# Chill Out: AC Refrigerants Cause Negligible Warming

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## ABSTRACT

The refrigerant R-410A, which has been used in heating, ventilation, and air conditioning (HVAC) systems since 2010, is in the process of being phased out due to the American Innovation and Manufacturing (AIM) Act of 2020 and the regulation passed by the Biden Administration's United States Environmental Protection Agency (U.S. EPA). The purported warming caused by the hydrofluorocarbons (HFCs) that comprise the refrigerant R-410A was cited as the reason behind this move. As a result, the refrigerant R-410A was to be replaced with more "environmentally friendly," but at the same time, more flammable and more expensive, alternatives.

To determine if such a move is necessary, the concentration and radiative forcing of the above-mentioned HFCs were used to predict the temperature rise caused by the continued emission of the current refrigerant. Based on our estimates, the continued emission of R-410A into the atmosphere would cause a temperature increase of about 0.044 °C in 100 years. Such a rise in temperature is negligible and cannot be measured or felt.

Moreover, the proposed replacements for the refrigerant R-410A also contain greenhouse gases with lower, but still very high global warming potential. These replacement refrigerants are expected to cause a warming of about 0.013 °C in 100 years. This means that the net warming averted by the switch is an incredibly small 0.03 °C in 100 years.

Therefore, curbing the emissions of refrigerants into the atmosphere is unnecessary and would have minimal effect on the climate, while at the same time, would increase the cost and fire risk for consumers. Given this conclusion, the selection of refrigerants for air conditioning systems should be based on the safety and the needs of the consumers, rather than on a purported environmental benefit.

## INTRODUCTION

The refrigerant R-410A has been "one of the most used refrigerants"(1) and has been used in heating, ventilation, and air conditioning (HVAC) systems since 2010.(2,3,4) The refrigerant R-410A proved to be advantageous compared to its predecessor, R-22, as not only is R-410A cheaper and not flammable, but using R-410A, instead of R-22, allows the HVAC system to work more efficiently, and R-410A does not damage Earth's ozone layer, as was alleged for R-22.

But despite these advantages, the refrigerant R-410A may also be phased out due to the American Innovation and Manufacturing (AIM) Act of 2020(5) and the regulation passed by the Biden Administration's United States Environmental Protection Agency (U.S. EPA), which claimed that hydrofluorocarbons (HFCs) that comprise refrigerants have significant warming effects on the climate:

> *"Hydrofluorocarbons (HFCs) are potent greenhouse gases developed and manufactured as replacements for ozone-depleting substances … They can have impacts on the climate hundreds to thousands of times greater than the same amount of carbon dioxide ($CO_2$). The impact is measured by the global warming potential (GWP) of a substance; one kilogram of a greenhouse gas with a GWP of 700 has an impact on the climate that is 700 times stronger than one kilogram of $CO_2$, which has a GWP of 1."*[6]

In response, the U.S. EPA under the Biden Administration mandated an 85% "phasedown" of HFCs by 2036.[7] Such a "phasedown" involved specifying allowances for the production and use of HFCs. Starting on January 1, 2025, restrictions were to take effect on the use of HFCs with high global warming potential for aerosols, foams and refrigeration, air conditioning, and heat pump equipment.[6]

Because the current refrigerant (R-410A) used by HVAC systems consists of 50% HFC-32 ($CH_2F_2$) and 50% HFC-125 ($C_2HF_5$),[8,9] and has a global warming potential of 2,088, which is considered extremely high, this refrigerant is being phased out.[2,10] Instead, more "environmentally friendly" and "sustainable" refrigerants were to be used, including R-454B and R-32, both of which also have high global warming potentials of 466 and 675, respectively.

The replacement refrigerant R-32 consists of the chemical $CH_2F_2$ (HFC-32).[11] The other replacement refrigerant, R-454B, is a mixture of about 69% R-32 (HFC-32) and 31% R-1234yf (which consists of the hydrofluoroolefin, i.e., HFO, HFO-1234yf, or $CF_3CFCH_2$).[12,13,14]

The transition from the current refrigerant (R-410A) to its replacements (R-454B and R-32) comes with major drawbacks in terms of safety and cost. For starters, while the current refrigerant has "no flame propagation," the proposed replacements are "mildly flammable".[10] This transition would mean that homes and businesses with HVAC systems that use the new refrigerants have greater fire risks, and the necessary additional precautions taken during the installation would result in higher bills.[15] Furthermore, a shortage in the replacement refrigerant R-454B due to high demand has resulted in soaring prices, further punishing homeowners and businesses.[5,15]

Given this situation, the question now becomes: Does the current refrigerant R-410A really cause dangerous warming to the point that we must sacrifice safety and pay more to install new HVAC systems?

To answer this question, we crunched the numbers.

## METHODS

Given that the global warming potential has been used as a metric to justify the phasing down of the refrigerant R-410A, it is worth mentioning that the global warming potential is not an appropriate quantity to use for estimating the warming caused by greenhouse gases.(16,17) For instance, the global warming potential quantifies the warming caused by the release of 1 kilogram (kg) (about 2.2 pounds) of a greenhouse gas over a specified time period relative to carbon dioxide ($CO_2$). However, given that greenhouse gases exist in the atmosphere in different amounts, using the global warming potential to compare the warming caused by these greenhouse gases makes for a misleading comparison. In addition, the global warming potential does not consider the atmospheric lifetimes of the greenhouse gases. Nor does the global warming potential account for feedback (i.e., warming amplification or diminishment) from the most abundant and dominant greenhouse gas in Earth's atmosphere by far: water.(18)

Given the shortcomings of the global warming potential, the combination of the radiative forcing (which quantifies the solar heat being retained by a greenhouse gas)(19) and concentration of each greenhouse gas have been recommended as the more reliable quantities for estimating the warming caused by each greenhouse gas.(16,17) Therefore, these metrics will be used to estimate and compare the feedback-free warming caused by the emissions of the chemicals that comprise the refrigerants R-410A (HFC-32 and HFC-125), R-454B (HFC-32 and HFO-1234yf), and R-32 (HFC-32). In addition, the water feedback will be considered, and it will be shown to be almost certainly negative, i.e., almost certainly *diminishes* the warming caused by the chemicals comprising the above-mentioned refrigerants.

The feedback-free warming caused by the emissions of the chemicals that comprise the refrigerants can be estimated by using the following equation:(20)

$$\Delta T = \lambda \Delta F. \tag{1}$$

In this equation, $\Delta F$ denotes the change in radiative forcing of each greenhouse gas over time, $\Delta T$ is the temperature increase associated with the change in radiative forcing over time, and $\lambda$ represents the climate sensitivity parameter, which quantifies the response of the worldwide mean surface temperature to the radiative forcing.

Unfortunately, no agreement has been reached regarding the value of the climate sensitivity parameter $\lambda$ in equation (1). For instance, de Lange et al.(19) estimated a value of 0.18 °C $m^2$ $W^{-1}$ for the climate sensitivity parameter through the incorporation of the change in the radiative forcing of greenhouse gases due to the change in altitude (where the atmosphere becomes thinner at increasing altitude), the annual change in the concentrations of the greenhouse gases, and the estimated temperature increase due to greenhouse gases. But if the temperature increase due to greenhouse gases is assumed to be uniform, regardless of altitude, the estimated value of the climate sensitivity parameter becomes 0.26 °C $m^2$ $W^{-1}$.(19,21,22) On the other hand, Soepyan et al.(23) estimated a value of 0.23 °C $m^2$ $W^{-1}$ for the climate sensitivity parameter, based on the Stefan-Boltzmann law, the thermal emissivity of Earth (from satellite observations), and the effects of increasing greenhouse gases on Earth's emissivity and temperature. Meanwhile, the Intergovernmental Panel on Climate Change (IPCC) described the climate sensitivity parameter as “a nearly invariant parameter … for a variety of radiative forcings,” with a typical value of about 0.5 °C $m^2$ $W^{-1}$.[20]

Given these variations in the value of the climate sensitivity parameter $\lambda$, we have opted to use the value of 0.5 °C $m^2$ $W^{-1}$ suggested by the IPCC to provide a conservative estimate.

## RESULTS AND DISCUSSIONS

The calculations for the estimates of the feedback-free warming caused by the emissions of the chemicals that comprise the refrigerants R-410A (HFC-32 and HFC-125), R-32 (HFC-32), and R-454B (HFC-32 and HFO-1234yf) are summarized in Table 1. We first begin with the concentrations of HFC-32 and HFC-125 in 2012 and 2019,[9] and the concentrations of HFO-1234yf in 2014 and 2019.[24] The concentrations of these chemicals during these years were used to compute the rate of increase of the concentrations of these chemicals, assuming a linear rate of increase.

Afterwards, we continued with the radiative forcing of these chemicals, with the values for HFC-32 and HFC-125 provided by Zhang et al.,[9] and the value for HFO-1234yf provided by Hodnebrog et al.[13] Then, the values of the radiative forcing were multiplied with the rates of increase in concentration to obtain the rates of increase in the radiative forcing of these chemicals. Finally, Equation (1) was used to estimate the warming caused by the emissions of these chemicals, where the rates of increase in the radiative forcing of these chemicals were multiplied with the climate sensitivity parameter of 0.5 °C $m^2$ $W^{-1}$.

**Table 1:** *Estimated warming caused by HFC-32, HFC-125, and HFO-1234yf.*[9,13,24]

| Chemical | Concentration (ppt) | | Concentration Increase (ppt $year^{-1}$) | Radiative Forcing (mW $m^{-2}$ $ppt^{-1}$) | Increase in Radiative Forcing (mW $m^{-2}$ $year^{-1}$) | Temperature Increase (°C $year^{-1}$) | Temperature Increase (°C in 100 years) |
|---|---|---|---|---|---|---|---|
| | **2012** | **2019** | | | | | |
| HFC-125 | 12.1 | 30.0 | 2.6 | 0.239 | 0.61 | 0.00031 | 0.031 |
| HFC-32 | 6.28 | 21.5 | 2.2 | 0.12 | 0.26 | 0.00013 | 0.013 |
| | **2014** | **2019** | | | | | |
| HFO-1234yf | 0.03 | 0.81 | 0.16 | 0.03 | 0.0047 | 0.0000023 | 0.00023 |
| | | | | | **Total:** | **0.00044** | **0.044** |

°C = degree Celsius
m = meter
mW = milliwatt, 1 mW = $10^{-3}$ W
ppt = parts per trillion, $10^{12}$ ppt = 100%
W = Watt

Because the current refrigerant R-410A is comprised of HFC-125 and HFC-32, the warming caused by the continued emission of this refrigerant amounts to 0.044 °C in 100 years, which is already absurdly small. Meanwhile, the continued emissions of either R-32 (comprised of HFC-

32) and R-454B (comprised of HFC-32 and HFO-1234yf) would cause a warming of 0.013 °C in 100 years, i.e., a value more than three times smaller than that for R-410A.

Taking the differences between the warming caused by the continued emission of R-410A to those from R-454B and R-32, replacing the refrigerant R-410A with either R-454B or R-32 would reduce the warming caused by the refrigerant's emission by 0.030 and 0.031 °C in 100 years, respectively. This temperature difference is so small that it cannot be measured or felt.

Turning now to the question of feedbacks from atmospheric water, Le Chatelier's principle states:

> *"If a system at equilibrium is disturbed by a change in temperature, pressure, or the concentration of one of the components, the system will shift its equilibrium position so as to counteract the effect of the disturbance."*[25]

In other words, feedbacks from atmospheric water to HFC and HFO warming are almost certainly negative. Since water is vastly more abundant in the atmosphere than HFCs and HFOs, and can be about 100 times more abundant in the atmosphere than $CO_2$, depending on the region,[26] this negative feedback to HFC and HFO warming is likely to be overwhelming. In other words, it is almost certain that the calculated tiny warming effects of the HFCs and HFO in Table 1 are *overestimates* of the true warming effects of HFCs and HFOs in Earth's atmosphere.

## CONCLUSION

Based on the tiny amount of feedback-free warming from the hydrofluorocarbons (HFCs) that constitute the refrigerant R-410A, and the diminishing effects of atmospheric water to that warming, any measures for curbing the emissions of these HFCs into the atmosphere are unnecessary and serve no useful environmental purpose. Therefore, the selection of the refrigerants for air conditioning systems should be based on both the safety and the needs of the consumers, rather than on a purported environmental benefit.

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