Framework for Standardized Baseline Appliance PUR Foam Blowing Agents

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1. Key Sectoral Context

Technology inherent factors due to economics:
Due to economics, enterprises up and down the supply chain form temporary technology or innovation clusters based on each foam blowing agent. The chemicals and the machinery required are available in all countries. No refrigerator manufacturer uses its own foam blowing machinery and all manufacturers buy blowing machinery from a few specialized machinery providers. The machinery providers are few and export to all countries. Besides HFO, all foam blowing agents are used worldwide since several years. Foam technology and economics do not influence appliance prices (unlike compressors). These providers have stable market shares and bind their clients, the refrigerator manufacturers. No new such provider has appeared in the last decade.

Technology inherent factors due to physics:
All agents work with polyurethane foam and the performance criterion insulation (thermal conductivity) can be achieved with all agents. All parameters for appliance users are the same for each agent.

Few Non-Annex I countries have HFC regulations aside of the Montreal Protocol: Belize, Colombia, Burkina Faso and Egypt (UNEP/OzL.Pro.WG.1/34/INF/4/Add.1).

Regulatory context factors:
All "Article 5 countries" (~Non-annex I in Kyoto P.) have an HCFC Phase-out Management Plan (HPMP) submitted and approved. Around one fourth of the Article 5 countries with manufacturing of refrigerators have received funding from the Multilateral Fund to replace HCFC foam blowing agents (a "double phase-out" or "second conversion" after first replacing CFC). These funds are used to pay for foam blowing machinery and the providers of this technology (most from Denmark, Germany and Italy) have responded to this demand for CFC and HCFC replacements, offering equipment for all such replacements that manufacturers prefer.
Multilateral Fund results show that of

> "48 Article 5 countries to phase-out CFC-11 using HCFC-141b technology in the domestic and commercial refrigeration sector showed: 119 enterprises chose cyclo-pentane and 335 enterprises selected HCFC-141b technology"
> (UNEP/OzL.Pro/ExCom/55/47, Annex III).

So 75% of the eligible enterprises chose to use the funding for switching to HCFC-141b and these are now receiving funding a second time for switching to pentane or to HFCs before 2030.

Kown-unkown regulatory context factors:
The machinery providers were aware of the funding levels from the Multilateral Fund per kilogramme of CFC consumption. At present, the Multilateral Fund defines the funding for the replacement of HCFC-141b and soon the Multilateral Fund will determine the funding levels for replacement of HFC-134a and HFC-245fa using foam blowing machinery. Machinery providers are again responding to this demand, offering equipment that manufacturers prefer.

2. Boundary of a Technology Switch

The standardizing of the GHG emissions from foam blowing agent release is straightforward because all variables that influence the GHG emissions arise in the same location, the refrigerator manufacturing line. The blowing agent remains in the foam and is released to the atmosphere at some time, irrespective of the lifetime of the refrigerator or the eventual disposal situation. The only variation of blowing agent volume reflects the refrigerator volume that requires specific volume of insulating foam. The design data of the blowing agent volume per refrigerator is accurate. The injection is fully automatised and last a few seconds. Charging boards accuracy is +/-0.5 gr, that is generally around 1% of the blowing agent volume.

The only modification of the GHG emission would arise if old refrigerators were disassembled or recycled and the foam blowing agent extracted from the insulating foam. Such installations only operate in Europe and Japan

(complete coverage), while only 2 or 3 operate in the US and in Brazil, none elsewhere.

The subject matter of the standardization is not physical like for electricity grid emission factors, or a uniform product as in the cement case, or a data approximation as for the rice milling, but the general upward linkages of foam blowing technology supply. Refrigerator manufacturers buy foaming machinery, PUR and blowing agent and since the sale and operation of the refrigerators are not in any way affected by the foam blowing agent, the manufacturers mainly react to and shape the quality, reliability and price of the supply of foaming machinery, PUR and blowing agent. The standardization of the GHG emissions from foam blowing is pertinent because the supply conditions affect all refrigerator manufacturers in the same way, the technology switch reasons and decisions are the same. A foam blowing agent baseline is a standardization type about upward supply chain relations. These upward supply chain relations are specific for the household appliance sector. In each country, such a standardized baseline allows the DNA to impact the refrigerator manufacturers in a way that the Montreal Protocol does not allow.

Ranking the GHG emission impact of foam blowing agents reflects only the GWP of the blowing chemical because the insulation property of the foam is the same for all chemicals. The performance of HFC-245fa, HCFC-141b and pentane is the same because all manufacturers operate the insulation foam injection for best insulation properties. HFO-1234ze is a new blowing agent, not yet available in most countries.

Table: Global Warming Potential (GWP) of Foam Blowing Agents

	GWP
HFC-134a	1,300
HFC-245fa	858
HCFC-141b	782
Pentane, c-pentane, iso-pentane, n-pentane	5
HFO-1234ze	6

Source: IPCC 2013 Fifth Assessment Report Working Group I Appendix 8.A. and UNEP 2015 Workshop on HFC management: technical issues Fact Sheet 13.

It is possible to collect the actual foam blowing agent charge design data for all refrigerator models with HCFC-141b and those models with Cyclo-pentane from a manufacturer and use this ratio in the emission calculations. This would have to be done for all manufacturers supplying a country. However the effort required is significant while the differences for the averages for each blowing agent are small and insignificant compared to the huge differences in GWP. Reliable empirical data exists from Europe with samples of PUR foam taken in the large refrigerator

recycling plants. The average volume of blowing agent per refrigerator across all sizes and appliances qualities can be treated as constant.

Similarly, there are differences in the release rates of the foam blowing agent, for instance in the IPCC data below. How fast the agent escapes from the PUR depends on mechanical stress on the foam, temperature, light, etc. Again the actual differences are minor. For a standardized baseline the time when the agent is released is not relevant.

In Europe, average foam blowing agent volumes are 230 gr/refrigerator HFC-134a, 270 gr/refrigerator pentane (ZVEI)

Table: Emissions rates for blowing agents

HFC-134a and HFC-152a				
	Product life years	First year loss %	Annual loss	Maximum potential end-of-life loss %
appliances	15	7	0.5	85.5
HFC-245fa and HFC-365mfc				
appliances	15	4	0.25	92.25

Source: IPCC 2006 Guidelines for Nat GHG Inventories, Vol.3 Table 7.6 and 7.7

The GHG impact of a technology switch from one foam blowing agent to another corresponds only to the difference in GWP of the agents.

3. Recent trends in blowing agent for appliances

Having excluded all other variables, it is then necessary to assemble the influences on the decisions by refrigerator manufacturers for a specific blowing agent. The factors for these choices vary between countries and thus DNAs defining the baseline would determine it in light of the decisions by refrigerator manufacturers and refrigerator importers. As described as technology inherent factor, all refrigerator manufacturers buy foam blowing machinery from a few specialized suppliers, who offer their wares in all countries.

Replacing one foam blowing agent with another agent is a technology switch that has no other outcome or repercussion. The user of a refrigerator never knows what foam blowing agent is in a refrigerator and gets the same use value from all of the possible foam blowing agents. Furthermore similar technology switches have occurred in the past, most prominently when CFC-11 was replaced. The technology switch has been shaped by the Montreal Protocol and will continue to be influenced by it. The Multilateral Fund reports

> "for the selection of alternative technologies the limited technical capabilities of many enterprises is most important. Enterprises have opted for HCFC-141b or for cyclo-pentane dependent on locally

available technical support from suppliers"
(UNEP/OzL.Pro/ExCom/55/47, Annex III, page 2).

To further understand this technology switch, one can analyze the choices outside of the Montreal Protocol, i.e. such technology switches in Europe (100% Cyclo-pentane in appliances in 2008) and USA (92% HFC in 2008). Upward supply chain relations are responsible for this stark difference. Manufacturers like Whirlpool have followed the blowing agent offered by DuPont and Honeywell, while the European manufacturers took a different route during the early 1990s (both for refrigerants and blowing agents), anticipating EU "F-gases Regulations".

Baseline and additionality reflect the decision-making of PPs and DNAs. PPs and DNAs are constrained by the implementation rules of the Montreal Protocol, notably the role of the four implementing agencies (UNDP, UNEP, UNIDO and World Bank) and the funding criteria. Both PPs and DNAs would use a standardized baseline especially to discriminate between the possible foam blowing agent replacements because the Montreal Protocol rules do not discriminate between replacements.

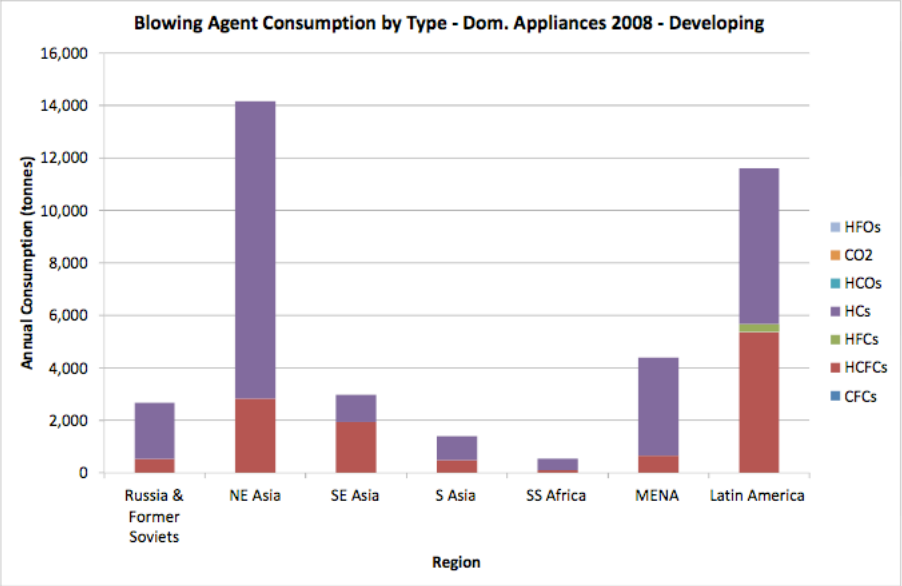
The procedures of the Multilateral Fund guarantee every country "full flexibility" in choosing HCFC replacements (as was the case for CFC replacements). This principle is also maintained in all four currently proposed HFC Amendments to the Montreal Protocol ("regime inertia"). A Ministry of Environment can choose any replacement blowing agent, when there is agreement with the implementing agency and the manufacturer.
In practice, manufacturers sometimes refuse Multilateral Fund support because their preference of an HCFC replacement is not accepted (costs are probably of similar importance as good cooperation along the supply chain). A Ministry of Environment defining a standardized baseline would thereby create an incentive to all manufacturers to pursue an HCFC replacement with least GWP. Therefore a standardized baseline reflects the Montreal Protocol HPMP in every particular country and this impact has two components, the impact on the Montreal eligible enterprises and the impact on the ineligible enterprises.

A standardized baseline can apply to all manufacturers and all importers of household refrigerators in a country. One important aspect for a standardized baseline concerns the ownership of the manufacturers in a country and the Montreal Protocol's distinction between national enterprises and those based in Annex I countries. Enterprises owned by companies based in developed countries and enterprises that produce appliances for exports to developed countries are not eligible. But joint ventures and forms of shared ownership leave a range for case-by-case reasoning for eligibility. The result is in Mexico, for example, the only refrigerator manufacturer still using HCFC-141b today is Whirlpool (US corporation), while Mexican MABE has already switched to Cyclo-pentane with Montreal Protocol funding as the first phase of the Mexican HPMP. Plants with Whirlpool and MABE capital are decided case-by-case.

Whirlpool Mexico is seeking funding for a NAMA from the German/UK NAMA Facility to support its replacement of HCFC-141b blowing agent.

The following graph shows the volumes of foam blowing agents in developing countries in absolute (metric) terms. The majority of appliances (AC and refrigerators) use Cyclo-pentane (labeled "HCs, violet) also because the major exporter, China, has the main appliances exporting companies who switched in advance of respective regulations in developed countries, where HCFC containing appliances are banned.

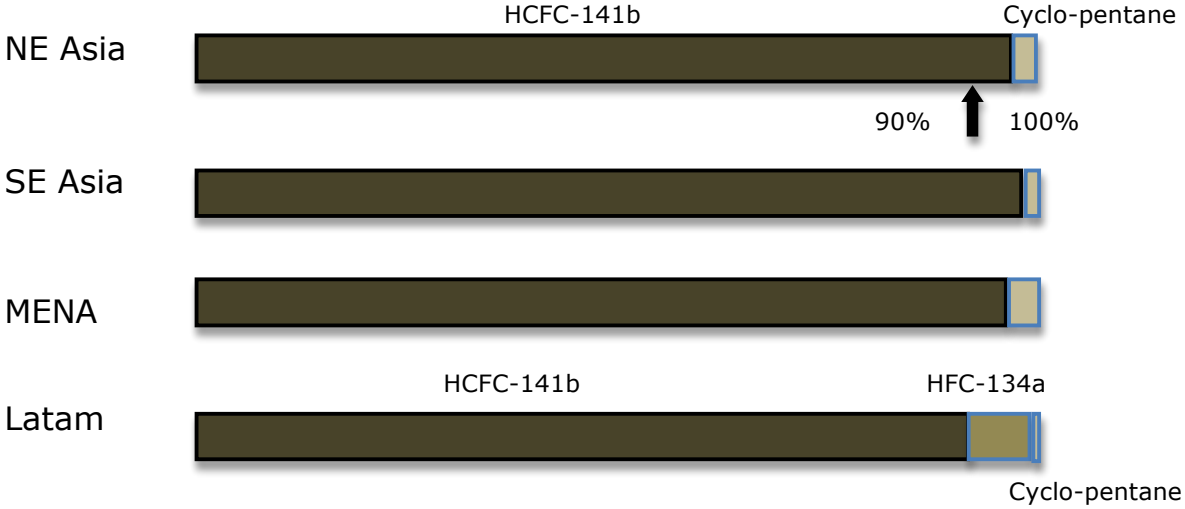
Graph



Source: UNEP 2010 Rigid and Flexible Foams Report, page 7

The HPMPs currently implemented as stage I are funding technology switches from HCFC-141b to ascertain the 35% reduction by 2020 target. The next step is 67.5% reduction by 2025. Cyclo-pentane and HFC-245fa are the only replacements pursued. Ranking these replacements for the entire sector is calculated multiplying total volumes and GWPs:

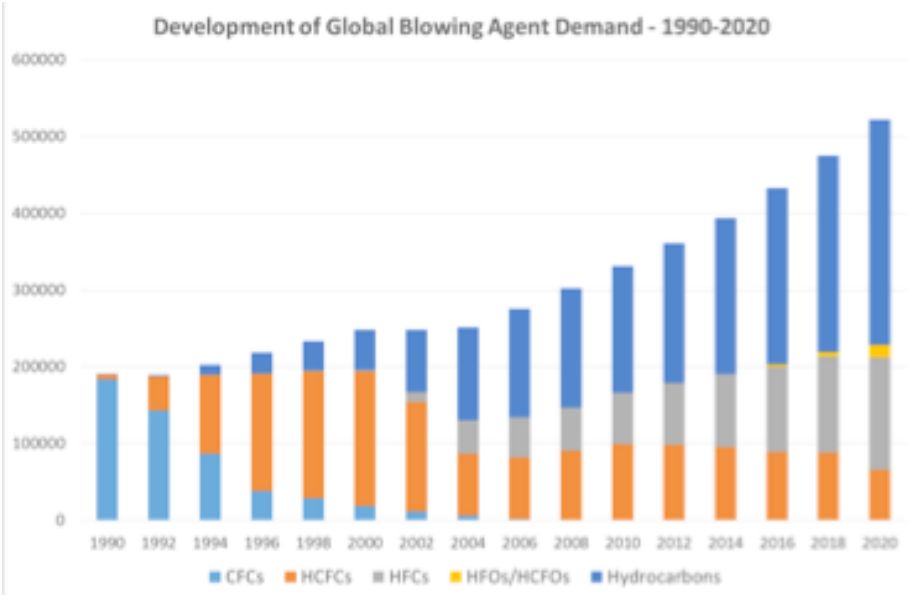
Graph: Bar charts



The above charts represent the context prior to the start of the Montreal Protocol's HPMP implementations, scheduled to continue until 2030. The

standardized baseline should reflect the context where two technology switches occur in parallel, some enterprises replace HCFC-141b with Cyclo-pentane and others opt for HFC-134a or HFC-245fa. These two technology switches are taking place and continue to get Multilateral Fund funding until 2030. The following Graph is the most recent prediction of the Montreal Protocol's FTOC. Key issue is that HFC (grey) use continues to expand with the reduction in HCFC-141b.

Graph Global trend in all blowing agents



SOURCE: UNEP 2014 Report of the Rigid and Flexible Foams Technical Options Committee, page 6.

4. Measure-specific standardized baseline

A foam blowing agent standardized baseline can aggregate HPMP ineligible enterprises, eligible ones and appliance imports or separate the three. The impact of the baseline threshold is similar because of the big difference in GWP between the HFCs and Cyclo-pentane (858 and 782 versus 5 for the latter). Even where Cyclo-pentane has a market share of 80% (NE Asia), 96% of the appliance foam blowing agents' GHG impact is from HCFC-141b (bar chart above). The impact on PP decisions is reducing the cost barrier and only the cost barrier. In the following table "retrofit" corresponds to adapting existing equipment, notably the foam dispenser versus replacing the dispenser. "High" corresponds to 75 tons of foam blowing agent use per year and "low" to 5 tons per year.

Table: Technology switch costs reported under the Montreal Protocol ($)

	HFC-245fa		Cyclo-pentane		
	low	high	low	high	
Retrofit	30,000	60,000	375,000	710,000	

Replacement	100,000	195,000	385,000	780,000	

Source: UNEP/OzL.Pro/ExCom/55/47, p.17

Table: Incremental operating cost ranges for blowing agents (US$/kg)

	low	high
HCFC-141b	2.5	3.8
Pentane	1.9	2.5
Cyclo-pentane	2.1	3.3
HFC-134a	5.6	7.6
HFC-245fa	10.4	12.0

Source: UNEP/OzL.Pro/ExCom/55/47, p.18

Most of the higher investment cost for Cyclo-pentane is for safety equipment like ventilators, leak detection and alarm sensors as it is flammable. Emission reduction credits for switching to Cyclo-pentane would compensate part of this cost. For a manufacturer producing 200,000 refrigerators per year, average refrigerator size, foam blowing agents volume of 50 tons per year are used, the difference between HFC-245fa and Cyclo-pentane corresponds to 43,000 tCO_2e annually, for HCFC-141b and Cyclo-pentane 39,000 tCO_2e.

For HPMP ineligible enterprises, a switch to Cyclo-pentane is generally not financially attractive, while for HPMP eligible enterprises the so-defined "incremental costs" are funded from the Multilateral Fund. Eligible enterprises in for example Thailand and Indonesia have refused to participate in the HPMPs so the Multilateral Fund definition of incremental costs funding is not always enough to compensate other negative factors (such as safety). All those who refuse opt for HFC blowing agent and refrigerants. A standardized baseline can add significant incentive for all HPMP ineligible and eligible enterprises to choose lowest GWP replacements.

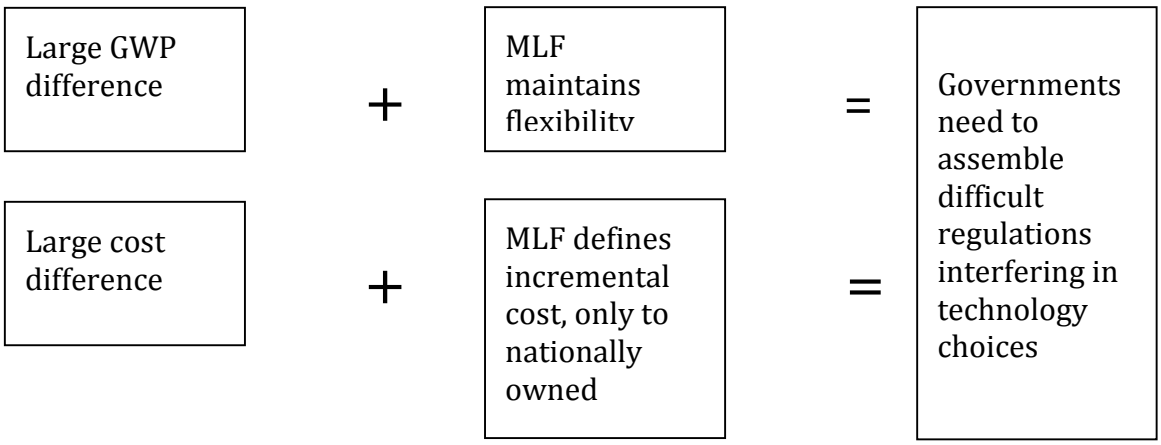
For HPMP ineligible enterprises, a standardized baseline effectively prevents a switch to HFC-245fa if the baseline includes HCFC-141b. In some countries such as South Africa and Brazil all foam blowing agent HCFC-141b users are ineligible for the HPMP because they are foreign owned and this is a factor why these enterprises explore using HFO and HFC-245fa.

Box: Differences in baseline scenarios among developing countries

Foam blowing agent technology switches in developed countries have been rather different between US opting for all HFC foam blowing agents and Europe plus Japan for Cyclo-pentane. In developing countries, technology switches also vary. Also because some have only HPMP eligible enterprises, others only ineligible enterprises and those countries with both eligible and ineligible ones. Although all developing countries have at least a HPMP stage I, the HPMP criteria are evolving and it is not certain for most developing countries how to convince all eligible enterprises (only for those eleven countries that have submitted HPMPs

with refrigerator foam blowing components the enterprises' reactions are clear). Some countries created legislation banning HCFC-141b, Turkey from 2013, Philippines from 2014, Peru from 2015, South Africa from 2018, ahead of their obligation under the Montreal Protocol.

A measure-specific standardized baseline is adequate for foam blowing agents because this technology switch is independent from other changes and all appliance manufacturers have the same choices. Cost differences are not the only factors because Multilateral Fund support is not always sufficient. The impacts and outcomes of a standardized baseline can be influential for two reasons, it addresses both ineligible and eligible enterprises and it discriminates between HCFC replacements reflecting their GWPs, both reasons are part of the Montreal Protocol regime (and not fully resolved in the procedures of the Multilateral Fund).



5. Currently implemented HPMPs for foam blowing agent

Almost all developing countries have an HCFC Phase-out Management Plan (HPMP) stage I approved by the Multilateral Fund and in implementation to achieve the 35% reduction for HCFC in 2020. Several have also embarked on stage II HPMPs. The rules for these HPMP are not complete because of different views on costs and benefits especially for refrigerants like HCFC-22 and the efficiency of these refrigerant replacements in high-ambient temperature countries. Furthermore there is controversy because of the frequent substitutions of refrigerant HCFC-22 with HFCs in connection with commercial interests of HFC compressor sales (Montreal decision XIX/6 and XXV/5). Contrary to refrigerants, the foam blowing agents' phase-outs are generally not controversial, also because these are not needed for refrigerator maintenance. The eleven HPMPs already in implementation in eligible enterprises have mostly switched to Cyclo-pentane with two exceptions, India where a mixture of Cyclo-pentane and HFC-245fa (75% / 25%) has been introduced, and Indonesia.

Table: Foam blowing agent cases for household appliances among all HPMPs in implementation worldwide

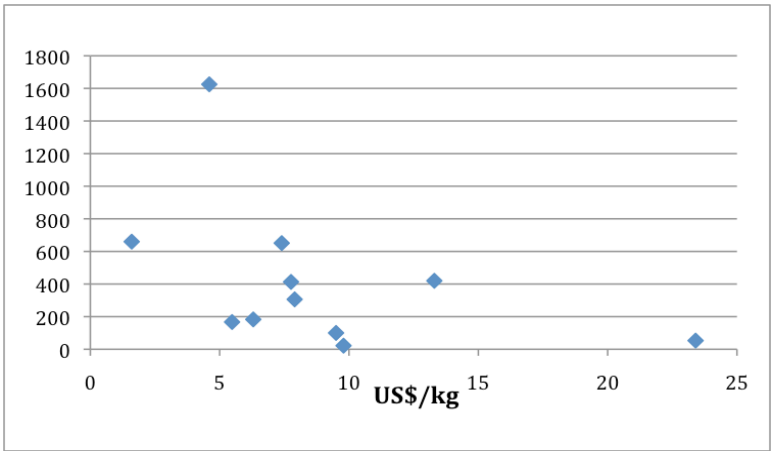
	HCFC-141b replaced metric tons	Cost mio US$	US$/kg	Cyclo-pentane mt	Submission ExCom#
Mexico	306	2.42	7.9		72/33
Colombia	420	5.61	13.3	426	60/25
Algeria	22	0.21	9.79		62/18
Morocco	100	0.9	9.5		62/41
Sudan	53	1.24	23.4		62/49
Pakistan	651	4.84	7.4	391	62/44
Bangladesh	183	1.15	6.3	114	65/24
Argentina	167	0.914	5.48		66/28
India	1,625	7.49	4.6	75% / 25%	66/29
Iran	660	1.09	1.6		72/29
Indonesia	413		7.76	370	75/49
				2+7 to 245	64/34

$/kg-ODS/y

The data in the above table are ex-ante because no verification documents have been submitted to the Multilateral Fund so far. Under the procedures of the Multilateral Fund, HPMPs are defined by one of the four implementing agencies, UNDP, UNEP, UNIDO and the World Bank. An implementing agency submits an HPMP on behalf of each government to the Fund and the influence of the respective Ministry of the Environment is different from one country to another. Implementing agencies advise the Ministry of the Environment and the enterprises and within this advise the experience of the implementing agency when interpreting Multilateral Fund procedures is influential.

The comparison of these first eleven foam replacements reveals that specific costs vary and long delays of 26 months on average (UNEP/OzL.Pro/ExCom/75/9, p. 2) occur. There is only a weak correlation between specific costs and production volume.

Graph: HCFC-141b volumes versus specific incremental costs per kg replaced in eleven HPMPs



The variation in specific costs is partially due to the variability of technical choices in equipment and partially to differences in prices for this equipment even so the manufacturers of equipment are the same (but not the suppliers of chemicals). Furthermore it is important to consider that the GHG outcome of the technology switch is not affected by other variables but there are other technology switch parameters important for the manufacturing process that motivate an enterprises to opt for certain equipment offering particular improvements on product range or quality (while not affecting GHG).

It is therefore unavoidable that a DNA's definition of a standardized baseline is informed by the particular HPMP. The equivalent of a DNA for the Montreal Protocol is called "National Ozone Office" (NOO). A foam blowing agent standardized baseline certainly requires good coordination between the DNA and the National Ozone Office and this coordination follows national policy making habits.

The only option for a positive list for blowing agents would be HFOs because this is the only new option. But this is not attractive for a DNA because there is only one or two possible suppliers worldwide. An additionality criterion based on investment costs can be developed based on HPMP results.

Additionality defined from blowing agent prices only ?

6. Baseline options

CDM methodology AMS-III.N concerns a technology switch from HFC to Cyclo-pentane and a standardized baseline for ineligible enterprises can apply this methodology when it used only HFC three year prior. However the project by project approach fails to address sectoral factors that are strong for foam blowing agents, the upward supply chain relations. Refrigerator manufacturers buying machinery, blowing agent and PUR from a small number of international suppliers and their technical support has been the first concern for the manufacturers. The decision by a PP using a standardized methodology is certainly informed by the foam blowing agent decisions by his competitor enterprises.

All manufacturers might chose to cooperate for foam blowing agent supply when they see it as advantageous to do so. Manufacturers linked to international corporations are mostly ineligible for Multilateral Fund support and these might also chose to not cooperate with other manufacturers. For appliances there is also a strong link among international corporations to their " Original Equipment Manufacturers " (OEMs) producing under licensing agreements with the corporations, especially for refrigerators.

A standardized baseline is a suitable instrument because of these upward supply relations and a DNA can decide to include all blowing agents, including HCFCs and cyclo-pentane (in the future perhaps also HFO) so that the GHG impact of the entire sector is reflected.

Related rulings have been used for AM0060 and AMS-III.N where all GHG defined in the Convention Article 5 are classified as leakage. Going forward it is also certain that HFCs will be included in the Montreal Protocol and this will certainly occur under the premise that HFCs are addressed both in the Montreal Protocol and the Kyoto Protocol so that all HFC rules in the Kyoto Protocol are not affected by the inclusion of HFCs in the Montreal Protocol. The Montreal Protocol rules for HFCs will promote technology switches from HCFCs to Hydrocarbons avoiding HFCs as a false short term option and therefore a Standardized Baseline should include HCFC in the baseline scenario.

A DNA might opt to include only Multilateral Fund ineligible enterprises in the baseline if the DNA wants to affect decision making in the ineligible enterprises alone, or the DNA might choose to include all manufacturers in the baseline. The latter option would increase the impact of the standardized baseline.

Next, a DNA might also include eligible enterprises if the DNA judges that the technology choices offered under the conditions of the Multilateral Fund (by the implementing agencies) do not reflect the conditions or interests of the eligible enterprises. A Ministry of Environment's policy choice to develop a HPMP is limited by the implementing agencies. One such situation that occurred is a case of an enterprise that wanted to install several pre-mixers in parallel so that it could switch faster between refrigerator model sizes and formulations but the Multilateral Fund secretariat argued that this was too costly. In such circumstances, a standardized baseline would be an alternative policy instrument that offers other conditions that those in Multilateral Fund procedures.

Table: Baseline scenario options

	Recent technology switches in Baseline scenario	Policy choices
	all BA used in all enterprises in the last 3 years PLUS all refrigerator imports in the last one year	DNA and National Ozone Office avoid influencing technology changes

	only ineligible enterprises BA choices in the last 3 years	DNA provides incentives for enterprises excluded from the Multilateral Fund
	only eligible enterprises BA choices in the last 3 years / only ineligible enterprises BA choices in the last 3 years	DNA and National Ozone Office pursue an articulated sector strategy for all enterprises

7. Benchmark level

Use of foam blowing agent results in "lumpy" decisions among a small number of plants of manufacturers in a country, for refrigerators typically between 5 and 15, and for Air-conditioners between 5 and 80. These decisions are also lumpy regarding the number of years in operation.

A baseline should reflect the overall sector, all foam blowing agents used a country as well as changes in the two or three years preceding. These two aspects reflect that manufacturers choosing a blowing agent not yet introduced might be paying a higher price than one that follows the preceding decisions. Besides this volume influence, a baseline should also reflect the size of the manufacturing plant. Montreal Protocol rules typically assume that investment costs vary by a factor of 2 between a 5 ton annually blowing agent using plant and a 75 ton using plant.
Baseline scenario the top 20% based on output delivered - a criterion used effectively in large industry for example aluminum or cogeneration.

A DNA's decision whether to include eligible or ineligible enterprises in the baseline is probably broader than the decision which blowing agents to include. Two aspects are decisive for this, first cost differential between HFC and Cyclo-pentane and second the rules for incremental costs applied by the implementing agency of the Multilateral Fund.

Benchmark definitions can target the best overall sector outcome using -
All eligible enterprises blowing agents in the preceding year as benchmark for the ineligible enterprises.
The baseline for eligible enterprises can be an 90% of the sector baseline if one or more eligible enterprises have introduced a blowing agent with more than 10% of the lowest GWP blowing agent in the preceding year.