Yup, international diplomacy is slow. One year ago, at their last meeting, the parties to the Montreal Protocol decided to proceed with negotiating an amendment to the treaty to limit HFCs. They negotiated that amendment in several sessions over the past year, and adopted it last Friday at the end of their 2016 meeting in Kigali, Rwanda. I posted a discussion of the background issues involved with that decision at the time, and Sarah Duffy posted a discussion of the new decision over the weekend. Those two posts give you what you need to understand the decision and its background.

Here, I just want to identify and highlight a few issues that make the new decision noteworthy and interesting.

- This decision is an extreme example of "multi-generational" environmental protection. Depending how you count, HFCs are something like the third generation of similar chemicals doing the same jobs, so the new decision makes the move to the fourth generation. The earliest action under the Montreal Protocol eliminated first the CFCs (chlorofluorcarbons), which were the most severe threat to the ozone layer. Under these cuts, CFCs were replaced first by HCFCs (hydrochlorofluorocarbons), which still destroyed ozone but a lot less than CFCs (about 1% to 10% as much), then second by the HFCs — which don't destroy ozone at all, but are still powerful greenhouse gases. The new decision means that HFCs too will have limited lifetimes, and will be replaced by yet another generation of alternatives — also non-ozone-depleting, and also much less powerful (but not necessarily zero) contributors to climate change. (And if we consider that the CFCs themselves were developed in the 1930s as benign replacements for the toxic and inflammable refrigerants that preceded them, you can add another generation to the count.)
- The HFCs nicely illustrate two general issues in managing environmental issues to which multiple things contribute, which are sometimes confusing and are subject to misleading claims.
- First, there can be extreme variation in the volume and the intensity of contribution of different chemicals to the same problem. The volume of emissions of HFCs is of order one-one-hundred-thousandth (i.e., a factor of 10^{-5}) that of the main greenhouse-gas, CO_2. Wow, so they must not be very important contributors to climate change, right? No, because pound for pound they are about one thousand times more powerful in contributing to heating the climate than CO_2. Put those factors together, and the HFCs are presently contributing about 1 or 2 percent of total anthropogenic heating from greenhouse gases: not nothing, but not enough to take much heat off the need for extreme cuts of CO_2 or other greenhouse gases either.
- Second, different chemicals have big differences in how long they stay in the

atmosphere after they are emitted. As a result, the size of a chemical's contribution to the problem can be highly sensitive to how long a time horizon you consider. HFCs are one of the short-lived climate pollutants, meaning that current emissions only stay in the atmosphere a few years to a few decades (versus thousands of years for CO_2). This means that if your aim is to reduce heating as fast as possible, controlling HFC emissions is one of the most powerful – indeed, one of the only – ways to do so. But if don't care about the heating underway right now and expected over the next 10 years or so, and instead care only about reducing the much more severe heating projected for some future year — say 2050 or 2100 — there is no urgency to control emissions of the short-lived species. If, for example, you only care about climate change in 2100 (I think this would be pretty foolish, but just suppose …), you could wait until 2080 or 2090 to get rid of HFCs, and their heating effect would still be almost gone by 2100. This is one of the arguments that industry opponents advanced to argue against strong near-term cuts in HFCs.

- The HFCs were introduced, recently and intentionally, to replace more environmentally damaging chemicals. For example, before 1995 the air conditioner in your car ran on (ozone-destroying) CFC-12. Since 1995, US car AC has run on (non-ozone-destroying) HFC-134a. Much coverage of the recent decision has focused on how fast HFCs have been growing. But their rapid growth is for this reason, and is — to at least a substantial degree — a good thing, since the stuff they are replacing was worse. This is even true if you ignore ozone depletion but consider only relative contributions to climate change, even though the Montreal Protocol is concerned with ozone depletion, not climate change: Yes, the HFCs are much stronger greenhouse gases than CO_2, but they are substantially weaker greenhouse gases than the CFCs they replaced — mainly on account of their shorter atmospheric lifetimes. So switching to them was a climate benefit – just not as big a benefit as we need.
- Because of this rapid recent growth, the apparent significance of the new decision can be strongly manipulated by focusing on different time horizons (and note – I'm no longer talking about atmospheric lifetime, but just at what year you state a comparison). For example, one organization that opposed cutting HFCs circulated a pamphlet that noted that HFCs were only 0.2% of total human greenhouse forcing in 2002. This is correct – but why do you suppose they chose 2002 to make the comparison, since HFC use has grown nearly ten-fold since then? As noted above, HFCs' contribution to heating (radiative forcing) today is between 1% and 2% of the total. But the big impact of the current decision comes when you consider how much HFCs are projected to grow absent controls. By IPCC projections, HFCs if not controlled would have reached about 20% of total radiative forcing by 2050 — due to continuing replacement of earlier, phased-out chemicals, and also due to rapid growth

of cooling demand in developing countries. So the main effect of the new decision is not to eliminate much heating today, but to eliminate a very large risk of additional future heating that would have been present if HFCs were not controlled and kept growing as projected.

- Mechanics of the decision: What the parties did on Friday was adopt an amendment to the existing, in-force treaty, the Montreal Protocol. To become binding, the amendment must enter into force, which requires ratification of the amendment by two-thirds of the states that are parties to the Protocol.
- Once in force, the HFC amendment becomes formally binding as a matter of international law, but like all environmental treaties the Montreal Protocol lacks strong provisions for enforcement. The good news, however, is that the Montreal Protocol has a remarkably strong record of implementation and compliance despite its weak formal enforcement provisions. Nations promised to phase out CFCs and a few other chemicals, and they did. They promised to phase out HCFCs and are well on their way to achieving this on the agreed schedule. The track record of this treaty suggests that once nations have agreed to cut HFCs, they will probably do it.
- In fact, the history of the Protocol suggests HFCs will in fact be cut more than the current commitments. The new decision is the first bite the Protocol parties have taken out of HFCs, but for all the chemicals they have previously controlled they have come back repeatedly, as innovation has expanded the availability of alternatives, to tighten and advance control schedules. There are even formal provisions in the treaty to drive this process, requiring parties to review control measures every few years in light of new advances in science and technology. Based on this history, the probable trajectory for HFCs will be to gradually tighten the controls, including moving to complete phaseouts with a special provision for limited life extension for essential uses.
- There is one weird precedent in the current decision, in the way it differentiates the treatment of industrialized and developing countries (called “Article 5 countries”). This decision follows normal practice in the Montreal Protocol by giving developing countries similar control commitments to those adopted by the industrialized countries, with two differences: the schedule of cuts is delayed a few years for developing countries; and their cost of making the transition is subsidized. The new decision departs from all prior practice, however, by sub-dividing the developing countries into two groups. The great majority of developing countries (including China, all of Africa, all of Latin America, and a bunch of others – more than 100 countries) get one schedule, in which limits start in 2024 and bottom out at an 85% cut in 2045. But a half-dozen countries get a more relaxed schedule, starting in 2028 and reaching 85% cuts in 2047. This second group of countries includes India, Pakistan,

Iraq, Iran, and the members of the Gulf Cooperation Council (Saudi Arabia, Kuwait, etc.). This is a weird group, hard to account for in any simple way. They're not the poorest countries – indeed, the group includes some of the world's richest countries. They're hot, but not the hottest. The best explanation is that they are the group that was most prepared to oppose the agreement, so this concession – which doesn't much set back the substantive global goal – was what it took to get them on board.