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Atmospheric Chemistry and Physics Discussions

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

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We would like to thank the Referee 1 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 is useful paper and on balance I recommend acceptance.

On one level, the central result is easy to obtain and not surprising. Using the back of an envelope, and knowing the forcings already presented in Velders et al. (2012) and a value for the climate sensitivity, one could simply estimate the equilibrium temperature change (perhaps lack of space prevented Velders et al from taking this step); with only a slightly bigger envelope, one could estimate the transient climate change.

Indeed, I would suggest that such a methodology would be more transparent, as one is never told, for example, the equilibrium climate sensitivity of the model used here, which is a significant omission.

Response: We agree with the reviewer this paper is based on Velders et al. (2009, 2012) forcing and taking one step further to highlight the temperature implication of these future HFC forcing, which is a critical piece of information not shown before. We now added in the text "climate sensitivity of the model used here is 0.8 C / (W/m2)."

The paper also overstates the "critical" role of HFCs. Clearly if other mitigation measures fail to hit the 2 degree target, then any other mitigation measure that takes you below this threshold can be seen as "transformative".

Response: The reviewer's point is correct; all the mitigation noted in the paper is critical for keeping below the 2C barrier. We have changed the title and relevant text to emphasize the significant contribution HFC mitigation can play in keeping warming below the 2C barrier.

Nevertheless, the work presented here is a refreshingly brief and useful reminder that all components need to be considered, if a target is to be achieved.

I also have a significant objection to the way the results are presented, although I understand there is an underlying (but unstated) political rationale for doing so. I do not think there is a compelling scientific case for grouping HFCs under SLCPs. Many of the other SLCPs are very much shorter lived, so that their distributions, given inhomogeneous emissions, are highly inhomogeneous. This is not the case for the major HFCs considered here.

Response: Most of HFCs have lifetime of years to decades, with globally weighted average to be around 15 years, which is much shorter than CO2 and other so called long-lived greenhouse gases (LLGHGs). We added in the intro-

duction section that "CH4 and halogen-containing compounds (including HFCs), therefore, are shorter-lived greenhouse gases in comparison with long-lived greenhouse gases such as CO2 and N2O (e.g. see Smith et al., 2012)."

There is a further objection to referring to the HFCs as pollutants. Most of the other members of this somewhat arbitrary grouping are pollutants in the sense that they lead to deteriorating air quality. Of course, there are many definitional arguments here, but I think the paper could be rewritten either to just discuss the impact of HFCs without any reference to whether it is a member of an arbitrary classification of other emissions (as was done in Velders et al. 2012), or else to make it explicit that the Climate and Clean Air Coalition has made an essentially political decision to include HFCs under this SLCP banner, even though the HFCs do not impact on "clean air" in any significant way.

Response: As the reviewer notes, the Climate Clean Air Coalition to Reduce Short-Lived Climate Pollutants includes HFCs among the climate pollutants they are addressing. In addition, in the 2009 US EPA endangerment finding HFCs were included as pollutants: http://www.epa.gov/climatechange/endangerment/

It would be useful if there was a reminder that the "net" climate effect of HFC reduction is important. If any replacement technologies or gases lead to less energy efficiency, then all the gains from the reduction would be lost. Just a sentence on this would suffice.

Response: We agree with this point. We now added at the end of 3.1 (Larger increase of HFC forcing) that "The climate mitigation assumes that the alternatives selected do not compromise energy efficiency, an assumption that appears reasonable in light of the historic trend to increase efficiency when chemicals are phased out under the Montreal Protocol (Andersen and Morehouse, 1997; Andersen and Sarma, 2002; Andersen et al., 2007)."

32613: Title – the "critical" in the title is hyperbole – the avoidance of HFC growth is

just one alternative for avoiding the 2 degree limit, and it is not the role of this paper to profess whether it is the most sensible (in a cost effective sense) of the many options. A more neutral title "On the role of HFC growth in keeping global warming ..." or something similar, would be less emotive.

Response: We have modified the title as suggested. Note that we are not presenting HFC mitigation as an "alternative for avoiding the 2 degree limit" but rather as a critical component of a strategy that also requires mitigation of CO2 and the other SLCPs.

32615, 3: Ravishankara citation is inappropriate – that paper is about the very long-lived perfluorocarbons.

Response: Thanks for pointing it out. We removed this reference.

32615, 6: "Are referred to as SLCPs" – they are referred to as this within the limited confines of the Climate and Clean Air Coalition, but their classification is somewhat arbitrary and politically motivated – and even then, the CCAC explicitly say "many" rather than "all" HFCs. The authors should either make clear that the classification of HFCs as SLCPs originates from the CCAC, or drop completely the attempt to somehow place HFCs in the same basket as things like black carbon. The authors might also refer to the paper by Smith et al. (doi:10.1038/nclimate1496) which arguably has a more scientifically rationale definition of short and long lived.

Response: Thanks for suggesting the new reference on long-lived versus shorter-lived greenhouse gases. We've added this reference to the introduction part "CH4 and halogen-containing compounds (including HFCs), therefore, are shorter-lived greenhouse gases in comparison with long-lived greenhouse gases such as CO2 and N2O (e.g. see Smith et al., 2012). "

32616, 22: I appreciate the reasons why HFC-23 was excluded from the analysis, but this needs to be spelt out, as it is one of the more important HFCs in terms of current radiative forcing.

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 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-2 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 Kuilpers L. J. M.: Projecting future HFC-23 emissions, Atmos. Chem. Phys., 11, 13259-13267, 2011.

32617,1: There is EU regulation (842/2006) aimed at moving away from high-GWP HFCs – is the effect of this regulation (both within and beyond the EU) included in the HFC projections used here? If it is not included, the projections (and hence the potential "savings") presented here may be an over-estimate.

Response: The effect of the EU regulation is included in the scenarios of Velders et al. (2009). This paper is referenced here with respect to the HFC scenarios.

32618, 1: Nowhere are we told the climate sensitivity of the RX10 model. This is important information. What assumptions are made for the geographical distribution of the

HFC emissions (and how this changes with time) as this really matters for the shorter-lived HFCs, as do assumptions about the dependence of the radiative efficiency on lifetime? Are thhe gases assumed well-mixed, and if so, is that consistent with their assignation as "short lived"?

Response: Climate sensitivity information is added in the method part as suggested : "climate sensitivity of the model used here is 0.8 C / (W/m2)." HFCs are assumed well-mixed and thus homogeneous forcing in terms of geographical distribution. We still call HFCs short-lived considering the lifetime of those is within years (details in table 1) as opposed to CO2's long lifetime of decades to centuries.

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