The EU HFC amendment proposal

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Support for decision-making: Country-specific case studies

Author: Bastian Zeiger (Öko-Recherche)

Frankfurt
June 2015

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1. Introduction

Hydrofluorocarbons (HFCs) are currently widely used substances in a variety of industrial sectors worldwide, including for refrigeration and air conditioning (RAC) as well as foam blowing. They were historically developed to replace chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC) – substances that deplete the ozone layer - because they have no ozone depleting potential. HFCs however are potent greenhouse gases and therefore contribute to human-induced climate change. Some of these substances have a global warming potential (GWP) four thousand times and more than that of carbon dioxide.

In these sectors HFCs are currently the prevalent technology in non-Article 5 (non-A5) countries and have by now almost fully replaced HCFCs (and CFCs). In fact, a number of non-A5 countries have implemented national regulatory control measures that aim at reducing the release into the atmosphere and/or consumption of HFCs. New and revived alternative technologies based on natural refrigerants with no or very low GWP are available as replacements for many applications. A phase-down of HFCs has already been set in motion in the European Union.

Article 5 (A5) countries, on the other hand, still predominantly use HCFCs. The HFC consumption in these countries is however projected to grow exponentially in the wake of the mandatory HCFC phase out under the Montreal Protocol. The expected economic development is further predicted to increase the demand for RAC (Refrigeration and Air Conditioning) and other applications of HFCs.

Recently the Parties to the Montreal Protocol have been discussing several amendment proposals that aim to include a global phase-down of HFCs. The EU has contributed to this on-going discussion with a novel proposal that foresees - as a starting point - a freeze of the climate impacts of the combined HFC and HCFC consumption in A5 countries.

The European Commission has been offering country-specific case studies to a number of A5 countries in order to support them in their decision-making during the negotiations. These case studies offer a tailored assessment of the actions each country should take to meet the additional measures on HCFC and HFC consumption contained in the proposal.

The case studies rely on a modelling approach. Data for the calibration of the model stems from the HCFC Phase-out Management Plan (HPMP) of the respective country, as well as any additional available data source on equipment sales, future trends, exports, imports etc. The case studies provide an overview of the most important (sub-) sectors that need to be addressed in order to curb the combined HCFC and HFC consumption. They include specific recommendations based on available alternative technology options with the aim to reduce the overall climate impact.

In the following, the results of three different exemplary case studies (from here on referred to as case study A, B and C) are utilized to explain the methodology, point out important influencing factors and synthesise overall conclusions.

2. Objective of providing the case studies

The case studies are meant to focus specifically on the unique needs of many A5 countries and their particular economic, climatic and regulatory situation. They are meant to provide a sound indication of the scope of action required for meeting the measures proposed by the EU and to highlight the most crucial sectors and sub-sectors for lowering the overall climate impact.

The case studies offer the additional benefit of portraying some of the most promising alternative technologies in the most common applications.

It is also important to remember the current lack of data on HFC consumption, especially in A5 countries. Official HFC reporting or accounting frameworks have not yet been implemented in most parts of the World and a global picture of HFC consumption therefore currently relies on estimates only. The case studies are meant to help countries understand their particular situation better, even in the absence of detailed HFC inventories.

3. The EU amendment proposal to the Montreal Protocol

The EU proposes a consumption baseline for a combined HCFC and HFC consumption, expressed in CO_2 equivalents. For A5 countries, the HFC and HCFC share are proposed as the average consumption of 2015 and 2016 (in CO_2eq).

The EU proposal suggests a consumption freeze in A5 countries at baseline levels from 2019 on. Currently the proposal does not include further provisions for a subsequent phase-down schedule. Instead these are to be agreed upon by 2020.

For A5 countries, the proposal also includes a freeze of HFC production by 2019 and a phase-down of HFC production to 15% by 2040 based on a combined baseline: The HFC share is proposed as the average HFC production in 2009 – 2012 and the HCFC share as 70% of the GWP-weighted HCFC production during that same period. The production phase-down is generally not addressed in the case studies.

4. The HCFC/HFC consumption model

In order to model the combined HCFC and HFC consumption until 2030 and to establish a baseline for the 2015/2016 HFC consumption, it is important to determine both the current HCFC and HFC consumption as well as project the future consumption of these substances.

HCFC and HFC consumption for the case studies is derived from a stock model, which uses a simple modelling approach to calculate the stock based on empirically derived ratios of RAC systems per household or per 1,000 inhabitants. These ratios are based on a previous study by Schwarz et al. (2011)[1], which estimated numbers of RAC equipment for developing and developed countries. The determining drivers are population, number of households and the corresponding needs for RAC systems. The model also draws on data behind the Green Cooling Initiative.[2] Although somewhat limited in its informative value, the model gives a first estimate of the number of systems in use and the annual unit sales.

The model includes the following sectors: unitary air conditioning (AC), chillers, mobile AC, domestic refrigeration, commercial refrigeration, industrial refrigeration, transport refrigeration, appliance as well as bulk foam (see Table 3). Preliminary stock and sales data are generated for each of these sectors and their sub-sectors.

The HCFC and HFC consumption is then calculated based on manufacturing and servicing consumption associated with this data. The refrigerant/blowing agent distribution in each (sub-) sector as well as the timing and rate of transition from HCFCs (and CFCs in some cases) to HFCs can be specified and adjusted.

[1] 2011; Schwarz et al.: Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases; prepared for the European Commission

[2] http://www.green-cooling-initiative.org/

5. Common data sources

In many cases, HFC consumption data is either not available or incomplete. This is first and foremost a result of the lack of an official reporting system in almost all parts of the World. Please note that the reporting data collected under the UNFCCC focuses on deriving emissions. It therefore underlies a number of general assumptions and is not necessarily suited (if available) as a means of obtaining accurate consumption data.

Nonetheless, a number of data points are available for almost all assessed A5 countries and are used to adjust the preliminary stock and sales data generated by the model. They usually include unit sales of unitary ACs and AC chillers for a number of years reported by the Japanese Air conditioning and Refrigeration News.[3] Where available, data on imports and exports of equipment are taken from the BSRIA World Air Conditioning Overview report.

Thanks to the official HCFC reporting system of the UNEP Ozone Secretariat, the past and current HCFC consumption is available in the form of HPMPs and through UNEP's Ozone Data Access Centre.[4] The data provided is available by substance. Sometimes the HPMPs also provide an indication of the importance of the refrigeration and air conditioning (RAC) and foam (sub-) sectors.

Besides the agreed phase-out schedule, HPMPs also often contain additional planned actions and targets with respect to the HCFC consumption. Such additional information is used to construct the likely HCFC consumption of the future.

Due to the availability and reliability of the HCFC data, it can be used to further calibrate the stock model. Figure 1 provides an example of how the modelled and known or projected HCFC consumption relate to each other.

The overall results from the model clearly correlate to the stage of economic development in the case study country and take into account servicing of domestically produced and imported equipment, manufacturing for export as well as specific regulatory circumstances in the respective country.

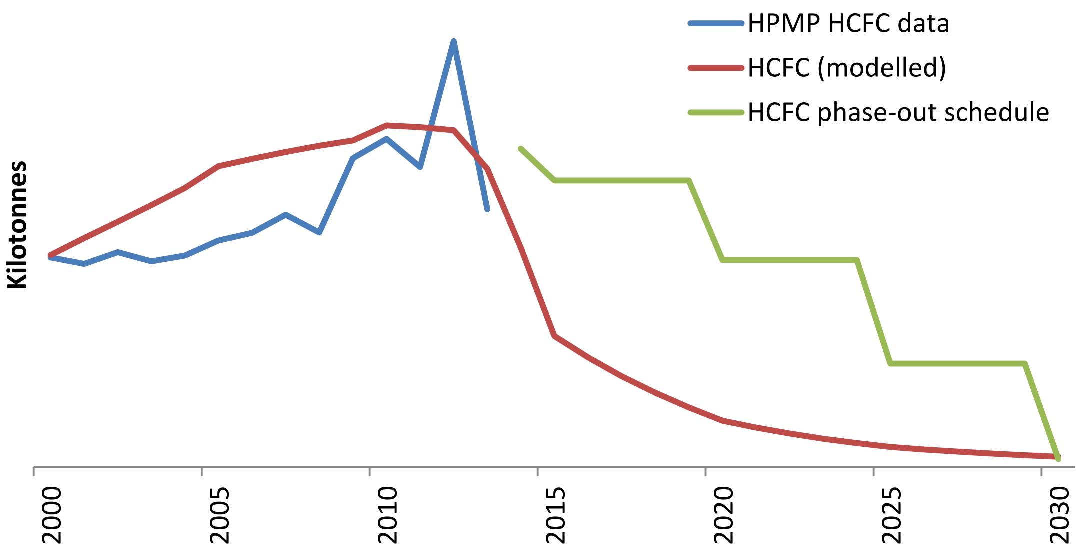

Figure 1: Comparison between reported HCFC consumption data (in metric kilo tonnes; blue line) including the phase-out schedule (green line) and the HCFC consumption modelled in case study B (red line).

[3] https://www.ejarn.com/

[4] http://ozone.unep.org/en/ods_data_access_centre/

6. Two model scenarios: business as usual vs. mitigation

The case studies generally highlight two different HFC consumption scenarios for each country, the business as usual (BAU) and the mitigation (MIT) scenarios. These scenarios are based on the modelled and calibrated unit stock and unit sales (and their growth rates) and sub-sector specific servicing emission rates, product lifetime, initial charge, etc.

While HCFC consumption remains the same in both scenarios, HFC consumption varies between the scenarios in 2016 to 2030. The two scenarios therefore represent two possible variations on the adoption of replacement technologies.

The **business as usual (BAU) scenario** assumes a widespread adoption of HFC technology in the wake of the HCFC phase-out. It is based on the assumptions developed by the Technology and Economic Assessment Panel (TEAP)[5] in their HFC BAU scenario (see also Table 1).

TEAP includes non-HFC alternatives only when they are already implemented today and assumes HFC as the future technology of choice in all other cases.

Table 1: Assumptions concerning the use of refrigerants and blowing agents under TEAP BAU Scenario.

<table>
<tr><th>Sector</th><th>Prevalent technology TEAP BAU scenario</th></tr>
<tr><td>Unitary air conditioning</td><td rowspan="2">R410A, R407A/C/F, R134a</td></tr>
<tr><td>Chillers</td></tr>
<tr><td>Mobile AC</td><td>R134a</td></tr>
<tr><td>Domestic refrigeration</td><td>HC-600a</td></tr>
<tr><td>Commercial Refrigeration</td><td rowspan="3">R134a, R404A, R407A/C/F, R422D</td></tr>
<tr><td>Industrial Refrigeration</td></tr>
<tr><td>Transport Refrigeration</td></tr>
<tr><td>Appliance Foam</td><td rowspan="2">Transition to hydrocarbons</td></tr>
<tr><td>Foam bulk</td></tr>
</table>

The **mitigation (MIT) scenario** on the other hand assumes that available alternative technologies are implemented wherever possible already by 2020, with a focus on natural refrigerants (Table 2). The penetration rates of alternative technologies are based on the Schwarz et al. 2011 study mentioned above as well as a technical paper on the suitability of these alternatives in high ambient temperature areas.[6]

The MIT penetration rates are adapted to suit each country's specific climatic, economic and regulatory characteristics. These rates assume an uptake of alternative technologies that goes beyond the assumptions in TEAP's RAC MIT1 scenario but are on par with those in the RAC MIT2 scenario. The MIT scenario in the case studies however assumes an uptake of these technologies by 2020 and therefore somewhat faster than in the RAC MIT1 and RAC MIT2 scenarios of TEAP.

[5] TEAP Taskforce Report Decision XXV/5, May 2014

[6] Zeiger et al. (2014): "Alternatives to HCFCs/HFCs in developing countries with a focus on high ambient temperatures" http://ec.europa.eu/clima/policies/f-gas/legislation/docs/alternatives_high_gwp_en.pdf and http://ec.europa.eu/clima/policies/f-gas/legislation/docs/alternatives_high_gwp_annex_en.pdf

Table 2: Assumptions concerning the use of refrigerants and blowing agents under the mitigation scenarios.

Sector	Prevalent technology MIT scenario
Unitary air conditioning	HC-290, R32 (-mixtures)
Chillers	HC-290, R717, R1234ze
Mobile AC	R1234yf, R744, HC-290*
Domestic refrigeration	HC-600a
Commercial Refrigeration	HC-290, HC-600a, R744, R1234yf (-mixtures)
Industrial Refrigeration	R717, HC-290
Transport Refrigeration	HC-290, R744, R1234yf (-mixtures), R32 (-mixtures)
Appliance Foam	HCs, Pentanes, R1234ze
Foam bulk	

*not used by original equipment manufacturer

7. Factors influencing projected future HCFC and HFC consumption

The calibrated model can accurately represent past and current unit stocks and sales and therefore HCFC and HFC consumption. A number of assumptions are however involved with respect to the future consumption of these substances.

The **growth rates of unit sales** (and the impact on future stocks) as well as annual imports and exports in the various sectors and subsectors obviously play an important role. The more units produced, the higher the manufacturing consumption. An increasing stock on the other hand means an increased consumption for servicing and maintenance. Table 3 presents the projected growth rates of unit sales applied by the model by default. These values are then adapted according to the data sources described above and to represent any regulatory circumstances in the country.

The **penetration rates of alternative technologies** by 2020 and later also have an important bearing on the model results. Penetration rates are defined as the proportion of new equipment using the respective technology installed in the respective year. Different technologies add up to 100% to represent all units being sold in one year. Table 3 contains the penetration rates assumed under the BAU and the MIT scenarios. Alternatives include only available technologies and - more specifically - technologies based on the refrigerants and blowing agents mentioned above in Table 2.

Where applicable, **high ambient temperature conditions** were also taken into account. Where they occurred various alternative technologies were excluded from the penetration mix according to the results of the technical paper mentioned above.

Table 3: Refrigeration and AC subsectors included in the stock model, projected growth rates of unit sales in these sub-sectors as well as the penetration rate of alternative technologies by 2020 used in the MIT scenario. These penetration rates may vary depending on the country examinded. Foam subsectors are not included here.

Sector	Subsector	Projected growth rates of unit sales		Penetration rate of low-GWP alternative technologies by 2020	
		2015-2020	2020-2030	BAU	MIT
Unitary air conditioning	Self-contained air conditioners	-2%	-2%	5%	90%
	Split residential air conditioners	5%	5%	0%	75%
	Commercial ducted split	5%	4%	0%	30%
	Multi-splits	9%	9%	0%	50%

Sector	Subsector	Projected growth rates of unit sales		Penetration rate of low-GWP alternative technologies by 2020	
		2015-2020	2020-2030	BAU	MIT
Chillers	Air conditioning chillers	3%	3%	10%	100%
Mobile AC	Car air conditioning	3%	3%	20%	100%
	Large vehicle air conditioning	10%	10%	20%	100%
Domestic refrigeration	Domestic refrigeration	6%	6%	95%	100%
Commercial Refrigeration	Stand-alone equipment	7%	5%	15%	100%
	Condensing units	6%	6%	0%	100%
	Centralised systems for supermarkets	1%	2%	20%	100%
Industrial Refrigeration	Centralised systems	5%	4%	20%	80%
Transport Refrigeration	Refrigerated trucks/trailers	9%	9%	0%	100%

8. Sample results from the BAU scenario

The BAU scenario represents unconstrained HFC growth during the HCFC phase-out and neither leap-frogging of HFC technology nor widespread adoption of available alternative technologies are assumed (see Table 1).

In most cases, the combined HCFC/HFC consumption increases under the BAU scenario over time, especially after around 2017 (Figure 2 and Figure 4). This trend makes it impossible to meet the freeze proposed by the EU. There was however also one particular case (out of 11 examined) in which the country was able to achieve the freeze even under BAU (Figure 3). This is primarily the case because the country already has a high HCFC/HFC consumption (it is a sizeable exported of equipment) which is not expected to grow after 2015.

The sample results presented here also highlight that a shift from HCFCs to HFCs occurs at different times and to different degrees in each of the countries. This is exemplified by the relative size of the green area compared to the red area in each year.

The growth of HFC consumption in the different subsectors provides additional insights. HFC consumption in the unitary AC sector dominates overall consumption in all case studies. Mobile AC also plays a significant role in almost all case studies, followed by industrial and commercial refrigeration. Other sectors are sometimes also of importance, such as AC chillers in case study A (Figure 2).

The sectors foam, transport refrigeration and domestic refrigeration on the other hand play a relatively minor role in the projected HFC consumption until 2030.

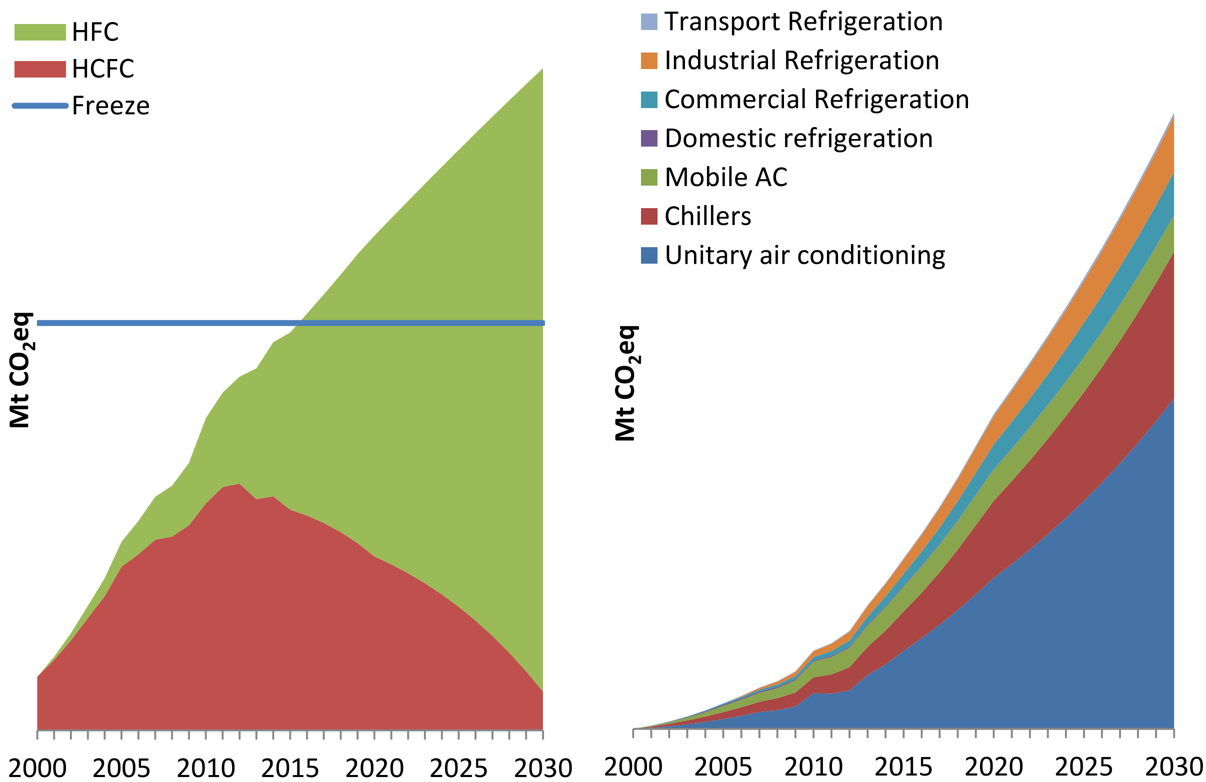

Figure 2: BAU HCFC and HFC consumption as well as sector split of HFC consumption in case study A (HCFC consumption based on the HPMP, HFC consumption based on TEAP BAU scenario).

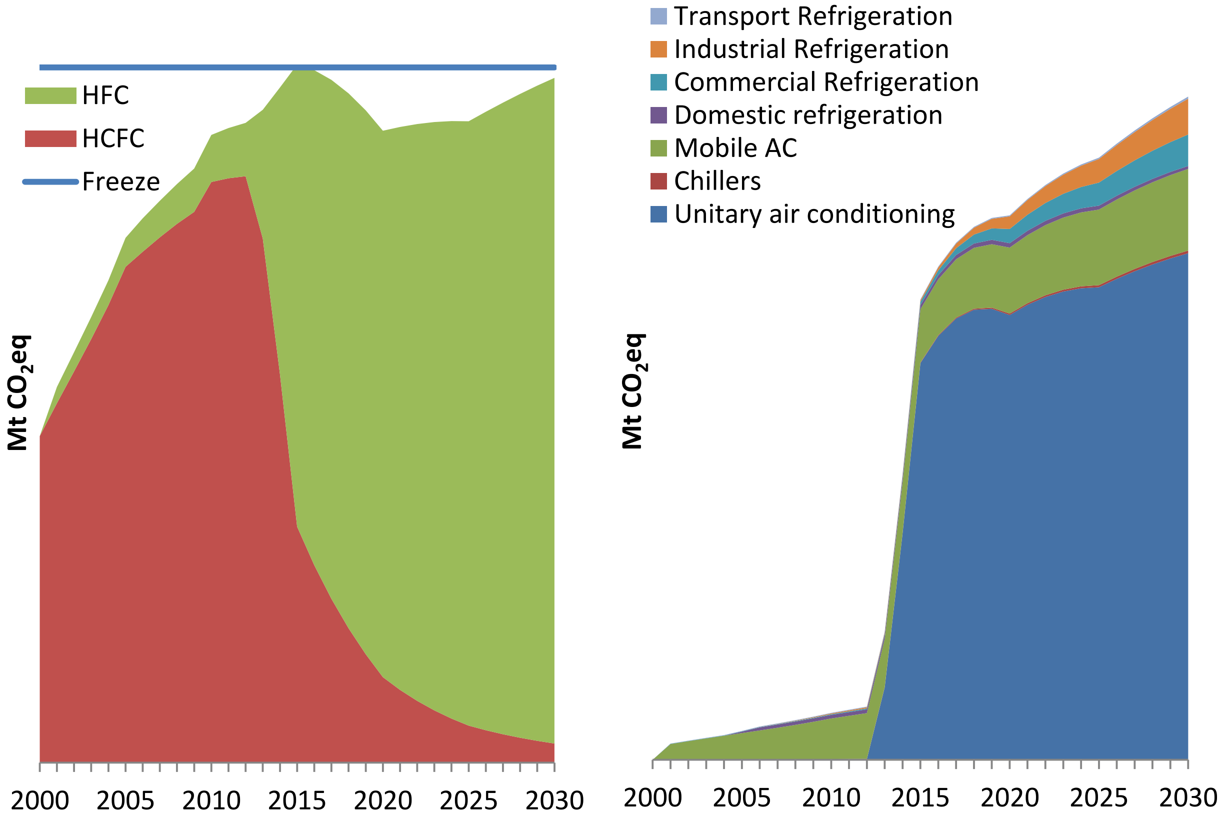

Figure 3: BAU HCFC and HFC consumption and sector split of HFC consumption for case study B (HCFC consumption based on the HPMP, HFC consumption based on TEAP BAU scenario).

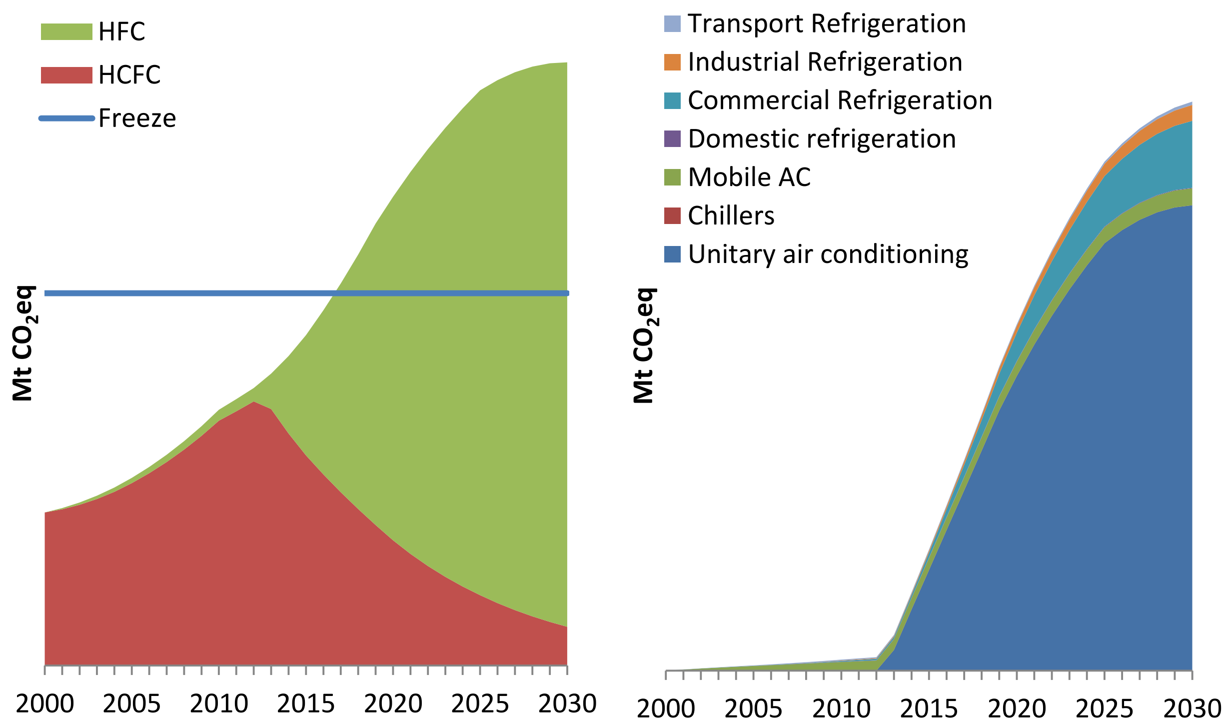

Figure 4: BAU HCFC and HFC consumption and sector split of HFC consumption for case study C (HCFC consumption based on the HPMP, HFC consumption based on TEAP BAU scenario).

9. Sample results from the MIT scenario

Results from the MIT scenario show that all countries can significantly reduce their HFC consumption in the medium and long term (Figure 5, Figure 6 and Figure 7). All of the countries for which a case study has been produced to date would thus be able to achieve the proposed freeze level by 2019 by focusing investments on alternative technologies where possible instead of widely adopting HFC technology. An important condition is that no time is wasted in switching to low GWP technologies, any delay would make it considerably more difficult!

The high importance of the unitary AC sub-sectors remains undisputed even under the MIT scenario as it still dominates total HFC consumption. Replacing new units sold by no-, low- or medium-GWP alternatives can halt the sharp increase in HFC consumption in the unitary AC sector between 2012 and roughly 2015. In order to ensure that the freeze can be met and sustained in the long run (post 2030), the role of R32 in the unitary AC sector should however remain secondary due to its still relatively high GWP of 675. This is the unequivocal result of modelling variations on the MIT scenario that assume large-scale adoption of R32 in this sector for a number of case study countries.

Under MIT, the mobile AC sector gains in relative importance. It contributes to HFC consumption because of the stock of passenger cars that already contains a considerable amount of air-conditioned vehicles with units that utilize R134a. This stock needs to be serviced and maintained until decommissioned. HFC consumption in this sector is however projected to slowly decline in all countries assessed after 2020, when alternatives have fully replaced conventional HFC technology.

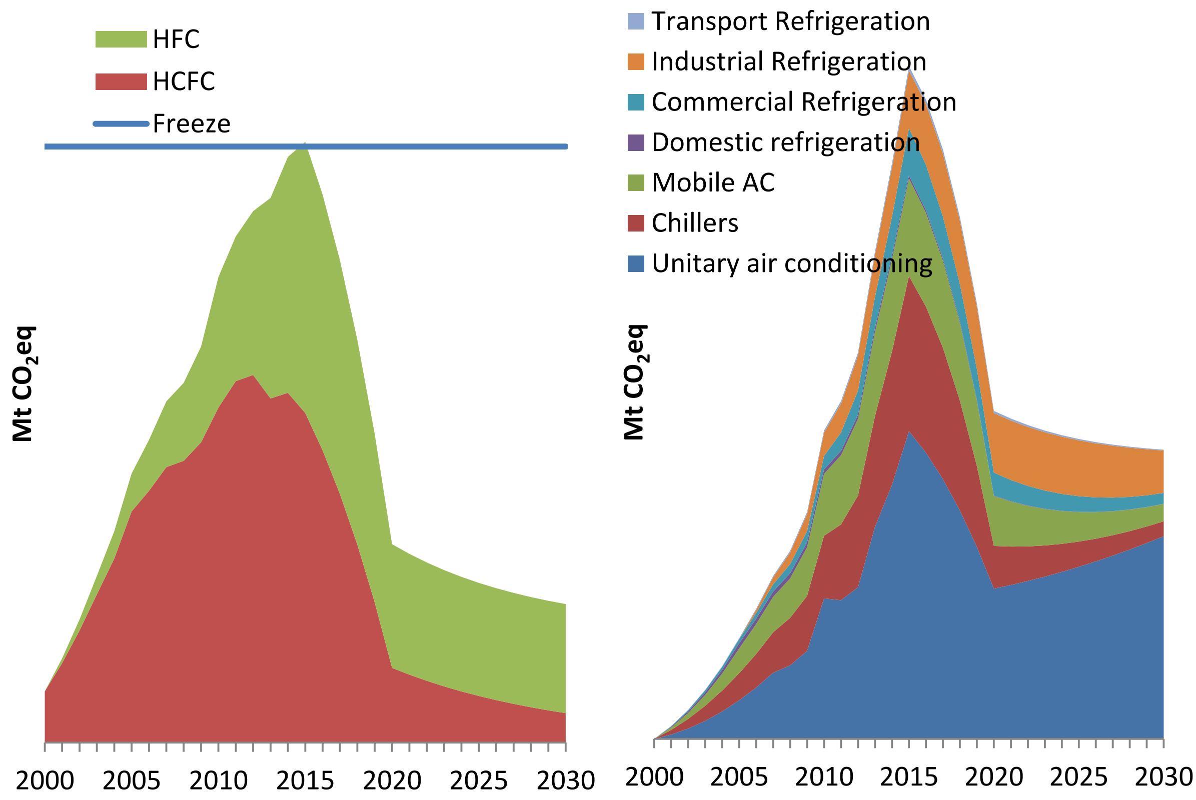

Figure 5: HCFC and HFC consumption and sector split of HFC consumption for case study A (HCFC consumption based on the HPMP, HFC consumption based on the MIT scenario).

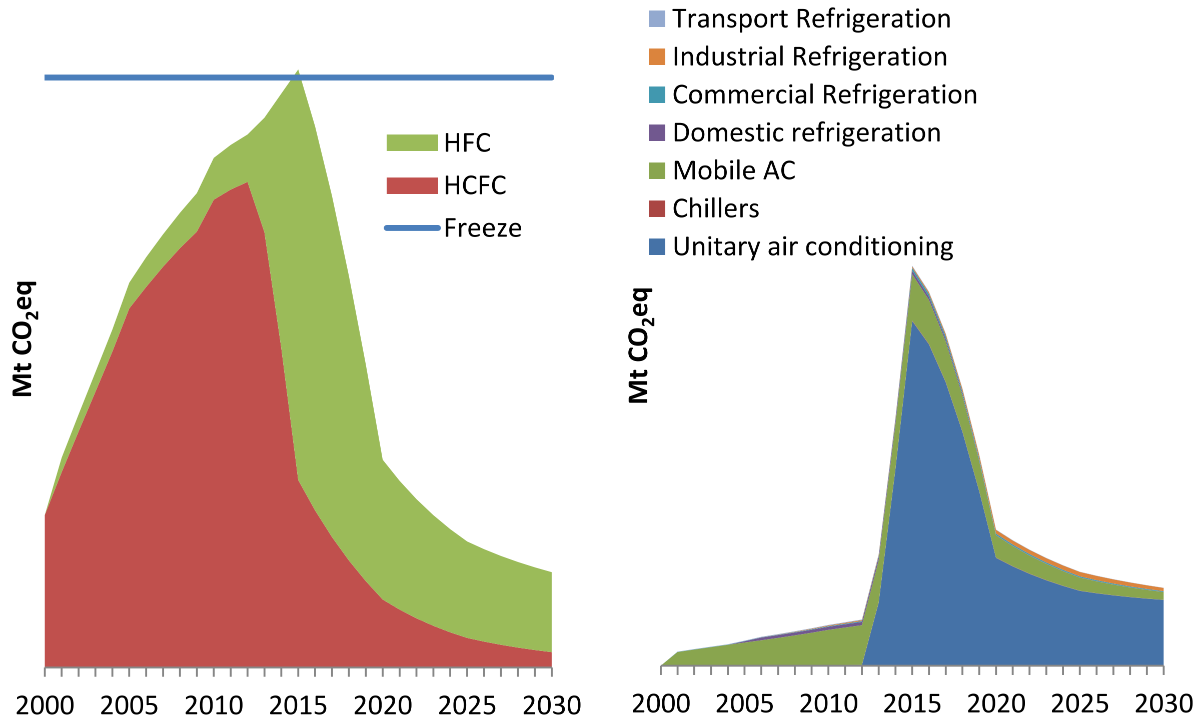

Figure 6: HCFC and HFC consumption and sector split of HFC consumption for case study B (HCFC consumption based on the HPMP, HFC consumption based on the MIT scenario).

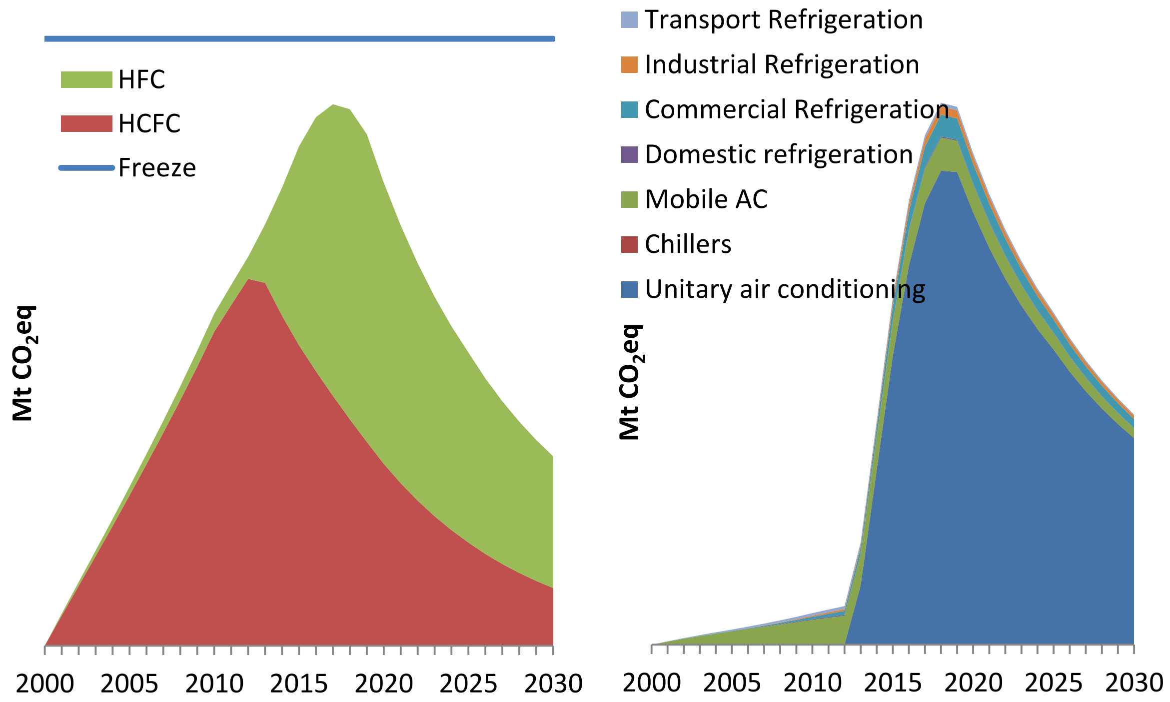

Figure 7: HCFC and HFC consumption and sector split for HFC consumption for case study C (HCFC consumption based on the HPMP, HFC consumption based on the mitigation scenario).

10. Overall conclusions

The case studies' results enable A5 countries to better understand their situation even in the absence of detailed inventories. The most relevant and promising sectors for going to low GWP technologies are identified. The countries are further pointed towards the most promising alternative technologies that fit their specific economic and climatic conditions.

More specifically, the results from the case studies highlight that A5 countries are generally able to meet the freeze level proposed by the EU. This ability however depends – in most but not all cases – on efforts to leap-frog HFC technology to the largest extent possible during the continued phase-out of HCFCs and without delay. This will require immediate investments in alternative technologies.

The results further show, that in order to meet the freeze level by 2019 and in the long term, countries should focus their efforts especially on the unitary AC sector. A successful shift to alternatives in this sector is a pre-condition for meeting the proposed freeze level in time and immediate investments are needed. In countries with expected high growth rates in this sector, R32 and future blends with HFOs can however only play a secondary role in most cases (e.g. in cases where lower refrigerants cannot be used due to safety concerns on higher charges) and would otherwise jeopardize the country's efforts in the long run.

The case studies clearly confirm that HFC consumption is projected to grow dramatically in almost all cases if investments in alternative technologies are delayed or remain low. If investment into conventional HFC technologies continues, most countries will not be able to meet the proposed freeze level.

Detailed inventory data would certainly improve the reliability of the current modelling exercise and should be envisaged once such data becomes available.

11. Links

General info on EU F-gas policy: http://ec.europa.eu/clima/policies/f-gas/index_en.htm

Preparatory study for the review of the EU F-gas Regulation: http://ec.europa.eu/clima/policies/f-gas/docs/2011_study_en.pdf

Technical paper on alternatives to HFCs under high ambient conditions: http://ec.europa.eu/clima/policies/f-gas/legislation/docs/alternatives_high_gwp_en.pdf