23 May 2007

MEMORANDUM to the European Commission

Assessment of Reduction of HCFC Production, Consumption, and Emissions under the Proposed Changes to the Montreal Protocol

The following memorandum prepare to the attention of the European Commission summarizes adjustments to the Montreal Protocol proposed by several Parties for discussion at the 27th Open-Ended Working Group (OEWG) Meeting of the Parties (4-7 June 2007). The memorandum also provides aggregate HCFC production, consumption, and emissions reductions under each of the proposed scenarios.

Authors:
Toby Krasney, Jess Kyle, Katrin Moffroid, Marian Van Pelt, Mark Wagner, ICF International

Contacts: European Commission, DG Environment, Unit C4.
Thomas Verheye (thomas.verheye@ec.europa.eu); Philippe Tulkens (philippe.tulkens@ec.europa.eu)

1. Introduction

This analysis estimates the stratospheric ozone and climate impacts associated with a number of different proposed adjustments to the Montreal Protocol to be examined at the 27th Open-Ended Working Group (OEWG) Meeting of the Parties. Specifically, this analysis calculates the ODP- and GWP-weighted production, consumption, and emission reductions associated with reduced HCFC production and consumption under each of the proposals. This analysis does not take into account other climate impacts such as the following:

- **Climate impact of the transition away from HCFCs to high-GWP alternatives** (e.g., HFC-134a, R410A, R407C). In phasing out HCFC consumption, users will inevitably transition to alternative chemicals. To the extent that these alternatives are high-GWP gases, the actual net climate impact of HCFC phaseout may be considerably less than the GWP-weighted consumption and emission reductions calculated in this analysis.

- **Climate impact of transitioning to more energy efficient equipment**. CO_2 emissions associated with the energy use of HCFC or alternative equipment are not included in this analysis. While it is likely that new or retrofitted equipment will have better energy efficiency, the GWP-weighted emission/consumption reductions presented in this analysis only relate to emissions/consumption of HCFCs, not any climate impact associated with energy use required to run the equipment (e.g., a chiller, refrigerator, AC unit).

- **Climate impact of reducing production of high-GWP byproduct**. The impact of by-product emissions, such as unabated HFC-23 emissions that result from the production of HCFC-22, is not included in this analysis. Including such emissions into the analysis would yield greater climate benefits than identified here.

2. Summary of Proposed Policy Options

Several countries proposed adjustments to the Montreal Protocol to be examined at the 27th OEWG Meeting of the Parties.

Alternative scenarios for the phaseout of HCFC consumption and production were proposed by:

- Mauritania
- Federated States of Micronesia
- Mauritius
- United States[1]
- Iceland, Norway and Switzerland, jointly
- Argentina and Brazil, jointly

The proposals by Mauritania and the Federated States of Micronesia are identical and, therefore, are presented as one proposal.

Tables 1 and 2, below, summarize the proposed alternative phaseout scenarios for HCFC consumption and production in non-Article 5 countries. Table 3 and Table 4 present the proposed phaseout adjustments for HCFC consumption and production in Article 5 countries.

[1] The adjustments proposed by the United States do not include specific phase-down steps for production; hence only reductions in consumption and emissions are analyzed under the U.S. proposal.

Table 1: Proposed Alternative Phaseout Scenarios for Consumption of HCFCs in Non-Article 5 Countries

Year	Montreal Protocol	Mauritania/ Micronesia/ Mauritius	USA		Argentina & Brazil
			All HCFCs	HCFC-22, HCFC-142b, HCFC-141b	
1989	Baseline				
1996	Freeze on 1989 HCFC consumption + 2.8% of 1989 ODP-weighted CFC consumption	Freeze on 1989 HCFC consumption + 2.8% of 1989 ODP-weighted CFC consumption	Freeze on 1989 HCFC consumption + 2.8% of 1989 ODP-weighted CFC consumption	Freeze on 1989 HCFC consumption + 2.8% of 1989 ODP-weighted CFC consumption	Freeze on 1989 HCFC consumption + 2.8% of 1989 ODP-weighted CFC consumption
2004	35% reduction from baseline	35% reduction from baseline	35% reduction from baseline	35% reduction from baseline	35% reduction from baseline
2010	65% reduction from baseline	90% reduction from baseline	65% reduction from baseline[a]	75% reduction from baseline	65% reduction from baseline
2015		99.5% reduction from baseline	90% reduction from baseline[a]	95% reduction from baseline	90% reduction from baseline
2020	99.5% reduction from baseline		100% reduction from baseline[a]	100% reduction from baseline	100% reduction from baseline
2030	100% reduction from baseline	100% reduction from baseline			

[a] Although a more stringent phaseout for HCFC-22, -141b, and -142b has been prescribed by the United States proposal, other HCFCs are permitted to be consumed up to the level of the cap on all HCFCs (i.e., up to 10% of baseline in 2010 and 5% in 2015). In practice, it is unlikely that this volume of other HCFCs will be consumed. However, for comparability, this analysis models total allowable consumption under all proposals.

Table 2: Proposed Alternative Phaseout Scenarios for Production of HCFCs in Non-Article 5 Countries

Year	Montreal Protocol	Mauritania/ Micronesia/ Mauritius	Iceland, Switzerland & Norway	Argentina & Brazil
1989	Baseline			
2004	Freeze on 1989 HCFC production + 2.8% of 1989 ODP-weighted CFC production + 15% for BDN	Freeze on 1989 HCFC production + 2.8% of 1989 ODP-weighted CFC consumption + 15% for BDN	Freeze on 1989 HCFC production + 2.8% of 1989 ODP-weighted CFC consumption + 15% for BDN	Freeze on 1989 HCFC production + 2.8% of 1989 ODP-weighted CFC consumption + 15% for BDN
2010		90% reduction from baseline + 15% BDN	65% reduction from baseline + 10%BDN	
2015		99.5% reduction from baseline + 15% BDN	90% reduction from baseline + 10% BDN	
2020			99.5% reduction from baseline + 1% BDN	100% reduction from baseline
2030		100% reduction from baseline	100% reduction from baseline	
2040				

Table 3: Proposed Alternative Phaseout Scenarios for Consumption of HCFCs in Article 5 Countries

Year	Montreal Protocol	Mauritania/ Micronesia	Mauritius	USA[a]		Iceland, Switzerland & Norway	Argentina & Brazil		
				All HCFCs	HCFC-22, HCFC-142b, HCFC-141b[b]		HCFC-22, HCFC-142b, HCFC-141b	HCFC-21, HCFC-123, HCFC-124, HCFC-225	Other HCFCs
2009									100% reduction in consumption
2010			Baseline Average of 2010-1012	Baseline	Baseline		Baseline	Baseline	
2011				Freeze on 2010 HCFC levels	Freeze on 2010 HCFC levels				
2012							Freeze on 2010 HCFC levels	Freeze on 2010 HCFC levels	
2014						Baseline			
2015	Baseline	Baseline				Freeze on the lesser of 2014 or 152% of 2005 HCFC level	20% reduction from baseline	10% reduction from baseline	
2016	Freeze on 2015 HCFC consumption level	Freeze on lesser of 2015 HCFC consumption level or [100% + X%] of 2006 HCFC level	Freeze on average of 2010-2012 HCFC level						
2020		65% reduction from baseline	65% reduction from baseline	65% reduction from baseline	75% reduction from baseline	35% reduction from baseline	40% reduction from baseline	20% reduction from baseline	
2025		90% reduction from baseline	90% reduction from baseline	90% reduction from baseline	95% reduction from baseline	65% reduction from baseline	65% reduction from baseline	30% reduction from baseline	
2030		99.5% reduction from baseline	99.5% reduction from baseline	100% reduction from baseline	100% reduction from baseline	99.5% reduction from baseline	100% reduction from baseline	40% reduction from baseline	
2035								95% reduction from baseline	
2040	100% reduction from baseline	100% reduction from baseline	100% reduction from baseline			100% reduction from baseline		100% reduction from baseline	

[a] This summary combines all four elements of the U.S. proposal: (1) adding interim reduction steps for A5 Parties; (2) setting an earlier baseline date for A5 Parties; (3) setting an earlier phaseout date for non-A5 and A5 Parties; and (4) phasing out HCFCs on a "Worst First" basis.

[b] The U.S. proposal considers HCFC-22, HCFC-141b, and HCFC-142b to be the "worst" and recommends that this group should be subject to advanced phaseout reductions.

Table 4: Proposed Alternative Phaseout Scenarios[a] for Production of HCFCs in Article 5 Countries

Year	Montreal Protocol	Mauritania/ Micronesia	Mauritius	Iceland, Switzerland & Norway	Argentina & Brazil		
					HCFC-22, HCFC-142b, HCFC-141b	HCFC-21, HCFC-123, HCFC-124, HCFC-225	Other HCFCs
2009							100% reduction in production
2010			Baseline Average of 2010-2012 production		Baseline	Baseline	
2011							
2012					Freeze on 2010 HCFC consumption levels	Freeze on 2010 HCFC consumption levels	
2014				Baseline			
2015	Baseline	Baseline		Freeze on the lesser of the average production and consumption in 2014 or 152% of 2005 average + 15% BDN	20% reduction from baseline + 15% BDN	10% reduction from baseline + 15% BDN	
2016	Freeze on average of 2015 HCFC production and consumption + 15% BDN	Freeze on lesser of 2015 HCFC consumption level or [100% + X%] of 2006 HCFC level + 15% BDN	Freeze on average of 2010-2012 HCFC level + 15% BDN				
2020		65% reduction from baseline + 15% BDN	65% reduction from baseline + 15% BDN	35% reduction from baseline + 10% BDN	40% reduction from baseline + 15% BDN	20% reduction from baseline + 15% BDN	
2025		90% reduction from baseline + 15% BDN	90% reduction from baseline + 15% BDN	65% reduction from baseline + 10% BDN	65% reduction from baseline + 15% BDN	30% reduction from baseline + 15% BDN	
2030		99.5% reduction from baseline + 15% BDN	99.5% reduction from baseline + 15% BDN	99.5% reduction from baseline + 1% BDN	100% reduction from baseline	40% reduction from baseline + 15% BDN	
2035						95% reduction from baseline+ 15% BDN	
2040		100% reduction from baseline	100% reduction from baseline	100% reduction from baseline		100% reduction from baseline	

[a] The adjustments proposed by the United States do not include specific phase-down steps for production; hence only reductions in consumption and emissions are analyzed under the U.S. proposal.

3. Methodology

3.1. Developing HCFC Production and Consumption Baselines

To develop baselines, it was assumed that HCFC production and consumption will equal the maximum allowable for both Article 5 (A5) and non-Article 5 (non-A5) Parties in future years. In actuality, production and consumption have often been below HCFC caps imposed by the Montreal Protocol. For example, in 2004, HCFC consumption by non-A5 countries was less than 11,000 ODP metric tons, far less than the allowed cap of almost 24,000 ODP metric tons. This is likely due in part to the fact that many countries have adopted their own regulations that are stricter than the phaseout schedule of the Montreal Protocol. For example, the European Commission's Regulation (EC) No 2037/2000 prohibits the use of HCFCs in solvent applications after 2001, in foams after 2004, and in refrigeration/AC equipment after 2010. As a result, the actual reductions may be less than the reductions calculated in this memorandum. Further analysis could be undertaken to more accurately estimate these reductions by taking into account existing national regulations.

Historical HCFC production and consumption data was obtained in aggregate for A5 and non-A5 countries from UNEP's website. The time series includes 1986 and 1989-2005.[2, 3]

In order to project future production and consumption of HCFCs for the purpose of comparing the proposed adjustments, it was assumed that production and consumption would be maximized, and therefore production and consumption under the baseline is set equal to the cap as defined by the Montreal Protocol. Since the caps on production and consumption of HCFCs in A5 countries will not enter into effect until 2016, growth through 2015 was projected as follows:

- For **consumption**, the average growth rate for 2000 through 2004 (12%) was used to project A5 consumption for 2005 through 2015. These years were chosen to provide what ICF considered a "reasonable" future consumption projection; the inclusion of earlier years in the time series would yield a much higher average growth rate.
- For **production**, a future growth rate of 5% was used to project HCFC production in A5 countries. This rate is based on an average estimate developed by the World Bank[4] for growth in HCFC-22 production in China.[5]

Consumption baseline estimates were developed through 2030 for A5 and 2040 for non-A5 countries based on the current HCFC phaseout schedules. Production baseline estimates were developed through 2040 for both A5 and non-A5 countries because no phaseout date is specified for HCFC production in the Montreal Protocol and thus non-A5 countries may continue to produce HCFCs to service demand in non-A5 countries through 2040.

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[2] 2005 data were not used for the consumption analysis because data had not been finalized and appeared to be incomplete.

[3] Published projections such as the TEAP HCFC Task Force Report (May 2003) were considered as sources of data for this analysis, however the data were not utilized due to unrealistically low estimates for the early portion of the time series. In particular, projections for 2002 through 2005 were significantly lower than the UNEP reported data for this period. However, TEAP's projections for HCFC demand in 2010 and 2015 are comparable to those which were derived using the average growth rate of consumption.

[4] World Bank. "HCFC-22 and Unavoidable Co-production of HFC-23 and CTC." Presentation given by Erik Pedersen at the 9th Annual Financial Agents Workshop at the World Bank in Washington, D.C.,March 31 - April 1, 2005.

[5] The average historical growth rate was not employed in the production projections; this rate averaged 22% for 2000 through 2004 leading to estimated production that surpassed projected demand, a situation that was not considered realistic.

Two baselines were developed for production in A5 and non-A5 countries: one including maximum allowable production for basic domestic needs (BDN), and one excluding BDN production. As a result, it was possible to calculate the incremental production reductions associated exclusively with proposed adjustments on controlled production and BDN production.

3.2. Estimating Production, Consumption, and Emission Reductions Associated with Reduced HCFC Consumption

The additional phase-down steps proposed by each Party are summarized in Section 2 above; this section describes the general assumptions used to calculate production, consumption, and emission reductions based on these phase-down steps. For each Party's proposed adjustments on production, two scenarios were calculated, one that includes the additional allowances associated with production for BDN, and one that excludes these estimates.

In order to calculate GWP-weighted reductions for each proposed adjustment, total production and consumption were disaggregated into HCFC-22, HCFC-141b, and 'other HCFCs,' where HCFC-123 was used as a proxy for 'other HCFCs.'[6] The method for determining production and consumption of HCFC-22, HCFC-141b, and other HCFCs for developing and developed countries is summarized below:

- For **developing countries**, the distribution of HCFCs by chemical was based on preliminary results from a draft UNDP survey study that was disseminated at the Stockholm Group meeting in The Hague, Netherlands, in February 2007. These preliminary results were based on 9 surveys received from countries in the Latin America, the Middle East, South Asia, and Southeast Asia regions.
- For **developed countries**, the disaggregation of HCFCs by chemical was based on U.S. consumption patterns in the year 2000 (prior to the phaseout of HCFC-141b), as modeled in the U.S. EPA's Vintaging Model (version VM IO file 12-26-06).[7] This information is used by permission of the US EPA to help facilitate the standardization of the various analyses of the OECD proposals, and also because the information was available off-the-shelf in the time necessary for this analysis.

To calculate emissions, estimated reductions in consumption of HCFCs were translated into emission reductions using the following 'emission-to-consumption' ratios: 71% for HCFC-22, 15% for HCFC-141b, and 44% for 'other HCFCs.' These ratios were developed based on U.S. consumption and emissions patterns as modeled in the US EPA's Vintaging Model and reflect the relationship between annual emissions from HCFC equipment and annual HCFC consumption for the United States.[8] Again, this information was available off-the-shelf in time for this analysis, and is used by permission of the US EPA.

These assumptions and others used for this analysis are summarized in Table 5.

[6] The ODP and direct GWP of HCFC-123 were used as a proxy for "other HCFCs," since it is assumed that HCFC-123 accounts for the majority of other HCFC use and has low GWP values, thereby providing a conservative estimate of consumption reductions.

[7] The year 2000 was chosen to represent a mature market for HCFCs prior to the phaseout of higher ODP HCFCs in the United States.

[8] The emission-to-consumption ratios were taken from the modeled year 2000 from the Vintaging Model, and are generally representative of a mature, but not yet declining, market, thus they are assumed to be an appropriate rule of thumb to estimate emissions relative to consumption across all HCFC-using end-uses.

Table 5. Assumptions[a]

HCFC Type	Article 5 Countries (% ODP-weighted HCFC Consumption)	Non Article 5 (%ODP-weighted Consumption)	ODP	Direct GWP	Ratio of Emissions to Consumption
HCFC-22	49.3%	44.9%	0.055	1,780	71%
HCFC-141b	49.3%	44.6%	0.11	713	15%
Other	1.4%	5.7%	0.04	76	44%

[a]Sources: ODP values are taken from the Montreal Protocol (UNEP 2003). Note that UNEP provides a range of 0.02-0.06 for HCFC-123, the HCFC used as proxy for 'Other'; the median of this range was selected for this analysis. GWP values are taken from IPCC/TEAP (2005).
Note: The SROC (IPCC/TEAP (2005)) reports different percentage breakouts for HCFC emissions: between 75-85% for HCFC-22, between 7-17% for HCFC-141b, and 8% for other HCFCs, depending on whether the bottom-up or top-down approach (based on atmospheric concentrations) is used. These percentages vary significantly from what is reported here because they are based on emissions in metric tons, whereas the percentages reported in the table above are based on consumption of HCFC in ODP-weighted tons. Because HCFC-141b has a high ODP, in a breakout based on ODP-weighted consumption, HCFC-141b appears to account for a higher percentage of consumption than it actually does in real tonnage. Because the percentages of HCFC emissions by HCFC type in the SROC are not disaggregated by developed and developing countries, assumptions from the UNDP preliminary survey results and the EPA's Vintaging Model were applied in this analysis.

4. Estimates of HCFC Reductions under Proposed Scenarios

4.1. HCFC Consumption and Emission Reductions

Table 6 presents the total reductions in HCFC consumption and emissions for each proposed scenario relative to HCFC consumption and emissions under baseline. Note that very broad assumptions were required to translate consumption estimates into emission estimates; constant ratios of emissions-to-consumption were assumed based on available statistics for the United States. These ratios may not be representative of the world, and should only be considered a general order-of-magnitude estimate of emission estimates. In addition, to model emission reductions and disaggregate consumption by HCFC, another set of broad assumptions was required, based on information obtained regarding the mix of A5 and non-A5 HCFC consumption by species.

Figure 1 and Figure 2 below represent the projected HCFC consumption over time for A5 and non-A5 countries, respectively.

Table 6: Aggregate Reduction in HCFC Consumption and Emissions under Each Proposed Adjustment

		Mauritania & Micronesia	Mauritius	USA	Iceland, Switzerland and Norway	Argentina & Brazil
ODP Weighted Consumption (ODP weighted MT)	NonA5	63,563	63,563	1,842 [b]	0	1,842
	A5	1,172,997	1,320,326	1,429,188	1,319,146	1,363,907
	TOTAL	1,236,560	1,383,889	1,431,030	1,319,146	1,365,749
GWP Weighted Consumption ($MMTCO_2E$) [a]	NonA5	1,212	1,212	452 [b]	0	35
	A5	22,499	25,325	27,895	25,303	26,220
	TOTAL	23,711	26,537	28,347	25,303	26,256
ODP Weighted Emissions (ODP weighted MT)	NonA5	28,265	28,265	846 [b]	0	819
	A5	504,598	567,976	614,432	567,468	586,677
	TOTAL	532,863	596,241	615,278	567,468	587,496
GWP Weighted Emissions ($MMTCO_2E$) [a]	NonA5	755	755	290 [b]	0	22
	A5	13,855	15,595	17,187	15,581	16,147
	TOTAL	14,609	16,350	17,476	15,581	16,169

[a] For this analysis, direct global warming potentials (GWPs) are taken from IPCC/TEAP (2006). Special Report on Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons. p. 162. Available online at: http://www.ipcc.ch/pub/reports.htm

[b] Although a more stringent phaseout for HCFC-22, -141b, and -142b in non-Article 5 countries has been prescribed by the United States proposal, other HCFCs are permitted to be consumed up to the level of the cap on all HCFCs (i.e., up to 10% of baseline in 2010 and 5% in 2015). In practice, it is unlikely that this volume of other HCFCs will be consumed. However, for comparability, this analysis models total allowable consumption under all proposals.

Figure 1. HCFC Consumption in Article 5 Countries Associated with the Proposed Adjustments to the HCFC Phaseout Schedule

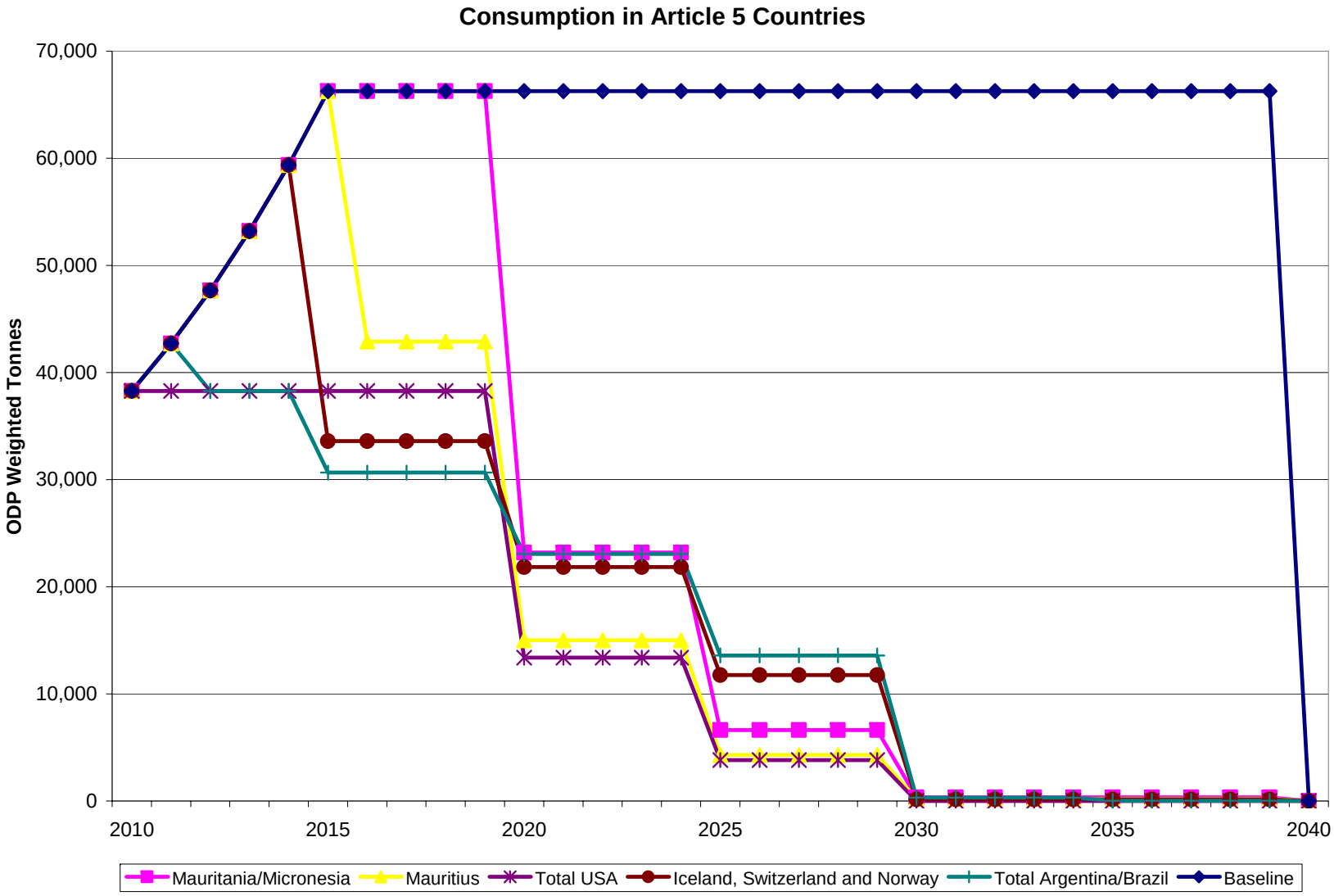
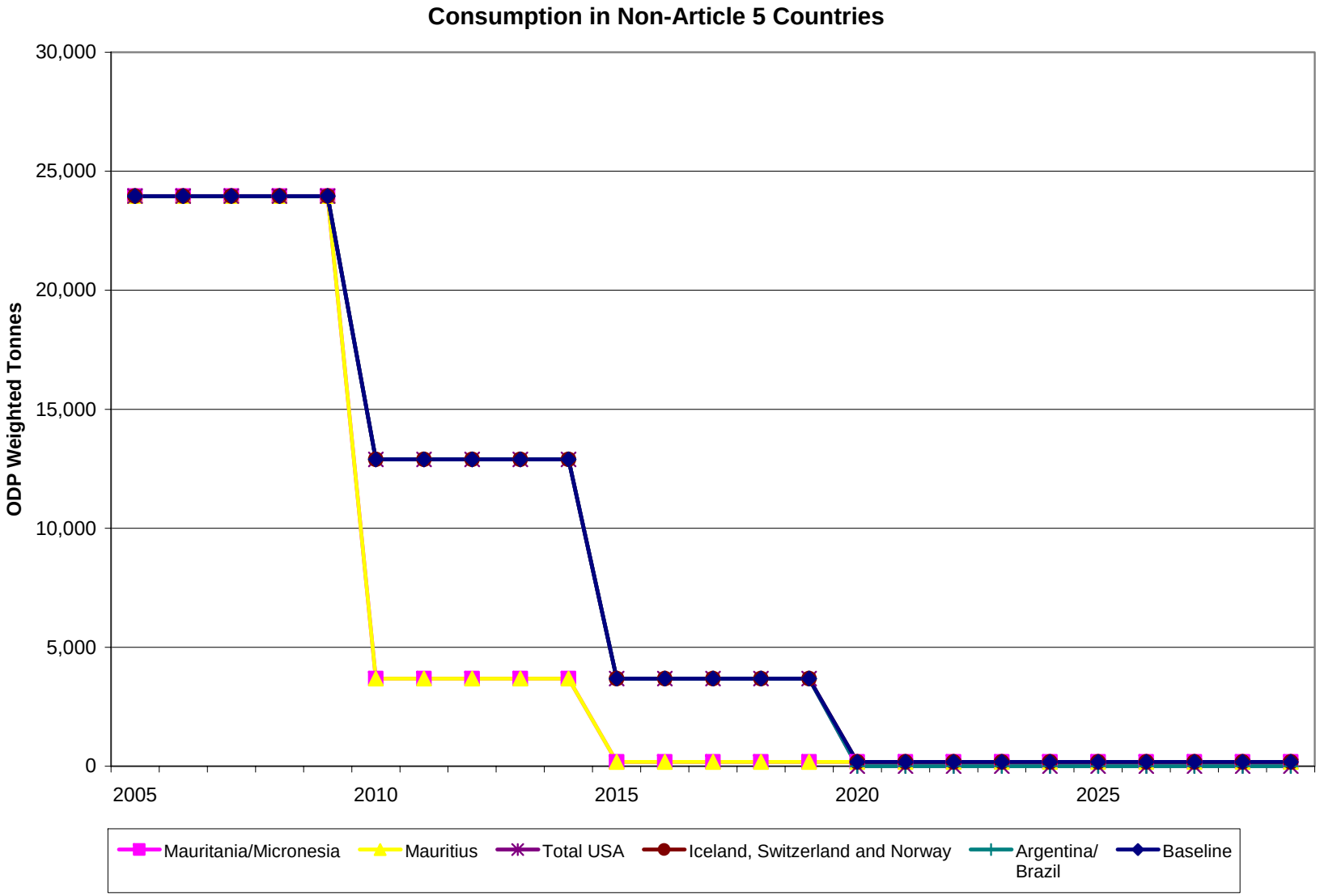


Figure 2. HCFC Consumption in Non-Article 5 Countries Associated with the Proposed Adjustments to the HCFC Phaseout Schedule



4.2. HCFC Production Reductions

Table 7 and Table 8 present the total reductions in HCFC production for each proposed scenario relative to the HCFC production baseline for the scenarios in ODP weighted tonnes and Million Metric Tonnes CO_2 Equivalent ($MMTCO_2E$), respectively. These tables disaggregate the estimates into reductions in the controlled production of HCFCs and reductions in allowances for BDN production. BDN assumptions are included in the proposal summaries in Section 2. Note that the proposal from the United States did not specify an alternate production phaseout schedule, and thus was not included in the production scenarios.

Figure 3 and Figure 4, below represent projected HCFC production, excluding BDN, for A5 and non-A5 countries, respectively. Figure 5 and Figure 6 represent production estimates inclusive of BDN for A5 and non-A5 countries, respectively.

Table 7: Aggregate Reduction in HCFC Production under Each Proposed Adjustment (ODP Tonnes)

		Mauritania & Micronesia	Mauritius	Iceland, Switzerland and Norway	Argentina & Brazil
Reduction in Controlled Production	NonA5	815,867	815,867	768,038	554,540
	A5	777,743	1,022,347	903,468	866,236
	TOTAL	1,593,610	1,838,214	1,671,506	1,420,776
Reductions in BDN Production	NonA5	41,590	41,590	94,272	83,181
	A5	-59,288 [a]	80,485	119,440	75,162
	TOTAL	-17,698	122,076	213,712	158,343
Total Reductions	NonA5	857,457	857,457	862,310	637,721
	A5	718,455	1,102,832	1,022,908	941,398
	TOTAL	1,575,913	1,960,290	1,885,218	1,579,119

[a] This scenario allows an increase in BDN production due to a higher calculated baseline; unlike other proposed adjustments, Mauritania and Micronesia's proposed baseline is based on historical consumption rather than an average of consumption and production or only production.

Table 8: Aggregate Reduction in HCFC Production under Each Proposed Adjustment ($MMTCO_2E$)

		Mauritania & Micronesia	Mauritius	Iceland, Switzerland and Norway	Argentina & Brazil
Reduction in Controlled Production	NonA5	15,550	15,550	14,639	10,570
	A5	14,918	19,610	17,329	16,675
	TOTAL	30,468	35,160	31,968	27,244
Reductions in BDN Production	NonA5	793	793	1,797	1,585
	A5	-1,137 [a]	1,544	2,291	1,455
	TOTAL	-344	2,337	4,088	3,041
Total Reductions	NonA5	16,343	16,343	16,436	12,155
	A5	13,781	21,153	19,620	18,130
	TOTAL	30,124	37,497	36,056	30,285

[a] This scenario allows an increase in BDN production due to a higher calculated baseline; unlike other proposed adjustments, Mauritania and Micronesia's proposed baseline is based on historical consumption rather than an average of consumption and production or only production.

Figure 3. HCFC Production in Article 5 Countries Associated with the Proposed Adjustments to the HCFC Phaseout Schedule, excluding BDN

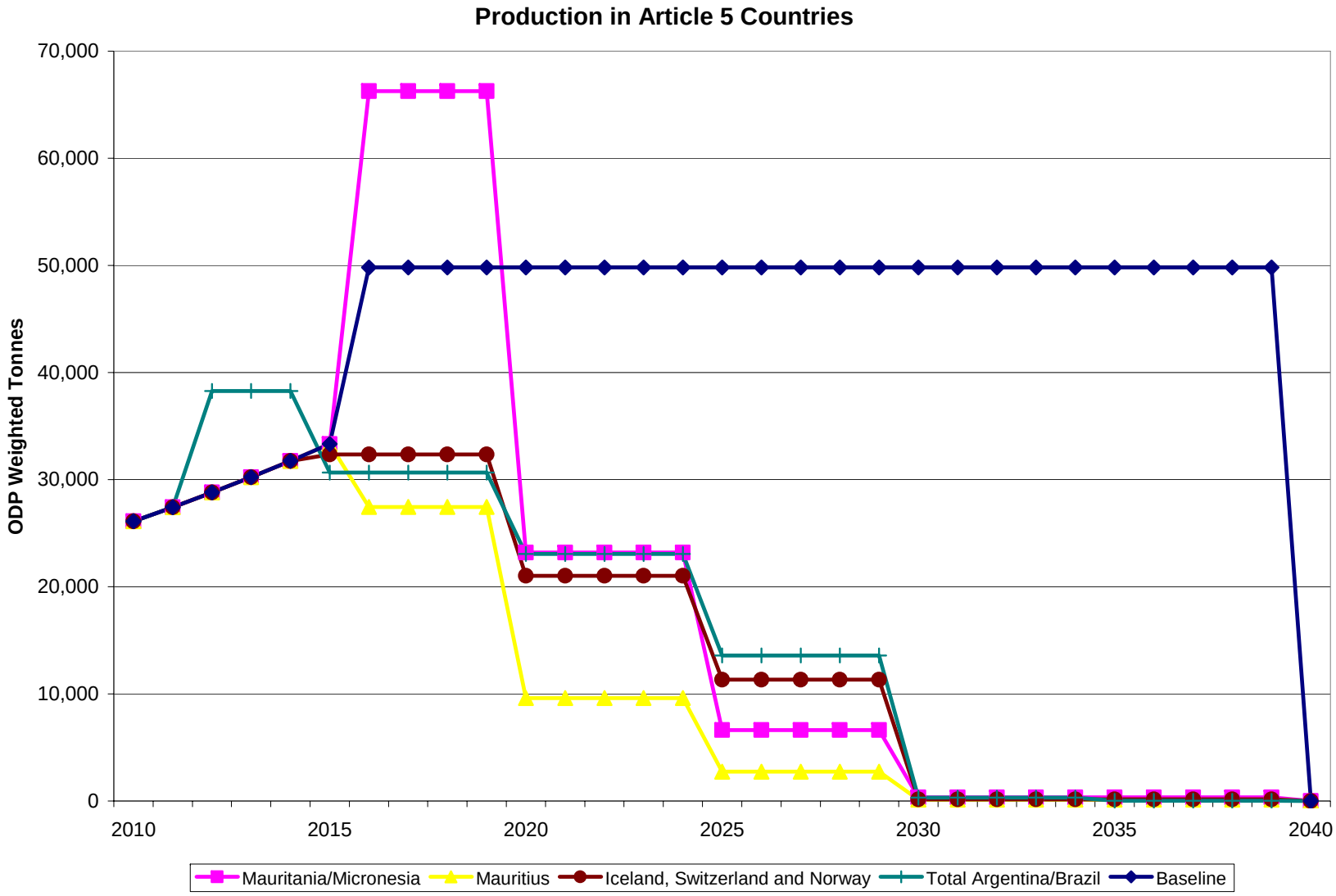


Figure 4. HCFC Production in Non-Article 5 Countries Associated with the Proposed Adjustments to the HCFC Phaseout Schedule, excluding BDN

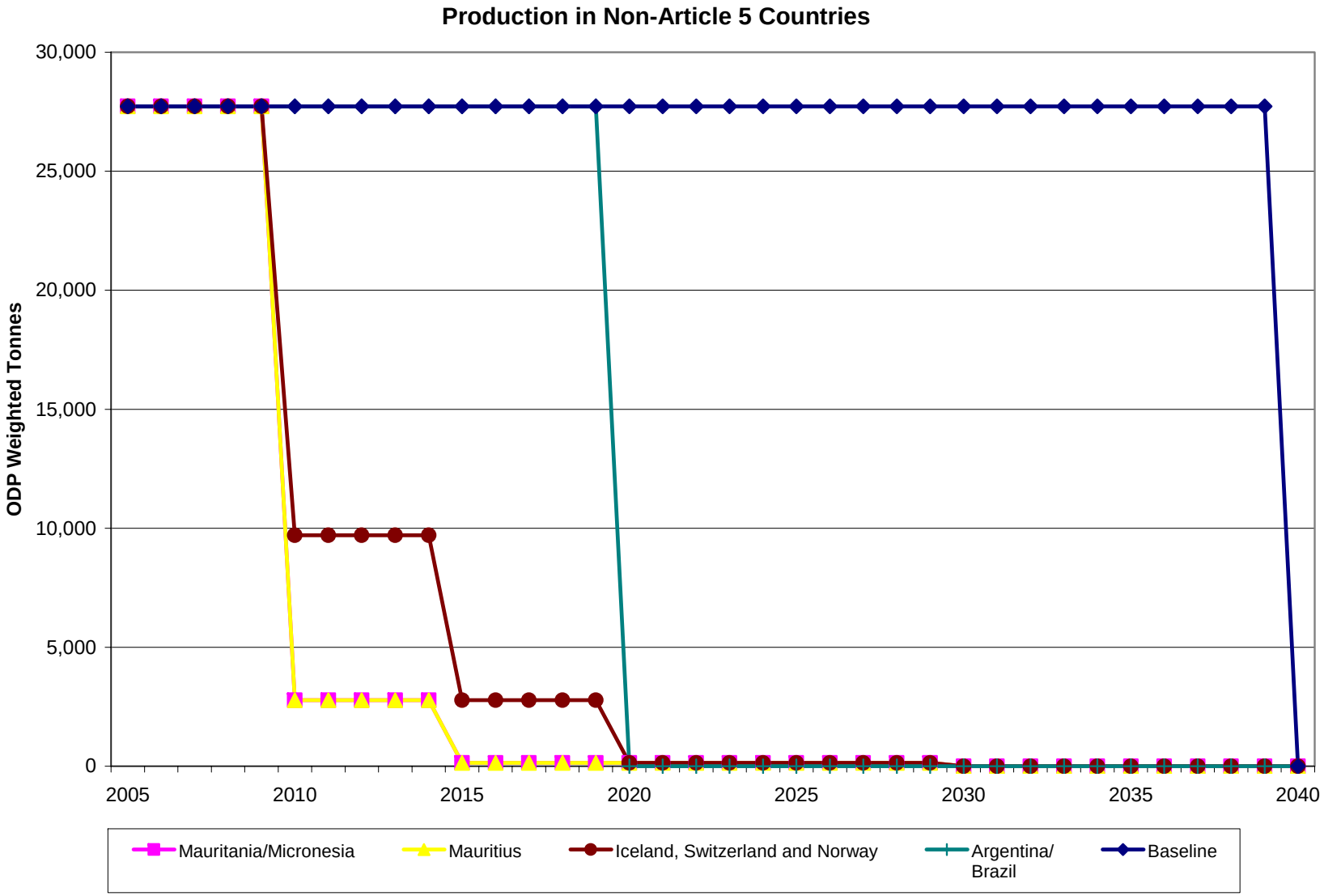


Figure 5. HCFC Production in Article 5 Countries Associated with the Proposed Adjustments to the HCFC Phaseout Schedule, including BDN

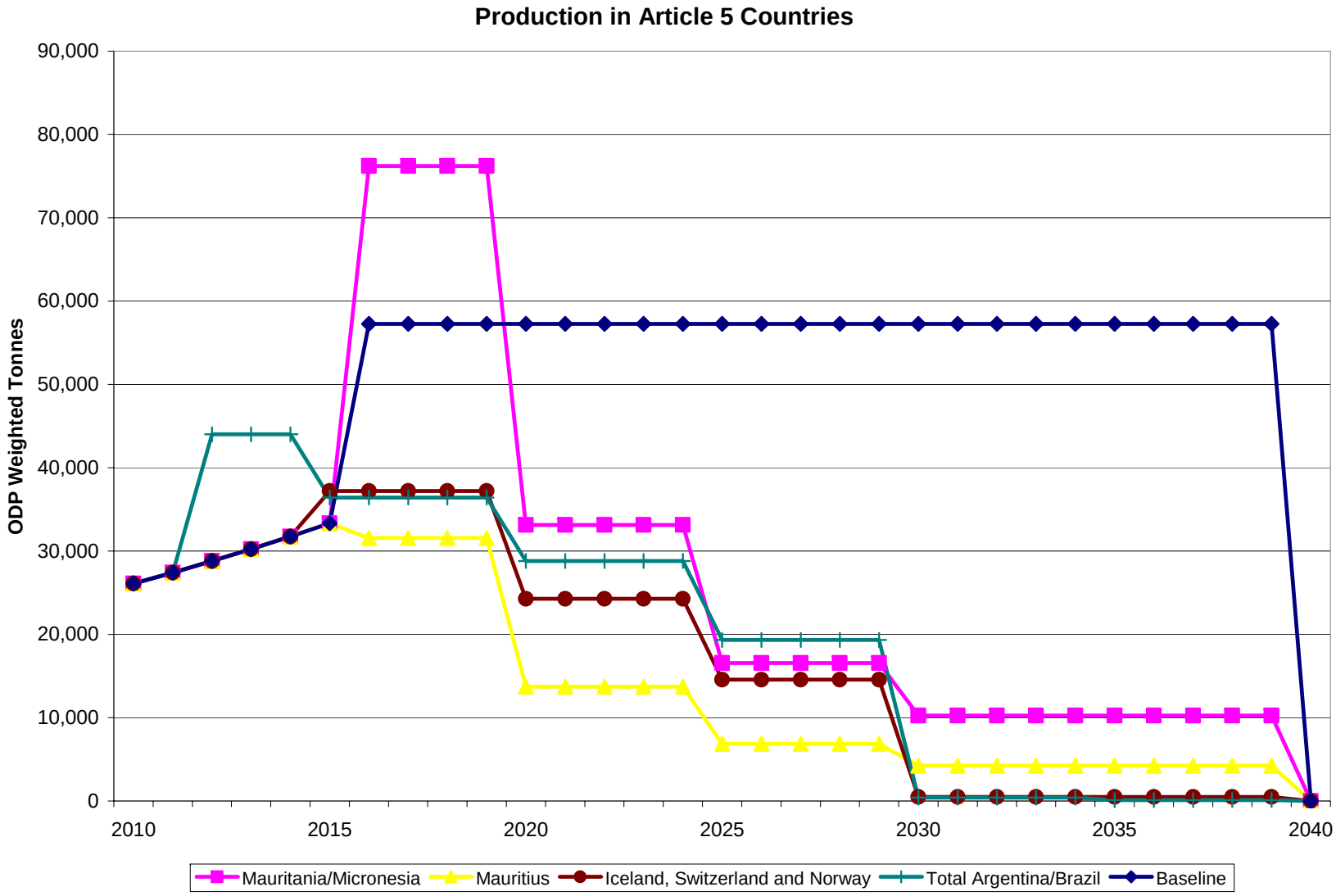


Figure 6. HCFC Production in Non-Article 5 Countries Associated with the Proposed Adjustments to the HCFC Phaseout Schedule, including BDN