Protecting the climate by reducing fluorinated greenhouse gas emissions

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Hydrofluorocarbons (HFCs), which have been used in recent years in increasing quantities as substitutes for CFCs, are also climatically very active and many are also extremely long-lived. In the renowned journal *Science* an international team of researchers recommends that the most potent of these gases also be regulated. This could save the positive «side effect» of the Montreal Protocol for the global climate.

It is regarded as the most successful international environmental agreement and has, to date, been ratified by 196 countries – the Montreal Protocol on Substances That Deplete the Ozone Layer. As a result, CFCs and ozone «killers» will gradually disappear from the atmosphere over the coming decades. And because many of these substances are also very active greenhouse gases, the Earth's climate will profit from the sinking concentrations too.

So far, so good. In many processes where previously CFCs were used, these are now being increasingly substituted by fluorinated compounds such as HFCs (which, simply put, are similar substances to CFCs but do not contain chlorine and do not deplete stratospheric ozone). They are used as cooling agents in air conditioning plants and refrigerators, as propellants in aerosol cans, as solvents and as foaming agents in the manufacture of foam products. However, there is a downside to the use of HFCs – they are also very potent greenhouse gases. HFC-134a, also known as R-134a, for example, which is used in automobile air conditioning units, is 1430 more active than the "classic" greenhouse gas carbon dioxide (CO_2).

International environmental agreements can also have unwanted side effects

The reduction of greenhouse gas emissions is covered by the Kyoto Protocol. This agreement is, however, not binding for the world's largest emitter of greenhouse gases, the USA (which has never ratified the protocol), nor for threshold and developing countries. In addition the Kyoto Protocol is currently limited to the period from 2000 to 2012. No agreement has yet been reached on extending it. What this means is that the significant increase in global emissions of HFCs seen over the past few years will soon negate the positive effects on climate brought by the Montreal protocol's CFC phase-out.

This link is shown by an analysis published in the latest issue of *Science*. An international team of researchers, headed by Holland's Guus Velders and including the chemistry Nobel laureate Mario Molina and Empa researcher Stefan Reimann, investigated the unintentional (positive) climate effects resulting from the Montreal Protocol. Since the year 2000 the radiative forcing (a measure of the effect on the climate of chemical substances) of all ozone-depleting substances including CFCs has remained at a more or less constant value of 0.32 W/m^2, compared to a value of 1.5 W/m^2 for CO_2. Had the Montreal Protocol recommendations not been implemented, today's value would be approximately double this figure, i.e. 0.65 W/m2. Putting things another way, the CFC ban has prevented the equivalent of 10 billion tonnes of CO_2 being emitted into the atmosphere in 2010, five times the annual reduction target set by the Kyoto Protocol.

Velders, Reimann and their co-authors fear that this positive effect will soon be negated by HFC emissions, which are currently increasing at 10 to 15% annually. In their article they state that "the HFC contribution to climate change can be viewed as an unintended negative side effect" of

the Montreal Protocol. At the moment the effect is still small – about 0.012 W/m2 for all CFC substitutes combined. But it is beyond question that radiative forcing due to HFCs will rise significantly in future as a result of increasing demand and production for these substances, above all in threshold and developing countries. The atmospheric scientists estimate that this value will rise to between 0.25 und 0.4 W/m^2 by the year 2050. The greatest problem is presented by saturated HFCs, which are extremely stable and survive in the atmosphere for up to 50 years, exhibiting a long-term global warming potential of up to 4000 times higher than CO_2. For Empa researcher Reimann the situation is clear: "Long-lived HFCs should no longer be used in these quantities."

A "simple" solution: expanding the scope of the Montreal Protocol

Among other things, the scientists recommend modifying the Montreal protocol so that it also covers the use of long-lived HFCs. Such proposals have already been tabled in previous years by various countries including the USA. "Since it is it is as a result of the Montreal protocol that these substances are being manufactured in increasing amounts, they could be included in the agreement too, so their use can be regulated as well," maintains Reimann. A stepwise phase-out of HFCs is technically feasible since, according to Reimann, chemical and technological alternatives are already available. In the USA for example refrigerators are cooled using HFC-134a; in Switzerland the use of this substance in refrigerators is banned and climate neutral hydrocarbons are used instead.

Provided by EMPA

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