

## ***Interactive comment on “Avoiding HFC growth is critical for keeping global warming below 2 during the 21st century” by Y. Xu et al.***

**Y. Xu et al.**

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**We would like to thank the Referee 2 for the comments. We have taken into account these suggestions and addressed the raised issues. Please see point by point responses to the comments.**

This paper takes the previously published work on the role of HFCs from the radiative forcing metric to a more “user friendly” temperature metric. This is a useful contribution to drive the point home about the potential role of HFCs. It also places the temperature changes in the “transient” time of the 21st century to note the immediacy of the issue. Because of this, I think that this paper merits publication.

However, before it is published the authors really need to address some key issues:

1. The paper does not provide any uncertainty estimates- either in the emissions or in the calculated temperature changes. I realize that they have run the RX10 model that reasonably reproduces observed temperatures. But, what is really more robust in these calculations is the contribution of HFCs relative to CO<sub>2</sub>. Why not couch it in those terms? In any case, they really should provide some estimates of uncertainties coming from the emission estimates as well as the calculations.

**Reponses: The uncertainty of HFC emission scenarios is shown as the upper (red dash) and lower limits (red solid) in Figure 1. The temperature uncertainty corresponding to HFC emission uncertainty is illustrated as the upper (red solid line in Fig 2) and lower limits (red arrow in Figure 2). Note that the uncertainty related to HFC scenarios is small (around 0.15K).**

**In addition, we agree with reviewer that future projected temperature may be subject to climate sensitivity uncertainty. So we now show the range of temperature projection due to climate sensitivity uncertainty in Figure 2.**

**Fig 2. Model simulated temperature change under various mitigation scenarios. BAU case (red solid line) considers higher estimates of future HFC growth (as red solid line in Fig. 1). BAU temperature at 2100 with lower estimates of future HFC growth (forcing shown as red dash line in Fig 1) is indicated by a red arrow on the right. MIT shows various mitigation scenarios that include CO<sub>2</sub> and short-lived climate pollutant (BC, CH<sub>4</sub>, HFCs). The uncertainty of temperature projection at 2100 due to climate sensitivity uncertainty is shown the vertical bar next to the curve. For simplicity, only the case with CO<sub>2</sub> mitigation (red dash line) and the case with full mitigation (black line) are shown.**

**Also, reviewer suggested the relative contribution to curbing global warming from HFC mitigation as a percentage of that from CO<sub>2</sub> mitigation, is more robust and not affected by climate sensitivity uncertainty. We add in the end of section 3 that “Based on our high HFC growth scenarios, the contribution to the avoided**

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warming at 2100 due to HFC emission control is about 40 percent of that due to CO<sub>2</sub> emission control. Considering the time scale of near term (2050), HFC emission is even more effective (140 percent of CO<sub>2</sub> mitigation) in curbing the warming. Given the limited knowledge regard to climate sensitivity (0.5 to 1.2 °C / (W/m<sup>2</sup>)), the absolute value of projected temperature at the end of 21st century is also uncertain (see the vertical bars in Fig 2), but the relative contribution of HFC to reducing the warming is still significant and less subject to such uncertainty.”

2. As noted above, the scenarios for HFC emissions are uncertain and the quoted 0.5C is an upper limit. Is this not true? Some of the lower emission estimates would give much lower temperature increases. This needs to be acknowledged. (Velders et al. evaluations are based on use of the current mix of HFCs in the developing world.)

**Response: The 0.5 C mitigation due to HFC growth control, as discussed in this study, is estimated with the upper limit of HFC growth (BAU high in Figure 1). We now added in the section 3.2 “If the lower limits of BAU increase of HFC (red dash in Fig 1) is taken, 0.35°C warming will be avoided.”**

3. The contribution of HFC-23 is glaringly missing. This is a molecule with huge GWP; its capture and destruction is a key component of reducing the contribution of HFCs. It also is a connection of HFCs to MP.

**Response: The discussion on not including HFC-23 is added in the end of section 2.1 (HFC emission projection): “Because the projected forcing from HFC-23 is much smaller than from the projected forcing from intentionally produced HFCs, it is not included in this study. The HFC-23 forcing in 2050 is 0.014 Wm-2 (Miller and Kuijpers, 2011) in spite of potential large increases in HFC-23 from the continued production of HCFC-22 for feedstock, and the associated warming is only about 0.01°C.” and as a footnote to Table 1: “HFC-23 is not included in the scenarios discussed here. Although it is currently the second most abundant HFC in the atmosphere, it is assumed that the majority of this chemical is**

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produced as a byproduct of HCFC-22 production and not because of its use as a replacement for CFCs and HCFCs. Hence, the emissions of HFC-23 depend on a completely different set of assumptions than the other HFCs (Velders et al., 2009). In addition, Miller and Kuijpers (2011) estimated that HFC-23 emissions increase could contribute additional 0.014 Wm<sup>-2</sup> to radiative forcing in 2050. Therefore, the contributed warming due to potential HFC-23 increase will be only about 0.01°C by our estimation.”

**Miller B. R. and Kuijpers L. J. M.: Projecting future HFC-23 emissions, Atmos. Chem. Phys., 11, 13259-13267, 2011.**

4. Not all HFCs are the same! Clearly, the uses of short-lived HFCs are precisely a way to reduce the emission of longer-lived more potent HFCs. Therefore, including HFC reductions a part of the short-lived climate pollutant approach is inappropriate and counter to what is being suggested. It is precisely the short-lived HFCs that should be used!

**Response: This is a good point. The phase “Short-lived climate pollutants” is a relatively new concept recently being put forward by both scientific and political community. The concept is phased to highlight the shorter lifetime of those pollutants (including HFCs currently being produced with globally average lifetime of 15 year) as compared to long-lived greenhouse gases (including CO<sub>2</sub> and CFCs) that are widely conceived as the dominant driving forces of climate change. Our paper is aimed to propose the replacement of current short-lived HFC with low-GWP HFCs with even shorter lifetime, so the overall forcing and associated warming due to HFC growth can be significantly reduced.**

5. Alternate technologies that completely avoid the use of HFCs are only mentioned in passing- it needs to be emphasized. This is a good way to avoid using HFCs of any kind.

**Response: Thanks for the suggestion. We now added in the end of section 2.1**

(large increase of HFC forcing) “Alternatives with no direct impact on climate, including ammonia, carbon dioxide, and hydrocarbons, as well as low GWP HFCs and not-in-kind alternatives, are already in commercial use in a number of sectors; for other sectors alternatives are being evaluated or further developed (UNEP, 2011).”

6. The conclusions read more like recommendations. Is this appropriate for a scientific paper? May I suggest that they rephrase this section to sound less prescriptive?

**Response:** Thanks for the suggestions. Now we removed the policy recommendation from the conclusion section. It is rewritten as the following “The results presented here could strengthen the interest of policymakers in promoting fast-action strategies to reduce SLCPs, including HFCs, as a complement to immediate action to reduce CO<sub>2</sub> emissions. There are several policy options for limiting HFC growth, separate from those for BC and CH<sub>4</sub>, including using the Montreal Protocol to phase down the production and consumption of HFCs (Molina et al., 2009; UNEP, 2012a; UNEP, 2012b), which would preserve the climate benefits the treaty has already achieved through its success in phasing out nearly 100 similar chemicals (Velders, et al., 2007; Velders, et al., 2012). Without the Montreal Protocol, the projected radiative forcing by ODSs would have been roughly 0.65 W/m<sup>2</sup> in 2010 (Velders et al., 2007), and the global temperature would have been higher (green line in Fig S2). It is also important to emphasize that the focus of this study is on near-term warming over the next several decades to end of the century. For the longer term (century and beyond), mitigation of CO<sub>2</sub> would be essential for a significant reduction in the warming.”

7. It is worthwhile for this paper to clearly stress that the current forcing by HFCs is negligibly small.

**Response:** Agreed. Now we added the statement in the beginning of section 3.1 (Large increase of HFC forcing) that “The radiative forcing of HFCs in 2008

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was small at less than 1 percent of the total forcing from long-lived GHGs (WMO, 2011).”

Minor comment:

Lines 21-22: Please give the time horizon for the GWP used.

**Response: We now rephrase the sentences as “IPCC studies confirmed this finding and estimated that CFC-11 and CFC-12 Global Warming Potential (GWP, using 100 year as time horizon) is 4750 to 10900 as summarized by IPCC-AR4 (Forster et al. 2007).”**

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Interactive comment on Atmos. Chem. Phys. Discuss., 12, 32613, 2012.

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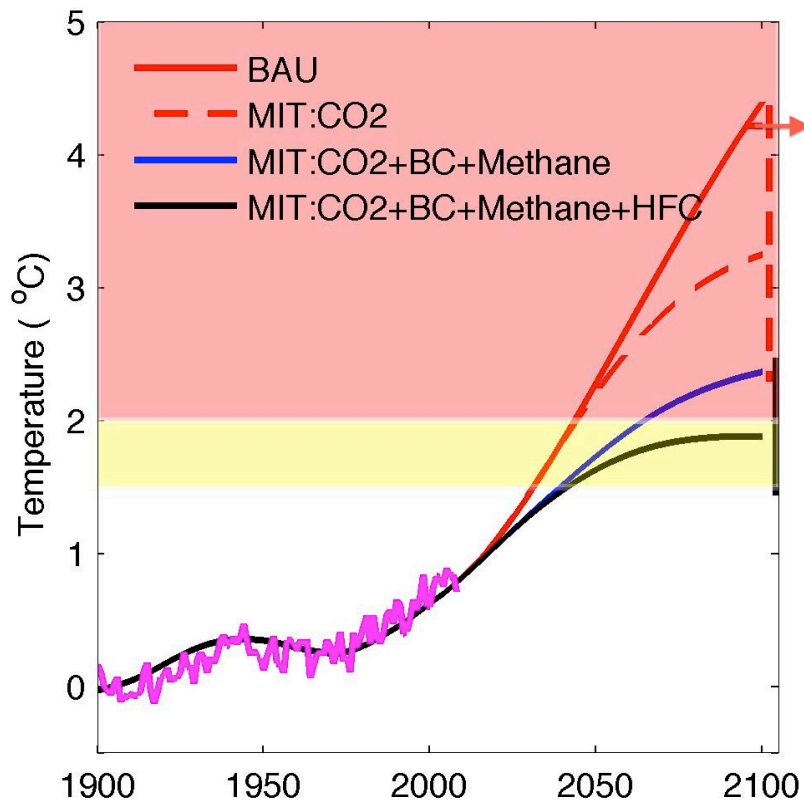


Fig. 1. Revised Fig 2 in the text

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