7% for the entire U.S., C_0 = 425 ppm, R = 2.5 ppm/year, Δt = 25 years, and Δt_{US} = 5 years, and using a climate sensitivity of 3.0 °C, which is the midpoint of the IPCC's estimated range, gives a temperature difference of 0.063 °C by 2500 if all U.S. CO_2 emissions were eliminated by 2030. A climate sensitivity of 1.3 °C, which assumes the direct warming from CO_2 without feedback, gives a temperature difference of 0.027 °C by 2050. Eliminating only U.S. CO_2 emissions from electricity generation, which are 3.8% of worldwide CO_2 emissions (f_0 = 0.038), would prevent a worldwide temperature increase of 0.019 °C by 2050 at a climate sensitivity of 3.0 °C and 0.008 °C by 2050 at a climate sensitivity of 1.3 °C.

The temperature change estimates using a climate sensitivity of 3.0 °C roughly correspond to the predicted values from MAGICC. However, going out to the year 2100, the equation from Lindzen et al. predicts temperature changes that are roughly 50% higher than what the MAGICC model predicts. This discrepancy may be due to the fact that MAGICC does not assume that the climate reaches equilibrium at any given end date, while the equation from Lindzen et al. is based on the *equilibrium* climate sensitivity, i.e., the climate is assumed to have reached equilibrium by the end date. Therefore, Lindzen et al. tends to produce a higher estimate of temperature changes.

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As part of the Life:Powered team, Dr. Bennett regularly speaks with policymakers, energy experts, and industry associations across the country. He is responsible for researching, fact-checking, and spearheading many of the team's policy and regulatory initiatives. He has written extensively on how America has improved its environment while growing its energy use and on future energy technologies.

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