

Gases from Asthma Inhalers Cause Negligible Warming

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Abstract

Various educational and medical institutions, as well as policymakers, have expressed concerns regarding the use of metered-dose inhalers to prevent or treat shortness of breath associated with asthma and chronic obstructive pulmonary disease (COPD), as these inhalers use hydrofluorocarbons (HFCs), which are greenhouse gases, as propellants. In response, “environmentally friendly” alternatives to metered-dose inhalers have been proposed for patients with asthma. To determine if prescribing these alternatives is necessary, we used the concentration and radiative forcing of the HFCs that are used as propellants (HFC-134a and HFC-227ea) in current inhalers to predict the temperature rise caused by the continued emissions of these HFCs into the atmosphere. Based on our estimates, the continued emissions of these HFCs would cause a combined temperature increase of about 0.0132 °C in 50 years and of about 0.0264 °C in 100 years. Such a rise in temperature is negligible and cannot be measured or felt. Therefore, curbing the emissions of HFCs from inhalers is unnecessary and would have minimal effect on the climate. Given this conclusion, the selection of inhalers to prescribe to patients with asthma or COPD should be based on the health, safety and needs of the patients, rather than on a purported environmental benefit.

Details

Various educational institutions have raised alarms regarding the greenhouse gases released by inhalers for preventing or treating shortness of breath associated with asthma and chronic obstructive pulmonary disease (COPD). For instance, Stanford University stated:

“Today, there are three main types of inhalers: metered-dose inhalers, which use a propellant gas to push medication powerfully into the lungs; dry-powder inhalers that contain doses of medicine in particle form that must be breathed deeply in; or soft-mist inhalers that turn liquid medication into a mist ... researchers showed that metered-dose inhalers emit high levels of hydrofluorocarbon propellants, which are thousands of times better at trapping heat in the atmosphere than carbon dioxide and are a key player in accelerating global warming. In part because of that data, the National Health Service of England ... as well as policymakers ... have encouraged clinicians to switch to dry-powder and soft-mist inhalers.” (Stanford University, 2024)

In fact, the United Kingdom National Health Service listed the global warming potentials (GWPs) of the hydrofluorocarbons (HFCs) HFC-134a (a propellant used in most current inhalers) and HFC-227ea (a propellant used in some current inhalers) as 1,300 and 3,350, respectively, where the GWPs represent “how powerful [a] greenhouse gas is relative to CO₂,” with the GWP of carbon dioxide (CO₂) being equal to one (Wilkinson and Woodcock, 2022). However, Slingo and Slingo (2021, 2024) noted that the GWP is not an appropriate metric for comparing the warming caused by greenhouse gases. When the GWP is used to compare the potency of greenhouse gases, the GWP assumes that these greenhouse gases are of the same mass and are present within the same time frame. Since greenhouse gases are present in the atmosphere at different concentrations (i.e., in different amounts) and with different atmospheric lifetimes, the above assumption is not valid.

To overcome the drawbacks of GWPs, Slingo and Slingo (2021, 2024) recommended the combination of the radiative forcing (which quantifies the solar heat being retained by the atmosphere, de Lange et al., 2022) and the concentration of the greenhouse gases to compare the warming caused by different greenhouse gases.

Table 1: The predicted temperature increases due to the increasing presence of hydrofluorocarbons (HFCs) in the atmosphere at the current rates of concentration increase (dC/dt).

Hydrofluorocarbon (HFC)	Temperature Increase (°C)	
	50 Years	100 Years
HFC-134a	0.0130	0.0260
HFC-227ea	0.000191	0.000382
Total	0.0132	0.0264

Therefore, the radiative forcing and the concentration of the propellants HFC-134a and HFC-227ea that are used in inhalers will be used to estimate the warming caused by these HFCs. Based on our estimates, the combined warming caused by these HFCs is in the order of a hundredth degree Celsius (°C), which would be too small to feel or measure, as shown in Table 1. The estimated

temperature increase shown in Table 1 is the key message from this manuscript. Readers who are interested in additional details, including those regarding the physics of global warming, may wish to continue with the discussion below, where additional metrics are provided in Table 2. The details, as well as the method of calculation, that are outlined below were taken from Soepyan et al. (2024).

At most locations on Earth, increasing concentrations of greenhouse gases, with no other changes of atmospheric properties (e.g., the altitude dependence of temperature, humidity and cloudiness), decreases the flux of thermal radiation to outer space. The magnitude, dF , of the decrease of infrared flux to space represents the forcing increment. Forcings are usually measured in Watts per square meter (W m^{-2}) at a particular altitude. We will consider the forcing at the top of the atmosphere, about 100 kilometers (km) above the surface, where most thermal radiation escapes freely to space.

An appropriate average of the thermal flux to space must equal the average solar heating of the Earth. If the outward thermal radiation flux to space decreases due to an increase of some greenhouse gas but the solar heating flux remains the same, the Earth will absorb more energy from sunlight than it can release by thermal radiation to space. The Earth will begin to warm as solar heat accumulates, mainly in the oceans, with their vast heat capacity, but also in the atmosphere and land.

The thermal emission of radiation from Earth to space increases rapidly with increases of the absolute temperature T . There is no single temperature of Earth. Earth is warmer near the equator and cooler near the poles. The temperature is cooler at nights and at higher altitudes, such as at mountain resorts. However, it is customary to characterize the Earth with an average temperature, T , which represents the average surface temperature. The warming of Earth due to forcing stops when the temperature increase, dT , is large enough to restore the original flux to space. The temperature increment dT is proportional to the forcing increment dF :

$$dT = \lambda dF. \quad (1)$$

Multiple values of the observational measurements of the sensitivity parameter λ of Equation (1) have been reported. For instance, it is very difficult to determine how much of the observed warming of the past two centuries has come from human emissions of greenhouse gases and how much has been a natural recovery from the Little Ice Age (de Lange et al., 2022).

A first-principle estimate of λ can be made by noting that the flux Z of thermal radiation to space is given very nearly by the Stefan-Boltzmann law:

$$Z = \varepsilon \sigma T^4. \quad (2)$$

Satellites observations show that the thermal emissivity ε of Earth is approximately:

$$\varepsilon = 0.7. \quad (3)$$

The Stefan-Boltzmann constant of Equation (2) is:

$$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}. \quad (4)$$

Adding greenhouse gases at constant temperature decreases the emissivity ε of the Earth, $\varepsilon \rightarrow \varepsilon + d\varepsilon$, where $d\varepsilon < 0$. But as discussed above, if the solar heating does not change, the temperature increases, i.e., $dT > 0$, to balance the decrease of emissivity. To keep the thermal radiative flux Z of Equation (2) constant, elementary calculus shows that we must have:

$$dZ = d\varepsilon \sigma T^4 + 4 \varepsilon \sigma T^3 dT = -dF + 4 \varepsilon \sigma T^3 dT = 0. \quad (5)$$

Based on Equation (5), the coefficient λ of Equation (1) becomes:

$$\lambda = \frac{dT}{dF} = \frac{1}{4 \varepsilon \sigma T^3} = 0.233 \text{ K m}^2 \text{ W}^{-1}. \quad (6)$$

We derived a somewhat smaller estimate, based on de Lange et al. (2022) and the observed warming over the past two centuries, where we assumed a value of one for the emissivity ε (instead of 0.7) and a temperature of 288.7 K (instead of 300 K):

$$\lambda = 0.177 \text{ K m}^2 \text{ W}^{-1}. \quad (7)$$

The forcing, dF , can be quantified using the well-established physics of radiation transfer. One finds that doubling the atmospheric CO₂ concentration would give a forcing of $dF = 3 \text{ W m}^{-2}$ at the top of the atmosphere (Happer et al., 2023). According to the Intergovernmental Panel on Climate Change (IPCC) (Forster et al., 2021), this will cause a warming dT that is between $dT = 1.5 \text{ K}$ and $dT = 4.5 \text{ K}$. In other words, the IPCC limits on λ are approximately:

$$\lambda > \frac{dT}{dF} = \frac{1.5 \text{ K}}{3 \text{ W m}^{-2}} = 0.5 \text{ K m}^2 \text{ W}^{-1} \quad (8)$$

and

$$\lambda < \frac{dT}{dF} = \frac{4.5 \text{ K}}{3 \text{ W m}^{-2}} = 0.9 \text{ K m}^2 \text{ W}^{-1}. \quad (9)$$

The IPCC estimates of Equations (8) and (9) are 2 to 5 times larger than the more plausible estimates of Equations (6) and (7). The reason is the large positive feedbacks built into the IPCC “general circulation models” to approximate how the climate responds to radiative forcing. However, a major point of this paper is that no matter which of the previous values of λ are assumed, i.e., Equations (6) to (9), the projected warming caused by the release of the hydrofluorocarbons (HFCs) that are used as propellants in inhalers will be trivially small.

As mentioned by Slingo and Slingo (2021, 2024), for reliable calculations of warming, it is best to ignore GWPs and compare the radiative forcings from different greenhouse gases. It is help to describe the forcings in terms of the forcing power per molecule (P). For reasons of basic physics and chemistry, the forcing power per molecule cannot exceed about 10^{-20} W for sufficiently small molecular concentrations. But P can be orders of magnitude smaller when there are enough higher-altitude molecules to block the escape of radiation from lower-altitude molecules to outer space. This well-known suppression of greenhouse gas forcing with increasing concentration is known as *saturation* (Happer et al., 2023).

Molecules emit and absorb thermal radiation because of their thermally fluctuating electric dipole moments. These act like tiny transmission and receiving antennas for thermal radiation. When a greenhouse gas molecule absorbs radiation, it uses the absorbed energy to heat the air. Conversely, a greenhouse gas molecule can convert heat from air molecules into emitted radiation. This cools the air.

To determine the forcing power per molecule, P , we note that the column density of air molecules, i.e., the number of molecules above a square meter of cross section of Earth's surface, is approximately:

$$N = 2.15 \times 10^{29} \text{ m}^{-2}. \quad (10)$$

If the forcing power per molecule is P , then the increase in forcing dF , produced by an increase dC of the fractional concentration of a greenhouse gas molecule, will be:

$$dF = N P dC. \quad (11)$$

Solving Equation (11), we find that the forcing power per greenhouse gas molecule becomes:

$$P = \frac{(dF/dC)}{N}. \quad (12)$$

Applying Equation (12) to the HFCs of interest, HFC-227ea has a radiative forcing of $dF = 0.313 \text{ W m}^{-2}$ for a concentration increment of $dC = 10^{-9}$ (one part per billion, ppb), where these values were obtained from Table 2 of Gohar et al. (2004) for the case of a clear, cloud-free sky. Using these numbers in Equation (12) yields the value of $P = 1.456 \times 10^{-21} \text{ W}$ shown in Table 2. As for HFC-134a, the radiative forcing was reported as 0.0275 W m^{-2} in Table 2 of van Wijngaarden and Happer (2023) for the case of a clear, cloud-free sky at the tropopause (altitude of 11 kilometers, km). Given that the atmospheric concentration of HFC-134a was 114 parts per trillion (ppt) in 2020, and that its atmospheric concentration was zero before the Industrial Revolution, the above value of 0.0275 W m^{-2} was divided by the concentration increment of $dC = 114 \text{ ppt}$, which is equivalent to $dC = 1.14 \times 10^{-10}$, to arrive at the value of the radiative forcing of $dF = 0.241 \text{ W m}^{-2}$ for a concentration increment of $dC = 10^{-9}$. Using these quantities in Equation (12) yields the value of $P = 1.122 \times 10^{-21} \text{ W}$ shown in Table 2.

The rate of temperature increase, dT/dt , with respect to time t , was derived using Equations (1) and (11):

$$\frac{dT}{dt} = \lambda \frac{dF}{dt} = \lambda N P \frac{dC}{dt}. \quad (13)$$

The concentrations C of HFC-134a and HFC-227ea in 2020 and 2010 are listed in the second column of Table 2 (van Wijngaarden and Happer, 2023; Vollmer et al., 2011). The increase in the concentration of HFC-134a was reported as 6.1 ppt y^{-1} by van Wijngaarden and Happer (2023), while the increase in the concentration of HFC-227ea in 2010 was reported as 0.069 ppt y^{-1} by Vollmer et al. (2011). These numbers are shown in the third column of Table 2. Estimates of the doubling time of these gases, obtained by dividing C by dC/dt , are $t_2 = 18.7$ years for HFC-134a and $t_2 = 8.39$ years for HFC-227ea, which are listed in the fourth column of Table 2. The last column of Table 2 shows the temperature increase per year, dT/dt , which is computed using

Equation (13), as well as the numbers for P and dC/dt in the earlier columns and the sensitivity parameter λ of Equation (7).

The rates of temperature increase caused by the increase in the atmospheric concentrations of HFC-134a and HFC-227ea are absurdly small, in the order of a ten thousandth of a degree Celsius per year or smaller. Table 1 shows the warming that would result if these rates of temperature increase remained constant for 50 years and for 100 years. The projected temperature increases are immeasurably small.

Table 2: Estimates of the warming from the hydrofluorocarbons (HFCs), listed in the first column. The second column shows the atmospheric concentrations C . The third column is the estimated rate of growth dC/dt of the concentrations. The fourth column is the approximate time needed for the concentrations to double. The fifth column is the forcing power per molecule P , obtained using Equation (12). The sixth column lists the rate of increase of radiation forcing, $dF/dt = N P dC/dt$, in accordance with Equation (11) and the numbers from the previous columns. The last column is the estimated warming rate, dT/dt , of Equation (13).

Hydrofluorocarbon (HFC)	C	dC/dt	t_2	P	dF/dt	dT/dt
	ppt	ppt y ⁻¹	y	10 ⁻²¹ W	mW m ⁻² y ⁻¹	°C y ⁻¹
HFC-134a	114 ^a	6.1 ^a	18.7	1.122	1.47	0.000260
HFC-227ea	0.579 ^b	0.069 ^b	8.39	1.456	0.0216	0.00000382

^a For the year 2020
^b For the year 2010

°C = degree Celsius
m = meter
mW = milliwatt, 1 mW = 10⁻³ W
ppt = parts per trillion, 10¹² ppt = 1
W = Watt
y = year

Conclusion

Based on the tiny amount of forecasted warming from the hydrofluorocarbons (HFCs) HFC-134a and HFC-227ea that are used as propellants for inhalers for preventing or treating shortness of breath associated with asthma and COPD, any measures for curbing the emissions of these gases into the atmosphere are unnecessary and serve no useful environmental purpose. The selection of the propellants, and in turn, the inhalers, for patients with asthma or COPD should be based on both the health, safety and needs of the patients, rather than on a purported environmental benefit.

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