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SUMMARY REPORT:

Barriers to the use of Low-GWP Refrigerants in Developing Countries & Opportunities to Overcome These

United Nations Environment Programme

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BARRIERS TO THE USE OF LOW-GWP REFRIGERANTS IN DEVELOPING COUNTRIES AND OPPORTUNITIES TO OVERCOME THESE

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SUMMARY

Hydrochlorofluorocarbons (HCFCs) are widely used throughout the refrigeration and air conditioning (RAC) industry, especially in Article 5 countries, and their use is continuing to grow at a significant rate. In 2007, at the 19th Meeting of the Parties of the Montreal Protocol an adjustment was agreed upon to accelerate the phase-out of HCFCs in developing (Article 5) and developed countries. The current "default" replacement of HCFCs in most RAC equipment is hydrofluorocarbons (HFCs). However, these have on average a higher global warming potential (GWP) than HCFCs, which could therefore increase the equivalent emissions of greenhouse gases from this sector if directly substituted. Alternative options include refrigerants with low-GWP, which include hydrocarbons (e.g. R290, R600a), ammonia (R717), carbon dioxide (R744) and new unsaturated HFCs (such as R1234yf). However, whilst these low-GWP alternatives (LGAs[1]) to R22 (chlorodifluoromethane) can be used across a wide range of RAC equipment, they are not generally applied. Therefore the objective of this study is to try to understand the reasons as to why this is, particularly in Article 5 countries.

The general approach for this study was through asking stakeholders within a variety of Article 5 countries about the types, causes and ways of overcoming the barriers to using LGAs. Over 100 individuals provided information from some 40 different countries, in response to a questionnaire and discussions during workshops and meetings.

The feedback yielded identification of about 30 different barriers of several different types: technical (refrigeration and safety), supply and availability, commercial, market, information resources, regulations and standards and psychological and sociological aspects, and that the relevance of each of the posed barriers will differ according to country, nature and size of the enterprise, design of system, type of refrigerant, and so on. These various barriers were allocated a significance rating in order to identify those which are most challenging. Those barriers identified by respondents in the survey which they considered to be the most significant were:

- "There are no systems using LGA refrigerants available to buy"
- "There is nothing to incentivise enterprises to invest in LGA technology"
- "No one is willing to invest in production of systems, parts, components and refrigerants"
- "Consultants developing HPMPs are not recommending LGA refrigerants for projects"
- "The rules for using LGA refrigerants are too restrictive to allow their use"
- "There is a general fear of the safety risks".

It is possible that the majority of the barriers can be overcome by determination in implementing a number of measures relating to the areas of awareness-raising within the industry, training that is focussed on LGAs, appropriate technical and other guidance, technical developments in the areas of system efficiency (for R744) and safety (for flammable refrigerants), local market development for LGAs, financial incentives to favour LGA technologies, improvements and changes to regulatory infrastructure, addressing Montreal Protocol issues (such as funding criteria and actions of implementing agencies) and activities of environmental non-governmental organisations (ENGOs).

[1] The initialism "LGA" is used only in the context of this report to refer specifically to refrigerants with low-GWP that may be used as alternatives to HCFCs, in particular R22.

1. INTRODUCTION

1.1 Use of HCFCs in refrigeration and air conditioning

Hydrochlorofluorocarbons (HCFCs) are currently used extensively throughout a range of different types of refrigeration and air conditioning (RAC) systems. The most commonly used HCFC in RAC systems is R22 (chlorodifluoromethane), where the annual consumption for developing (Article 5) countries in 2009 is around 300,000 tonnes. Some of this is for charging new appliances or newly installed systems (no more than a quarter of this amount), whereas the remainder goes towards replenishing the refrigerant in existing systems; the bank is estimated at over 1 million tonnes. As a result, it can be estimated that the R22 emissions equate to around 400 million tonnes of CO_2-equivalent per year[2] (based on a 100 year time horizon of 1,800 $kgCO_2/kg$). Table 1 shows the approximate split in the consumption and bank of R22 between different types of systems. Other sectors such as domestic refrigeration, mobile air conditioning, transport refrigeration, etc., have a negligible use of R22.

Table 1: Approximate split between R22 consumption and bank in different types of systems [3]

Type of system	Consumption (tonnes)	Bank (tonnes)
Commercial refrigeration – supermarkets	10%	10%
Commercial refrigeration – condensing units	35%	10%
Industrial refrigeration	5%	10%
Stationary AC – chillers	5%	10%
Stationary AC – large central	10%	15%
Stationary AC – split, window	35%	45%
Total	100%	100%

1.2 Framework

At the 19th Meeting of the Parties of the Montreal Protocol in 2007, an adjustment was agreed upon to accelerate the phase-out of HCFCs in Article 5 and non-Article 5 (developed) countries.[4] This was primarily intended to further mitigate ozone depletion. Figure 1 presents the current phase-out schedule for HCFCs, where there is a freeze in 2013 based on the average of 2009-2010 consumption/ production levels, and from 2015 there is a step down every five years. From 2030 only 2.5% consumption is permitted for 10 years for servicing only. Also indicated in Figure 1 is the rate of "uncontrolled growth" of HCFC consumption.

[2] Estimated from UNEP Technology and Economic Assessment Panel Task Force Decision XX/8 Report, "Assessment of alternatives to HCFCs and HFCs and update of the TEAP 2005 supplement report data", May 2009

[3] Based on data within 2006 UNEP Refrigeration and Air Conditioning Technical Options Committee Report

[4] UNEP/OzL.Pro.19/7

In considering the significant greenhouse gas emissions resulting from the potential options to replace HCFCs, this adjustment also included additional requirements to consider reducing global warming emissions. In particular, it was stated:

- *Item 9.* "To encourage Parties to promote the selection of alternatives to HCFCs that minimise environmental impacts, in particular impacts on climate, as well as meeting other health, safety and economic considerations"
- *Item 11 (b).* "Substitutes and alternatives that minimise other impacts on the environment, including on the climate, taking into account global-warming potential, energy use and other relevant factors"

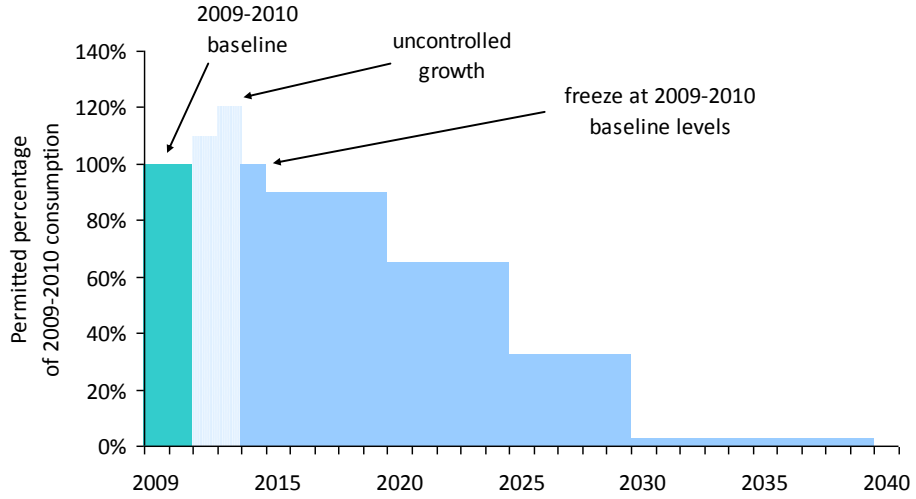

Figure 1: Current HCFC phase-out schedule for Article 5 countries

This adjustment therefore implies that the use of low-GWP refrigerants should be considered when replacing HCFCs. Furthermore, during the 60th meeting of the Executive Committee of the Multilateral Fund (ExCom), it was agreed for HCFC phase-out projects, to achieve the 2013 and 2015 HCFC phase out compliance targets, that additional funding of up to 25% above the cost effectiveness threshold will be provided for projects when needed for the introduction of low-GWP alternatives.[5] The reason for this is to help Article 5 countries overcome the additional barriers to the use of low-GWP alternatives. However, it should be noted that this is implied to apply to investment projects only, for example conversion of factories and not capacity building activities.

The task of phasing out R22 can be considered to be a major challenge. Since 1998 there has been a steady linear growth in the consumption of HCFCs, equating to around 50,000 tonnes per year, or 35,000 tonnes per year of R22.[6] Based on 2005 levels, this is an average of around 10% per year (bearing in mind that in certain countries this rate is exceeded and may approach up to 20% per year in some cases). If this trend is extrapolated, the business-as-usual scenario suggests that R22

[5] Under Decision 60/44 in UNEP/OzL.Pro/ExCom/60/54
[6] Velders, G., et al, 2009, The large contribution of projected HFC emissions to future climate forcing, www.pnas.org/cgi/doi/10.1073/pnas.0902817106

consumption in 2020 would be double the 2009-2010 value; in order for Article 5 countries to achieve the 35% reduction required by the adjustment to the Montreal Protocol, significant interventions are necessary. If this growth is simply substituted for "conventional" alternatives, such as hydrofluorocarbons (HFC), the climate impact arising from emissions could be further intensified. Assuming direct substitution of HFCs for R22, the equivalent direct greenhouse gas emissions could become 50% higher than the business-as-usual scenario. For this reason, there is a strong motivation to encourage the adoption of low-GWP alternatives.

To help assist developing countries with the accelerated HCFC phase-out, UNEP DTIE has undertaken the "JumpStart" project [7] with support from the European Union. One element of this project is the present study to carry out a survey to identify the barriers to the use of low-GWP refrigerants as alternatives to HCFCs (in particular, R22), in countries operating under Article 5 of the Montreal Protocol (i.e. developing countries).

1.3 Alternative refrigerants

As detailed above, there is a tremendous amount of R22 consumption that must somehow be avoided. There are various means of achieving this, including:

- Better leak prevention (tightness)
- Improving recovery and reuse practices (supported with availability of recycling facilities)
- Application of alternative refrigerants

Since the use of HCFCs must ultimately be completely eliminated, then the use of alternatives refrigerants is a core element of the approach. There are a variety of different alternative refrigerants, and these may be categorised into the following several groups:

- HFC/PFC (perfluorocarbon)/HC (hydrocarbon) mixtures used as "drop-in" replacements (e.g., R417A, R419A, R422D, R424A, R422A, R427A, R428A, R434A)
- HFC single component/HFC mixtures (e.g., R134a, R407A, R407C, R404A and R410A)
- HC and HC mixtures (e.g., R600a, R290, R1270, R433A, R436A)
- Ammonia (R717)
- Carbon dioxide (R744)
- Unsaturated HFCs (also marketed as "HFO"; e.g., R1234yf, R1243zf)

Each of these groups of alternative refrigerants possesses different characteristics that affect their suitability to be used, according to environmental, safety, cost and efficiency constraints. From a climate perspective, the first two groups – HFC/PFC/HC mixtures and HFC single components/HFC mixtures – all have high GWPs, (typically higher than R22). In relation to the consumption data in Table 1, if the use of R22 was directly replaced by HFCs in the same manner as has been the case in non-Article 5 countries (i.e., R404A [GWP = 3,900] in commercial and industrial refrigeration, R134a

[7] http://web2.unep.fr/hcfc/Default.aspx

[GWP = 1,430] and R407C [GWP = 1,800] but mainly R410A [GWP = 2,100] in air conditioning)[8] then it would result in a significant climate impact. The "lumped" GWP of the combined substitution of R22 with various HFCs would be around 3,000 kgCO_2/kg; some 65% greater than the GWP of R22. Instead of the emissions being 400 million tonnes of CO_2-equivalent in 2009, it would increase by around 270 million tonnes to 670 million tonnes of CO_2-equivalent. Projected to 2020, emissions would be more than 1,300 million tonnes of CO_2-equivalent.[9]

These emissions could be greatly reduced if refrigerants with a low-GWP were used instead. Therefore, within the context of this current work, the latter four groups of alternatives are of interest. Table 2 provides an overview of these low-GWP alternative (LGA[10]) refrigerant categories and their general characteristics with regards to typical application criteria.

Table 2: Overview of implications of low-GWP refrigerant options

Refrigerant type	Safety	GWP	Efficiency	Cost	Other
HC	Lower toxicity, higher flammability – changes to system construction MUST be addressed, and reduce charge sizes to mitigate flammability risk; easier to use in new systems	~ 3	Good	½ × to 2 × R22	Miscible with mineral oils, but should avoid drop-in for safety reasons
Ammonia	Higher toxicity, lower flammability – use mainly limited to indirect systems or direct systems in unoccupied spaces; needs specialist design work	0	Excellent	<< R22	Incompatibility with copper materials, cannot be used as drop-in
Carbon dioxide	Lower toxicity, non-flammable – very little restriction in application, but has high operating pressures so entire construction must be suitable for such pressures	1	Good in cool, poor in hot climates	< R22	High operating pressures so cannot be used in existing systems; supercritical cycle demands expert design work
Unsaturated HFC	Lower toxicity, lower flammability – changes to system construction is necessary (if shifting from R22, few changes from R134a)	~ 4	Medium	>> R22	Very new products not commercially available yet, many unknown factors

Due to the characteristics summarised in Table 2, any one of these LGA refrigerants is not universally applicable in all situations where R22 is normally used. In certain types of systems, LGA refrigerants are currently used, in others they can be used for the same application but systems may not necessarily have been developed or commercialised. Table 3 provides an indication as to the types of systems for which the various LGA refrigerants are currently and potentially applicable. Note that in

[8] Based on use profiles indicated within the 2006 UNEP Refrigeration and Air Conditioning Technical Options Committee Report

[9] A comprehensive table listing that latest GWPs for all common refrigerants can be found in Chapter 2 of the UNEP Refrigeration and Air Conditioning Technical Options Committee Report

[10] This initialism "LGA" is used only in the context of this report to refer specifically to refrigerants with low-GWP that may be used as alternatives to HCFCs, in particular R22.

the table, other subsectors are also included that do not necessarily use R22, but where LGA refrigerants could be used.

Within Table 3, where the suitability is provided in parentheses – (Y) – this indicates that there is usually a change in the architecture of the system necessary in order to apply the refrigerant. An indication of this would be the use of an indirect system instead of a direct system.[11] Similarly, for certain applications the use of two LGAs may be used in combination, for example, a cascade type system.[12]

Table 3: Approximation of suitability of different refrigerant options in new systems

Type of system	Currently available				Viable/under development			
	HC	R717	R744	uHFC	HC	R717	R744	uHFC
Domestic refrigeration	Y	Y †	N	N	Y	Y	Y	Y
Commercial refrig – s/markets	(Y)	(Y)	Y	N	(Y)	(Y)	Y	(Y)
Commercial refrig – cond units	N	N	N	N	(Y)	N	Y	(Y)
Commercial refrig – stand alone	Y	N	Y	N	Y	N	Y	Y
Industrial refrigeration	Y	Y	Y	N	Y	Y	Y	Y
Stationary AC – chillers	Y	Y	Y	N	Y	Y	Y	Y
Stationary AC – large central	N	N	Y	N	(Y)	N	Y	(Y)
Stationary AC – split, window	Y	N	N	N	Y	N	Y	Y
Air conditioning – cars	N	N	N	N	Y	N	Y	Y
Air conditioning – other vehicles	N	N	N	N	N	N	Y	Y
Refrigerated trucks	Y	N	Y	N	Y	N	Y	Y
Other refrigerated transport	N	Y	N	N	N	Y	Y	Y

Y = generally yes; (Y) = change in system usually necessary, N = generally no

† Applicable for ammonia-water sorption systems only

1.4 Objective and scope

From Table 3 it can be seen that amongst all of the commonly available options, there is scope for using at least one LGA refrigerants in virtually any system and application that currently uses R22. Thus, with varying degrees of technical investment and innovation, the majority of those refrigerant-related emissions could be avoided through the adoption of LGA refrigerants. With these refrigerants already being available and systems being available or at least viable, the potential (and as yet largely unrealised) opportunities for emissions mitigation using LGA refrigerants are considerable.

[11] A "direct" system is one where the refrigerant-containing parts are located within the cooled occupied space (such as a split type air conditioner, where the evaporator coil containing refrigerant is located within the space), whereas an "indirect" system is one that uses a secondary heat transfer fluid – such as water or brine – to remove heat from the space being cooled (such as a chiller that cools water which is then pumped to the conditioned room). The advantage of the latter is that it provides an additional degree of separation between the flammable and/or toxic and/or asphyxiant refrigerant from the persons potentially at risk.

[12] A "cascade" system is where two refrigerants are used in separate circuits, thereby maximising the better properties of each refrigerants (such as a system using R717 in the high-stage and R744 within the low stage).

Furthermore, a recent review of projects supported under the Multilateral Fund [13] found that (apart from those for converting domestic refrigeration from CFCs to HCs) so far only one investment project out of several hundred had involved LGA refrigerants.[14]

Therefore, the objective of this work is to try to determine the reasons for why the wider introduction and use of LGA refrigerants has not occurred. In particular the primary objective of the work is to identify the specific barriers that inhibit the uptake of LGA refrigerants as alternatives to HCFCs. These barriers may relate to different stages in the development, marketing or servicing of systems and equipment, or may relate to different stakeholders within the industry. Further to this, the intention is to determine ways and means of overcoming such barriers, and to identify opportunities to aid with the wider adoption of LGA refrigerants as replacements for HCFCs.

Conducting an investigation of this type at the present time is particularly pertinent, since nearly all Article 5 countries are embarking on developing HCFC Phase-out Management Plans (HPMPs). For the reasons discussed previously, it is desirable that these HPMPs embrace the possibilities of using LGA refrigerants. It is hoped that the output of this work will provide some insights into the approaches to be necessarily integrated into HPMPs in order to accelerate the use of LGA refrigerants.

To date, there has only been the one notable study of Ciconkov[15] that has investigated this issue in any depth. Whilst this study has provided a useful introduction to the issue, UNEP considered that an in-depth study was necessary and that it should specifically be based upon the views and experiences of those working within the RAC field in Article 5 countries.

As indicated in the previous discussion, the focus of this study is targeted towards the use of LGA refrigerants as replacements for R22. Refrigerants that are considered to be "low-GWP" are those that are considered to have a "negligible" GWP in comparison to the majority of the conventional refrigerants. Specifically, this includes the so-called natural refrigerants (R717, R744 and HCs) as well as the recently developed unsaturated HFCs. All of these are broadly accepted to have a GWP of less than 15.[16] It is also noted that the work broadly pertains to the use of these refrigerants within new

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[13] Ciconkov, R. 2010, "Natural refrigerants in developing countries, problems and suggestions", 9th IIR Gustav Lorentzen Conference, Sydney, Australia; it is noted that with the onset of HPMPs, this situation is changing and may further change in the near future. See for example the approval of two demonstration sub-projects in China for conversion in the air conditioning sector from R22 to propane (Decision 61/35 at the 61st ExCom).

[14] However, it is also noted that one agency (GTZ Proklima) has, outside the scope of the Montreal Protocol, carried out groundbreaking work in securing and implementing a number of LGA refrigerant projects in a number of Article 5 countries, for applications such as split and window air conditioners, chillers, stand-alone commercial refrigeration, supermarket refrigeration (http://www.gtz.de/en/themen/umwelt-infrastruktur/27241.htm)

[15] Ciconkov, R. 2010, "Natural refrigerants in developing countries, problems and suggestions", 9th IIR Gustav Lorentzen Conference, Sydney, Australia

[16] For the purpose of the discussion, any mixtures that contain components with a GWP > 15 whose inclusion in small quantities which would otherwise result in a low GWP are rejected from this definition. It is acknowledged that one saturated HFC, R161, which has a GWP of around 12, also falls into the scope of this classification – given that its characteristics are somewhere between R1270 and R1234yf, this work may also be

systems – i.e., those specially designed and constructed for the given refrigerant – rather than for the purpose of converting, retrofitting or dropping-in to existing systems. The reasoning behind this is that the barriers associated with conversions, retrofit and drop-ins are primarily technical which are not intended to be handled here. Also, for purposes of clarification, this work concerns the use of HCFCs as refrigerants, and not in any other use such as a blowing agent in foams.

1.5 General approach

The activities that led to this report involved an initial analysis of the issue under consideration, formulation of the survey, distribution and receipt of survey forms and analysis of the feedback. In general, work was been carried out in three main stages.

i) Initially a general analysis of the types of barriers was carried out in the form of a desk study in order to develop an overview of the situation that one would expect in relation to the application of LGA refrigerants, the situations under which these barriers may occur, and the stakeholders involved with both creating and also overcoming these barriers. (The output of this initial work is detailed within Section 3 of the full report.) This was conducted during March 2010.

ii) Based on the conclusions drawn from the desk study, a comprehensive survey form was developed, intended to draw out views and opinions from stakeholders within Article 5 countries. These were distributed as widely as possible amongst individuals (via email) and presented at workshops. The topic was also presented and discussed at various meetings, both in a plenary and on a one-to-one level.[17] (Telephone interviews were attempted, but were found to be a poor use of resource time due to various technical and logistical complications). Further to this, a second survey form was also developed, which was internet-based and less detailed than the first one. This was circulated widely to a variety of contacts in Article 5 countries and to UNEP Regional Network Coordinators for wider distribution amongst their contact groups and included on the *UNEP Jump Start* and *Shecco* internet sites. (These activities are described further in Section 4 of the full report.) This was begun during April 2010 and finalised in August 2010.

iii) The final stage was to analyse the responses from the completed survey forms, and to subsequently propose, on the basis of these responses, ways and means to overcome the proposed barriers. A statistical overview of the responses to the questionnaires was carried out in order to characterise the profile of the respondents (in terms of location, job, etc) and the amount of detail provided. The analysis was carried out by grouping most of the "statements" within the responses into sub-categories that were considered to represent a tangible "barrier". Using all of the statements within each sub-category a description of each barrier was built up, and subsequently complemented by the causes of the barrier and suggestions for overcoming

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applied to its use. However, it has not been addressed specifically since it widespread use is not widely encouraged.

[17] This included: Bogota, April 2010, Belize, April 2010, Istanbul, April 2010, Seoul, May 2010, Geneva, June 2010.

it. (These activities are described further in Sections 5 and 6 of the full report.) The analysis using the initial feedback from the survey forms was started during June 2010 and was completed in August 2010.

Upon completion of the draft report, it was circulated to all of the respondents of both the comprehensive questionnaire and internet survey for comments and further feedback. Following receipt of the comments, the report was finalised in the first two weeks of September 2010. Overall, the work spanned six months.

The target groups for this report include those involved in the implementation of alternative refrigerants at the time of HCFC phase-out. This is primarily implementing agencies, policy-makers, national ozone units (NOUs) and to a lesser extent, trade associations and external consultants. However, for those enterprises wishing to apply LGA refrigerants (such as refrigerant producers, equipment manufacturers/suppliers, contractors and end users), the information provided throughout the report should also be useful to assist with directing their efforts.

1.6 Additional information of the full report

The full report contains subsequent sections on the following:

- Categorisation of barriers and stakeholders, including discussion on the types of barriers, the routes for placing equipment on the market and stakeholder implications
- Survey forms, including explanation for the design of the survey and the target groups
- Response to the survey including a breakdown of the types of responses
- Analysis of responses in detail, including an overview of the barrier, perceived causes, proposals for how to resolve the barrier and additional remarks

For clarification of the findings, the reader is directed towards the full report.

2. OUTCOME OF THE STUDY

2.1 Response of the survey

There were a large number of views gathered from a wide range of stakeholders, covering a broad array of sectors. Amongst the statements received, few specific points were isolated thereby suggesting that those which were captured probably represent a large portion of the entire experienced and perceived barriers throughout the majority of the RAC industry. There were many remarks, observations and experiences that would not normally be obvious, so it is evident that the survey exercise yielded valuable information that can further assist with overcoming the barriers.

The breakdown of the responses implies that the variety of respondents is fairly comprehensive. In particular, a large number of countries have been included as well as a good range of stakeholders. However, there is a striking absence of responses from East and South East Asia, especially those countries whose HCFC consumption dwarves the rest of the world. Similarly, there is a major absence of responses from Africa and the Middle East. Any future study should focus on obtaining considerably more responses from these regions, especially since the characteristics of some of these countries' industries are significantly different in scale from the countries that are predominant in the responses.

In terms of the stakeholders a greater number of responses from equipment (system and component) manufacturers and suppliers are needed as well as refrigerant suppliers, since these are fairly critical stakeholders especially in terms of creating and removing barriers. Also more responses from end users would also be of benefit since in many cases they will dictate the "acceptance" of certain refrigerants. For the remaining issues, there were fairly comprehensive levels of responses to most of the questions, typically with between 70 – 90% of questions answered to some extent.

2.2 Summary of barriers and ways and means [18]

Throughout the various types of barriers, 32 separate barriers were identified. Below, all of these barriers are listed, and the main ways and means of overcoming those barriers are listed. Also, an indication of the significance of each separate barrier is provided, as a score out of ten. (This was obtained as the sum of the "severity rating" and the "unachievability rating" as mentioned in Section 5.3 in the full report.) It should of course be noted that this significance rating is fairly broad in its interpretation, since it covers many countries, equipment types, sectors, and stakeholders. These rating were not obtained from a representative poll, such that the analysis of the barriers can only be qualitative and thus the significance should be taken in many cases with some reserve.

[18] Again, the statements and associated views expressed below – as consolidated from those in Section 5 of the full report – are those of the respondents to the survey and do not reflect the views of the author, the European Commission or of UNEP.

Technical (refrigeration and safety)

"Some systems have poor efficiency"

- Invest in and carry out more research and development, including collaboration with institutes in non-Article 5 countries — 7/10

"The design of systems using flammable refrigerants is not fully established"

- Carry out more research and development, including collaboration with institutes in non-Article 5 countries — 5/10

"There is an additional level of complexity involved with working with low-GWP refrigerants"

- Conduct quality technical training at all levels (that is: design engineering, production and technicians). — 5/10

Supply and availability

"There are no systems using low-GWP refrigerants available to buy"

- Stimulate interest through awareness raising within the industry, particularly amongst end-users
- Institutionalise the interest in LGAs by informing younger engineers and technicians
- Open up the supply stream by developing a database of producers of LGA equipment to encourage links between these companies and local suppliers
- Formulate national policies to stimulate demand for LGA systems, such as financially orientated incentives (for LGA) and disincentives (for high-GWP)

— 8/10

"There are problems with obtaining the correct servicing equipment and the use of improper servicing equipment"

- Specific requests made to importers to source the needed service equipment
- Local enterprises can develop their own service equipment products
- Agencies should routinely specify only dual purpose service equipment be purchased
- Agencies to subsidise the cost of any service equipment for LGA whenever needed

— 4/10

"There are no parts/components for systems using low-GWP alternatives"

- Encourage local producers to develop suitable parts such as electrical components
- Satisfy the larger manufacturers of components by national authorities developing infrastructure to improve the safe working practices of the local industry

— 4/10

"The refrigerant is not available"

- Stakeholders highlight market demand by requesting wholesalers and suppliers to import/stock the LGA refrigerant
- National authorities develop industry guidance (based on national legislation) for safely handling the relevant substances

— 6/10

"The industry is insufficiently trained to handle these refrigerants"

- Extend and elaborate current training practices for LGAs, but ensure that these events are dedicated to specific LGAs under consideration (avoid "general" training)
- Involve system manufacturers to incentivise two-way interest
- National authorities to review the knowledge of teachers and lecturers to identify if and where the gaps are
- Send local teachers/experts to other regions of countries to receive intensive high level training

— 5/10

Commercial

"There is a significantly greater cost for setting up for production of systems"

- Introduce tax benefits/rebates for companies that adopt LGA technologies
- Authorities to provide complimentary promotional activities to promote use of LGAs
- Implementing agencies provide additional funds for conversion to LGAs
- Implementing agencies to develop conversion guidelines for manufacturers, draft in experts to work with the manufacturers

4/10

"The products/systems using LGAs demand a greater cost"

- Authorities to reduce either import duty or sales tax on systems that use LGAs in order to develop market momentum
- Authorities to offer to provide tax rebates on the relevant purchases necessary for the production of systems
- Awareness-raising programmes should be encouraged to advise (typically end users) of the environmental and energy related benefits

5/10

"The service equipment and spare parts needed for a system using an LGA cost more"

- Implementing agencies should make a commitment to purchase a certain quantity of equipment for certain countries/regions to obtain volume discounts
- Local or regional enterprises to begin to manufacture equipment and parts locally
- Government to offer subsidies to those that purchase these equipment and parts

5/10

"The LGA refrigerant is priced higher than conventional refrigerants."

- Prohibit conventional refrigerants thereby forcing the market open for the LGAs
- Introduce import duty on high-GWP refrigerants, and again lessen the duty on LGAs

6/10

"There is nothing to incentivise enterprises to invest in LGA technology"

- Offer government rewards for producing, working with or purchasing systems using LGA refrigerants
- Develop rules to make the use of conventional refrigerants more onerous or to have finite lifetime
- Provide financial or in-kind support aimed at LGA projects to help entrain external funding
- Governments to promote wider awareness on environmental and any economic potential that the use of LGAs may offer

9/10

Market

"There is no demand for products using LGAs"

- Introduce legislation that permits only systems using LGA refrigerants in particular situations (where the technology is suitable)
- Offer financial incentives for where applications that use conventional refrigerants are penalised and those that use LGA refrigerants are benefitted
- Pressure on end users should be applied by environmental NGOs

5/10

"There is a fear of market acceptance of systems using these refrigerants"

- Implementing agencies may try to encourage a number of enterprises to enter the market with LGAs at the same time
- Local enterprises be made aware of and become familiar with comparable products being developed/sold in other countries or regions
- Sales and marketing staff to be well orientated with the relevant issues such that they can adequately respond to concerns

5/10

"No one is willing to invest in production of systems, parts, components and refrigerant"

- Demonstrate that there is greater certainty that LGA refrigerants will not only be used, but also demanded by end users

8/10

Information resources

"The industry is unaware of LGA refrigerants and their use in systems"

- Hold seminars/workshops which should be directed specifically at individual LGAs
- Training sessions to be devoted to changing the culture of the workforce to understand the unique characteristics of LGA refrigerants (such as safety)
- Focussed awareness-raising schemes should be targeted towards end-user sub-sectors (such as catering, leisure, food processing, and so on)

5/10

"There is a broad absence of general technical information"

- Disseminate information in a targeted manner
- Training/seminars/workshops to be dedicated to specific stakeholder groups
- Highlight specific advantages such as energy efficiency, environment and technical benefits
- Information should be provided by respected authorities

5/10

"There are no demonstration projects or installations to learn from"

- Implementing agencies should encourage demonstration projects for production line conversions as well as installation of larger systems using LGA refrigerants
- Multilateral Fund to allocate a minimum proportion of quota for funding of LGA projects
- Organise regular site visits for other stakeholders and broader dissemination of findings

6/10

"There is no experience in using LGA refrigerants within the local industry"

- Ensure that local training institutes have set up trial equipment for technicians to practice on
- Larger companies should set up similar types of trial systems in-house
- Engineers, consultants and technicians could spend a limited amount of time with other enterprises who have already embraced the technology

5/10

"There is a lack of local experts on LGA refrigerants"

- Set up collaborative efforts between the industry and technical institutes to carry out trials
- Agencies to fund specialist intensive educational sessions, drawing in expertise from countries with LGA experience

4/10

"Consultants developing HPMPs are not recommending LGA refrigerants for projects"

- Educate those involved in the process, through dedicated training
- Agencies to enable LGA experts to attend HPMP stakeholder meetings to address specific issues, to assist HPMP consultants

9/10

Regulations and standards

"There are no suitable rules to direct users how to use the LGA refrigerants properly"

- Government authorities to review current legislation and develop new legislation where needed
- Adopt international or another country standard and modify it to suit national situation, however, ensure rules are not written such that they are more prohibitive than constructive

4/10

"The rules for using low-GWP refrigerants are too restrictive to allow their use"

- Engage relevant departments and NOUs to advise the department or authority of the needs for LGAs
- Amend regulation to account for the characteristics of LGA refrigerants and applications
- Develop a national code of practice or national standard instead of relying on prohibitive international ones
- Develop a dedicated standard for the specific refrigerant and type of equipment
- Engage government in assisting with the adoption or changes to standards
- Any draft regulation or standard to be reviewed by independent, neutral bodies especially to help avoid the problems associated with dominant involvement of large enterprises

9/10

"Some stakeholders are unaware of the existence of the rules"

- Carry out a thorough review of national regulations and standards to thereby summarise rules for industry
- Initiate awareness campaign for stakeholders.

5/10

Psychological and sociological aspects

"Lobbying activities in favour of the use of LGA refrigerants is insufficient to influence decision-makers"

- Invite speakers, figures of authority who speak positively on LGA refrigerants to events on refrigerants
- Develop positively-orientated literature targeted at policy makers, end users and investors

3/10

"There is a natural fear of change to use something notably different"

- Distribute general and technician information targeted to the relevant categories of individuals (i.e., design engineers, technicians, end users, etc) — 5/10
- Promote case studies of demonstration and pilot conversions to LGAs
- Organise site visits and discussions for those decision makers

"There is a fear that the cost of systems and equipment will be very high"

- Develop informative cost analysis of certain generic LGA projects and case studies, including life cycle cost comparisons — 6/10

"There is a general fear of the safety risks"

- Inform and educate stakeholders, teach how to think about the issues in a rational manner — 7/10
- Design and installation guides should be made available dedicated to all levels of detail

"One cannot rely on technicians and others to handle the refrigerants responsibly and according to the rules"

- Establish training centres dedicated to LGA refrigerants
- Introduce certification schemes for technicians, where they may only practice, purchase refrigerant, etc, once they achieve a certain level of competence — 4/10
- Set-up inspection schemes with random checks of installations, etc, to ensure rules are followed
- Encourage enterprises to introduce (even simple) quality control systems
- Improve the quality, rigour and "competence criteria" of local training centres

"Enterprises consider embarking on the production or installation of LGA refrigerants too risky"

- Create a sense of greater confidence in LGA refrigerants through seminars designed to focus on the benefits of LGAs
- Promote robust case studies and experiences from other countries and enterprises, demonstrating maturity of the technology, guidelines as to what refrigerant to use, when to use and how — 6/10
- Environmental NGOs to carry out stronger activities within countries

"It is not necessary to use these refrigerants"

- Convince decision-makers and stakeholders of the importance of climate change
- Environmental NGOs to play a greater part in awareness raising of consumers — 4/10
- Educate end users and other stakeholders in all benefits of LGAs

The significance of each of the barriers is summarised in graphical format within Figure 2 to help indicate the most important barriers.

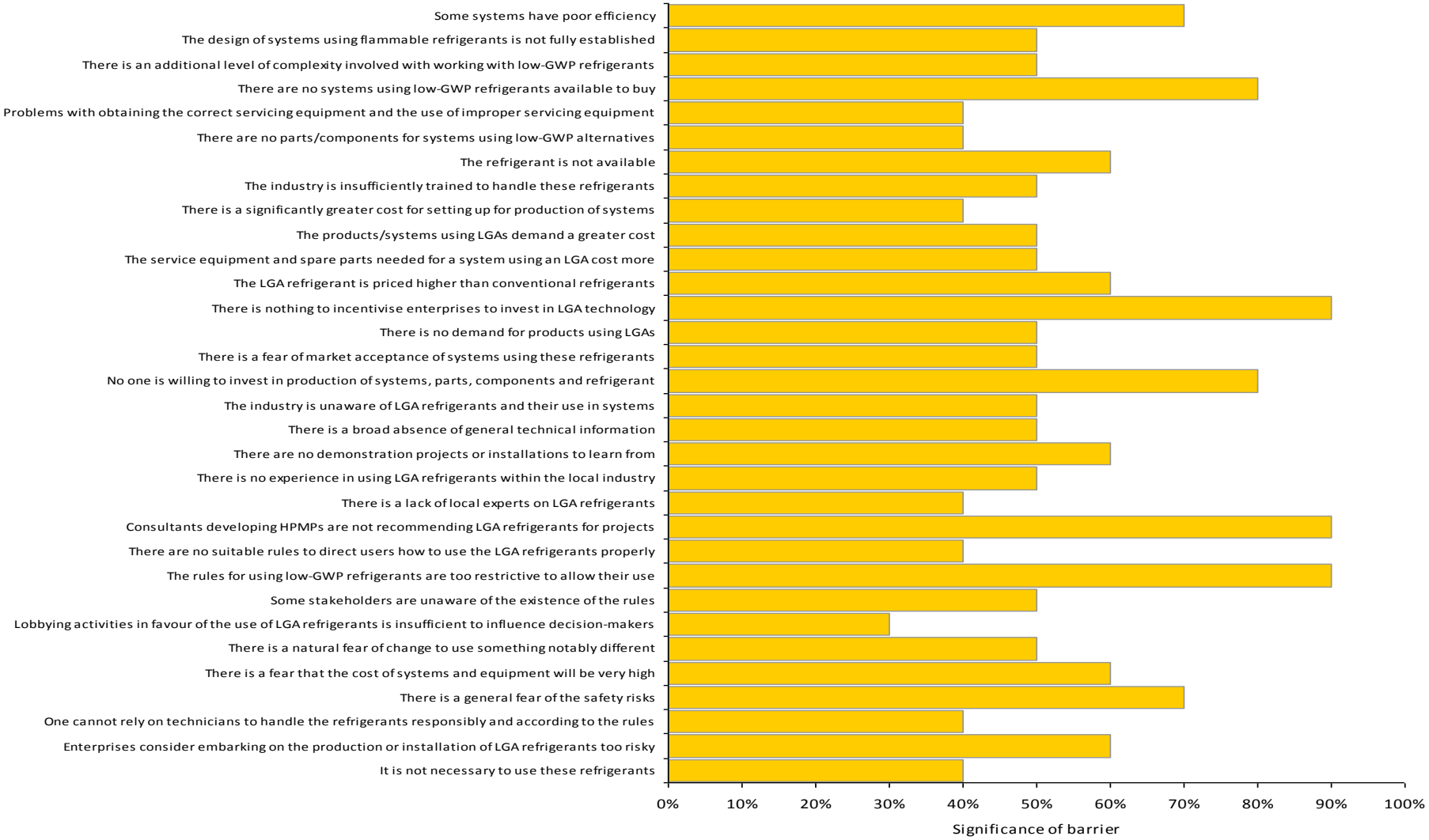

Figure 2: Summary of the significance of the various barriers

2.3 General recommendations

It can be seen from the list above (as well as the discussion in Section 5.3 in the full report) that many of the ways and means of overcoming one barrier are consistent with one or more of the other barriers. From this, it is possible to identify a number of generic options for helping to overcome a broader number of barriers. There are nine such fields that have been identified from the respondents, which are discussed below.

NB: The discussion below is a synthesis of the responses from the survey. It is noted that many of the statements detailed hereafter may be considered by some to be controversial, incorrect, politically motivated or unfair – since the responses from individuals are reported on here, all views must be included regardless of whether or not they may cause disagreement. Very rarely, remarks were omitted where they were deemed factually incorrect or irrelevant to the topic under consideration. Therefore, the statements and associated views expressed below are those of respondents and interviewees of the survey and do not necessarily reflect the views of the author, the European Commission or UNEP.

It is known that as the reader considers many of the means to overcoming the barriers, they may deem them to be difficult to achieve, impractical or impossible. Of course, were these issues not so challenging, the majority would have been otherwise resolved through natural market forces.

Awareness-raising

It is important to stimulate interest – in both the "problem" (climate change) and the "remedies" (e.g., including use of LGA refrigerants) – through awareness raising campaigns. This should obviously be directed towards the typical industry stakeholders, but particularly to policy makers, end-users and investors. Awareness of such issues should encourage decision-makers and other stakeholders of the importance of tackling climate change through approaches such as using LGA refrigerants. In order to enhance the effectiveness, information should be provided by respected authorities. In addition to the general issues, awareness-raising should highlight the environmental, energy, technical, economic/life-cycle cost and other related benefits of using LGA refrigerants.

Specific awareness-raising exercises, for example, in the form of seminars, workshops and similar events should be targeted specifically at individual groups of stakeholders. Rather than aiming them at "end-users", they should be further focussed towards specific sub-sectors, for example, catering, leisure, food processing, and so on. In this way, the important messages (about environmental, technical, economic, etc. aspects) can be presented in a way that is most relevant to the recipients, thereby enhancing the appeal of the LGA refrigerants. Similarly, awareness-raising activities should try to focus upon specific individual LGA refrigerants, rather than discussing them as a whole. This helps to clarify the "direction" and be more concise with the useful information.

Whenever conferences or seminars are organised, it is preferable to ensure that not only figures of authority are selected as speakers, but also that they speak positively and rationally. Where events are organised but are comprised of speakers with conflicting views on the use and application of

LGAs (or not), the audience is less likely to take positive and progressive messages away with them. Presentations should not only be given in a steady, logical manner, but also it is important to offer rational ways of interpreting issues under discussion (in particular, safety) so that they can be better related with the wider context.

It should be recognised that many of the described barriers may be perceived rather than tangible and those negative perceptions may come from reading or hearing information that compares two "competing" refrigerants ("x is better than y") as opposed to observing a discussion that handles a given refrigerant in isolation.

Another key element to awareness-raising is the dissemination of positive messages about the technical maturity of the technology (when applicable). Activities should include familiarising stakeholders with comparable products being developed/sold in other countries or regions, organising site visits or enabling key stakeholders to spend a limited amount of time with other enterprises involved in that technology in order to develop a sense of comfort with it. Publications can include case studies of demonstration and pilot conversions, which should highlight life cycle cost comparisons, technical advantages and environmental benefits.

Training

Specialised training is considered to be a critical element necessary for overcoming many of the barriers. Perhaps the most important aspect related to training is to ensure that sessions are targeted at specific stakeholder groups and well focussed on individual LGA refrigerants. Often, training programmes can be too general and tend to be biased towards the teacher's own experience; in Article 5 countries where experience in LGAs is at times limited, the consequence is a deficiency in focus on critical material. In order to help overcome this, local teachers/experts may be sent to other regions or countries to receive intensive high level training.

Thus training should be dedicated to particular groups – not only service and maintenance technicians, but also design engineers, production line and factory workers and not excluding people such as sales and marketing staff who also need to be well orientated with the relevant issues. Also, HPMP consultants and others involved in the HCFC phase-out process should also receive proper training. Training sessions should be on HCs, R717, R744 or low-GWP HFCs individually (rather than combined), so that an entire period can be dedicated to the critical topics. Of course, where applicable, training should comprise significant practical elements; training institutes must be well equipped with trial systems and equipment for technicians to practice on.

On a broader level, training schemes should be set up and devoted to changing the culture of the workforce to help deal with the particular characteristics of LGA refrigerants (such as flammability, higher toxicity and higher working pressures), that would otherwise render technicians vulnerable. Ideally, countries should set up training centres dedicated to LGA refrigerants.

Guidance

In order to supplement awareness-raising activities and training, high quality industry guidance should be developed. These should cover the key topics, including national legislation, safe handling requirements, conversion guidelines for manufacturers, and so on. What is often overlooked is the value of providing clear and constructive direction as to which LGA refrigerant should be used in particular situations, whilst minimising the extent of choice across the entire area. As with awareness-raising and training, guidance must be targeted towards individual stakeholder groups, industry sub-sectors and readership (i.e., design engineers, technicians, end users, small commercial, industrial, etc) in order to make reading and understanding more concise. Drafting of the material must be done by experts competent in the application of LGAs.

Technical development

There are always an extensive number of topics that require further research and development activities in order to make LGA refrigerants more widely applicable. Three of the most crucial research areas which could yield the greatest benefits for LGA refrigerants include:

- Improving efficiency of R744 systems for air conditioning under warm climate conditions
- Reducing refrigerant charge sizes for systems using HCs
- Developing safety control mechanisms for system using flammable refrigerants

Therefore manufacturers and technical institutes should invest in and carry out more research and development into these and other issues.

In terms of less formal development work, there is also a need for carrying out trials, as a means to demonstrate the applicability of a new development in specific circumstances and to help identify less fundamental options for improving the operability of systems. Such activities may be in the form of collaborative efforts between the industry and technical institutes.

Market development

In the context of this study, the broad term ‘market development’ refers to means of engaging and stimulating the industry into being involved with LGA refrigerants.

In regions where there are little or no manufacturing, the interests and purchasing requirements of local enterprises should be consolidated so as to encourage wholesalers and suppliers to import/source and stock the LGAs refrigerant, systems, parts and service equipment. Similarly, the decision-making bodies within the Montreal Protocol community as well as the implementing agencies should consider setting conditions that only equipment that may be used with LGA refrigerants as well as conventional refrigerants may be procured. Also they should encourage consolidated purchasing contracts that increase the quantity of systems and equipment for LGA refrigerants so as to obtain volume discounts and reduce prices of similar items.

Where there is an active local industry, local enterprises should be encouraged to develop their own service equipment, parts and related products locally. Of course the same applies to the manufacture

of systems. Where concerns exist, similar enterprises should be encouraged to develop products and enter the market with LGAs simultaneously so as to spread the perceived business risk. Experts may be employed to provide advice and guidance for specific or even group projects.

In either case, a database or directory of local, regional and international LGA refrigerants and LGA-using products should be developed and made available to Article 5 countries in order to bridge the gap between producers and buyers, where local importers, suppliers and retailers may (unintentionally) form a barrier. Such a database or directory will encourage and incentivise two-way interest. At the same time, it is important to demonstrate the market demand for such refrigerants and products and activities should be carried out to promote use of LGAs.

At national authority level, severe interventions could be developed, such as prohibition of conventional (high-GWP) refrigerants as has been done in some European countries, such as Denmark. Less strict versions may be the introduction of rules to make the use of LGA refrigerants attractive and those of conventional refrigerants more onerous (rigorous demands to prevent the possibility of emissions, bureaucratic measures, obtaining permits, etc), or to allow only LGA refrigerants in specific circumstances. They should consider of course what is feasible in terms of the economic and industrial impact of such incentives/disincentives and in terms of fair competition as per national law. Initially such rules could target sub-sectors (where LGAs are already applied) but gradually be expanded to cover a boarder range. The anticipation of such rules will encourage investment and product development. On the other hand, such actions could intensify counter-activities on the part of those enterprises that would lose out by strict/severe interventions, and depending upon the circumstances may only work to a limited degree.

Financial incentives

Financial incentives are an essential means to overcoming a variety of the barriers to LGA refrigerants. These may involve subsidies or taxation adjustment.

As a temporary measure, governments could offer financial subsidies for the purchase of systems that meet certain environmental criteria, or for equipment that will be used to build such systems. Similarly, implementing agencies could subsidise the cost of service equipment or other parts that would be applied to LGA refrigerant systems. Subsidies could also be provided by various bodies to offset the difference in first cost between LGA and conventional LGA applications. The same applies to in-kind support, where, for example, expert time or services could be provided free of charge. In any case, financial or in-kind support aimed at LGA projects is an excellent vehicle to help entrain external funding from other investors.

Governments can also introduce adjustments to taxation either on the refrigerant itself or on the systems. The adjustments could be applied for import duty, sales tax, rebates or elsewhere within the system. Tax increases could be imposed as a disincentive for high-GWP refrigerants, or as a discount for LGA refrigerants. However, a two-way approach is also desirable where the revenue benefits for one product type are used to offset the losses for the other, thereby achieving parity. A similar approach could be a GWP-weighted deposit scheme for refrigerants sold and returned (such

as in Norway). In any case, such financial incentives have been seen to be excellent stimuli in countries where they have already been applied.

Regulatory infrastructure

'Regulatory infrastructure' refers to various types of rules which are applied to safety and quality concepts, and covers both legislation and standards (which are not necessarily mandatory).

As a general approach, countries should develop infrastructure to improve the safe and responsible working practices of the industry, especially at the technician level. This may involve the formation of certification and registration schemes for technicians, for example, where they may only practice, purchase flammable refrigerant, etc, once they achieve a certain level of competence. This could be complemented with inspection schemes with random checks of installations to ensure that the necessary safety practices are being put in place. Enterprises, however small, should be encouraged to introduce (even simple) quality control systems. At the same time, the quality and level of rigour and "competence criteria" of local training centres should be assured, so that those being trained are much more likely to achieve the desired levels.

In terms of specific rules for handling and working with LGA refrigerants, it is critical that all relevant current legislation is reviewed and considered with respect to the storage, distribution, handling and application of all LGA refrigerants. It may be found that certain legislation inadvertently prohibits its use or where some specific reference is necessary, nothing currently exists. In these cases national authorities must amend or develop new legislation as needed; in all cases it should be done in collaboration with industry stakeholders and experts.

Whilst it is key to the application of LGA refrigerants that standards covering the selection, design, construction and operation of systems are available, it is absolutely vital to ensure that those standards are constructive to the application of LGA refrigerants, rather than prohibitive. It is the case in several situations that rules severely hinder the application of LGA technology; standards may be drafted by industry participants with overriding vested interests to the detriment of certain alternatives. National authorities may adopt international standards or a standard from another country, and fail to apply the needed modifications. Similarly, the industry may wish to develop a national code of practice or national standard instead of relying on what could be prohibitive international standards. Authorities and sub-sectors of the industry directly affected by standards and guidelines must be engaged to ensure against undue influences of potentially dominating interests.

There is a possibility to address the RAC sector in Nationally Appropriate Mitigation Actions (NAMAs) as well (under the UNFCCC), which could bring in further financial resources and help to address the underlying issues from a broader and more comprehensive perspective.

Montreal Protocol issues

There are a number of adjustments suggested by respondents that could be considered directly under the Montreal Protocol processes. One possible option could be for the Parties to the Montreal

Protocol and the Executive Committee to consider allocating a minimum number of projects (or a minimum quantity of reduced consumption through any number of projects) approved under HCFC phase-out to be LGA refrigerant projects (in addition to the possibility of funding up to 25% for LGA projects). Non Article 5 Parties, which are donors to the Multilateral Fund, could specifically take a more proactive role in encouraging the formulation and acceptance of projects involving LGAs, and specify that justifications must be made for not selecting LGAs. Similarly, implementing agencies could invite experts in LGA refrigerants and applications to attend HPMP stakeholder meetings to address specific issues and to assist HPMP consultants in integrating LGA refrigerants into country plans. Assessment reports (such as those by the Technical and Economic Assessment Panel) could be drafted specifically on the application of individual LGA refrigerants, and should not be formulated in a way that creates conflict with each other or conventional refrigerants, which otherwise results in downplaying the possibility of their use.

Implementing agencies are seen as entities that have considerable influence in encouraging wider use of LGAs. They can be even more proactive in encouraging HPMP consultants and NOUs to explore the possibilities of using LGAs more widely, and drawing-in the expertise of LGA experts to assist with such exercises. Bilateral agencies, especially those which see possibilities in the wider use of LGAs, could give more prominence in addressing the identified barriers. They could also consider targeting the 20% of their contributions to the MLF towards LGA related projects.

Whilst slightly removed from this theme, but also important is that specific funds, such as the Global Environment Facility (GEF) could be tapped into to assist with specifically funding the overcoming of these barriers at a regional level, but also could be used to address individual barriers at country levels.

Environmental non-governmental organisations (ENGOs)

Whilst there is broad international recognition of the problem of climate change and some progressive companies have shown leadership in climate protection, more can be done by enterprises to address climate change. Traditionally within many non-Article 5 countries ENGOs have carried out campaigns to motivate enterprises and members of the public into reacting to environmental issues. Many such campaigns have been on the theme of refrigerants. ENGOs should also conduct such activities in Article 5 countries in order to encourage manufacturers, end users and consumers to switch to LGA refrigerants.

2.4 Conclusions

Summary of findings

The survey yielded a large number of barriers, some of which were considered to be of lesser importance and some which were deemed to be more significant. Some of the statements dealt with were very specific issues, whereas some provided a general overview. Individual barriers may be country specific, refrigerant specific, stakeholder specific and sector specific, and therefore each barrier should be assessed within the context under consideration.

Those barriers identified in the survey which were considered to be the most significant were:

- "There are no systems using LGA refrigerants available to buy"
- "There is nothing to incentivise enterprises to invest in LGA technology"
- "No one is willing to invest in production of systems, parts, components and refrigerant"
- "Consultants developing HPMPs are not recommending LGA refrigerants for projects"
- "The rules for using LGA refrigerants are too restrictive to allow their use"
- "There is a general fear of the safety risks"

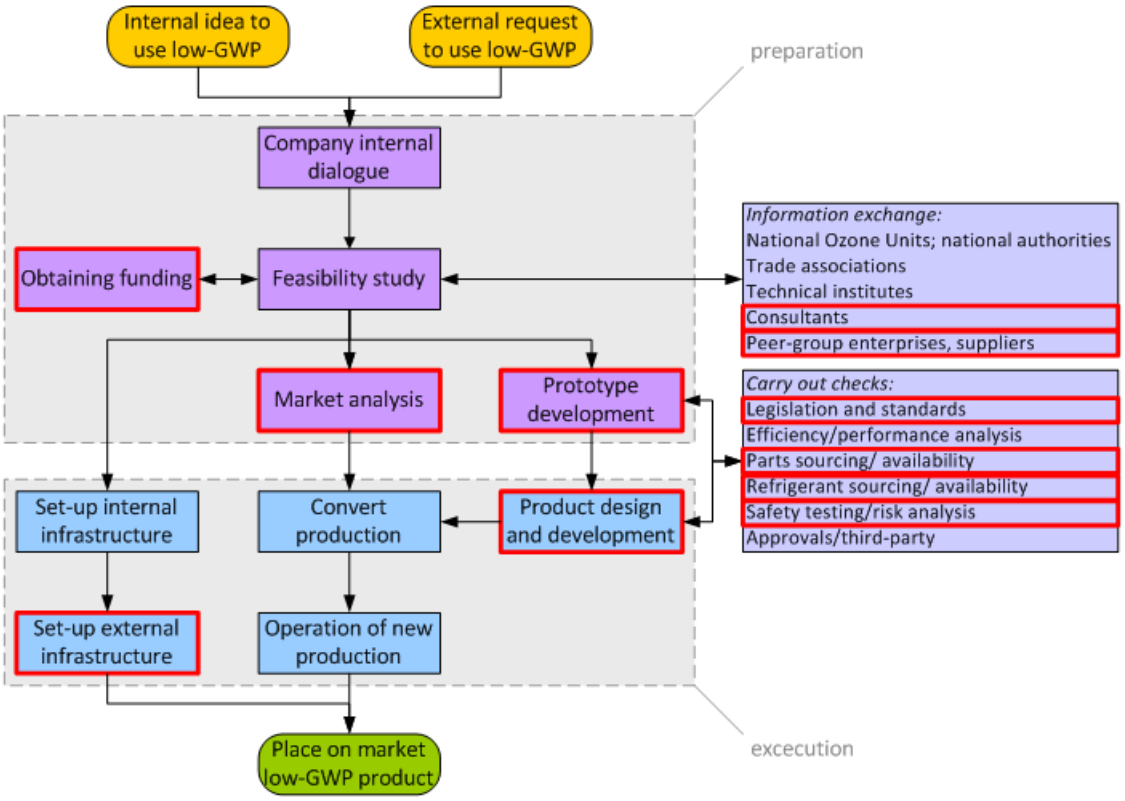

Figure 3: Identification of the stages (red boxes) likely to experience the most significant barriers during the general process for placing a new product on the market

These were in addition to a broad number of other barriers identified in the study. There are many causes for the existence of all of these barriers, spanning technical, commercial and psychological and sociological reasons. However, it is apparent that many of the barriers and causes of barriers are circular or at least strongly interlinked issues, for example:

- It is not possible to purchase LGA systems because no one else wants to buy them; this is because products are not available.
- People will not purchase systems because they are too expensive; this is because the volumes are too low.
- Regulations are not in place to allow their use; this is because there are no systems in use to justify the development of regulations.

- Technicians and engineers do not have experience with LGA refrigerants to be able to construct them; this is because there are no systems to gain experience with.

These types of circumstances can be seen throughout the large proportion of the reported barriers and their causes. This highlights the importance of developing interventions to help break the "chicken-and-egg" situation. Consequently, when attempting to intervene and tackle one of the barriers, it is absolutely essential to consider all of the related barriers and adopt a more holistic approach such that the attempt to overcome one barrier is not undermined simply by the existence of another.

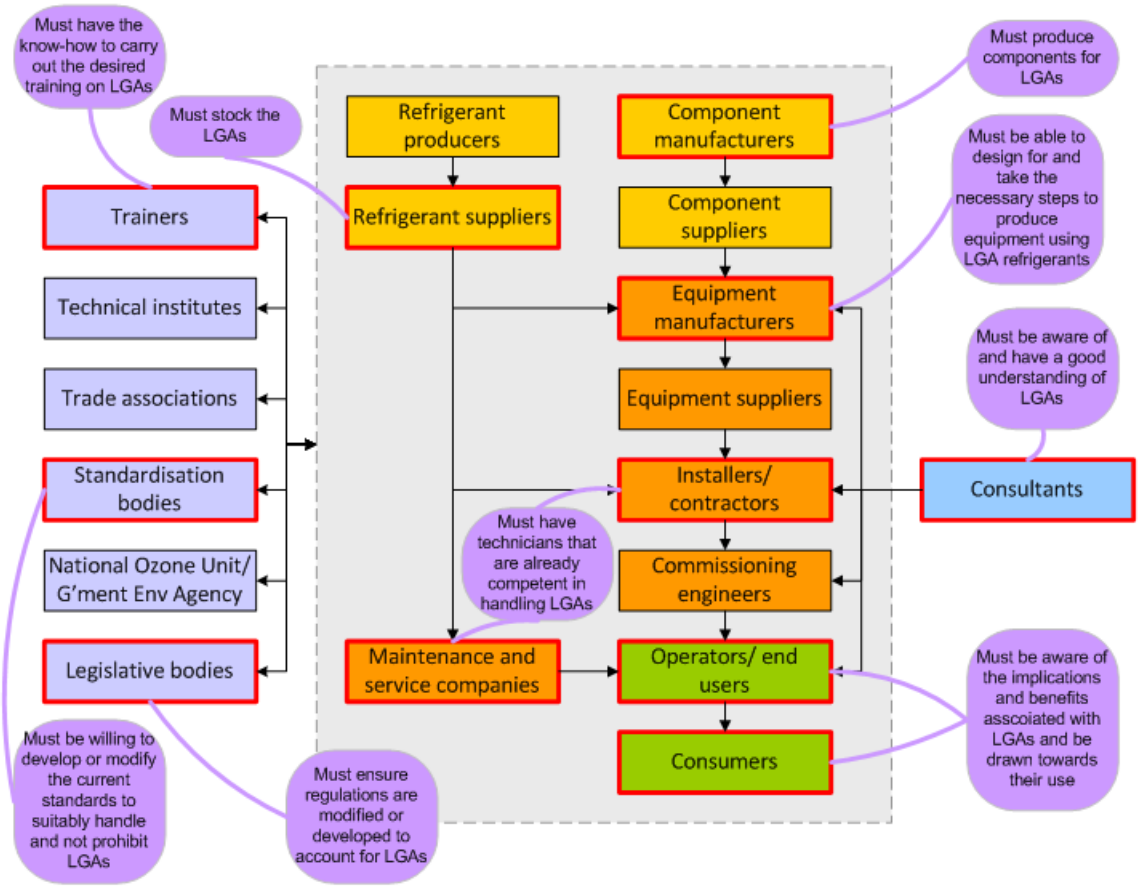

Figure 4: Identification of the stakeholders who have greatest impact on the existence of dissolution of barriers when introducing, applying and using LGA refrigerants

Such considerations can be illustrated by reconsidering the stages within the development process undergone by an enterprise when approaching the adoption of LGA refrigerants. Figure 3 repeats **Error! Reference source not found.** but highlights the stages, sources of information or work items where barriers are most likely to occur (as identified in Section 5.3 in the full report). It is important that those involved with any of these activities within an enterprise are aware that the barriers are most likely to occur here and that the focus of efforts should be concentrated accordingly to help overcome them. However, efforts neglecting to tackle one barrier may be ineffectual if others are not also handled.

Similarly, Figure 4 builds on the information within **Error! Reference source not found.** in order to highlight the stakeholders who are likely to have the greatest impact on barriers and who also have the greatest opportunity for dissolving the barriers to thereby allow the "flow" of the use of LGA refrigerants from the initial manufacturing stage (of refrigerant and components through to end users and consumers). Correspondingly, a brief note indicating the important features that those stakeholders must take on board in order to dissolve those barriers are also indicated in the Figure 4. Again, if any of the barriers within the series of activities get neglected despite others being overcome, LGA products will otherwise be prevented from reaching the market.

Issues associated with types of LGAs

Another issue that should be raised is that amongst the individual LGA refrigerants, there are distinct families, for example, the so-called "natural refrigerants" and the synthetic fluorinated refrigerants (unsaturated HFCs). In this case, there are three issues:

- The first is that from the position of public environmental perspective, the natural refrigerants may be more attractive, since there exists in some groups a fear of unknown hazards associated with engineered molecules. This in itself is a psychological (and maybe a physical) barrier for the fluorinated products.
- The second issue is that there is embedded value for the producer of the synthetic molecules, which provides a driving force to market and sell these substances, and in turn identifying and overcoming many of the barriers. On the other hand, the natural refrigerants are largely 'valueless' products resulting in a counter-intuitive situation that large business has little interest in marketing and selling the substances since the potential for gaining profit from them is much less. As such, the drive to overcome the barriers is weaker, being left instead to those who can financially gain from the products that use them.
- The third issue is that some respondents expressed the view that if investment should be made it should be for natural refrigerants rather than providing further funding to those enterprises that have already gained from high-GWP refrigerants.

Nevertheless, within the category of "natural" refrigerants, there are often strong views expressed by some respondents with the intention of differentiating one from the other. For example, because of the flammability risk, some respondents stated that HCs should only be limited to small (domestic) refrigeration appliances and conversely the use of ammonia should only be applied to industrial type applications where use is well established. Others express the view that there is nearly always no need to use higher flammability (i.e., HCs) or higher toxicity (i.e., R717) refrigerants, when a "safe" non-flammable, lower toxicity alternative – i.e., R744 – is widely available and widely applicable.

For reasons such as these, it must be recognised that some of the barriers and therefore the ways of overcoming them during the introduction of LGA refrigerants may and should be handled differently amongst the various natural and synthetic options.

Outcome of interventions

It has been identified that the majority of the barriers can be overcome by determination in implementing a number of measures relating to the areas of:

- Awareness-raising
- Training
- Guidance
- Technical development
- Market development
- Financial incentives
- Regulatory infrastructure
- Montreal Protocol issues
- Environmental non-governmental organisations (ENGOs)

As the interventions detailed within these recommendations are implemented, the use of LGA refrigerants will escalate, and the severity of the barriers will diminish. Of course a critical element to achieving all of these is funding, and sourcing the funds is perhaps one of the most difficult barriers to address. One means of helping to lessen the financial burden is the introduction of strong new legislation, but this in itself may demand courageous and comprehensive actions on the part of policy-makers. Since one of the important issues to address is the extent of doubt about the future ("will another, better refrigerant come along?"), such interventions are critical to helping develop certainty for those who may be potentially investing in a particular technology. To effectively overcome these barriers, it is essential that governments and implementing agencies are visibly seen to support the use of LGA refrigerants as legitimate options to be considered at least on an equal basis along with conventional high-GWP refrigerants. These entities should further promote the possibility of support – experience shows that there are many "pockets" of individuals who are keen on using LGA refrigerants, but the authorities and agencies must put the means in place to help mobilise those people. Other sources of funding have also been mentioned, of which many are linked to environmental goals. It is evidently important to provide robust data to indicate the environmental-cost benefits that are achievable through talking these barriers.

It should be recognised that in many applications the use of LGA refrigerants do not necessarily have to be any more expensive than conventional refrigerants, but in order to make them financially viable it requires efforts to kick-start the sub-sector. It needs a critical mass of units to be produced to generate widespread uptake, either by one major producer or several smaller ones. Eventually, once an enterprise can see that there is no additional cost burden for them, or that they are forced by law, and especially if there are clear economic rewards to be gained, the majority of the technical and psychological barriers will be easily overcome. Many of the barriers are interrelated and overcoming one will help to overcome others.

On the other hand, some of the means of overcoming one set of barriers may conflict with other issues thereby fortifying other barriers. (One example is the introduction of legislation to enhance safety, which in itself deters enterprises – especially the smaller ones in Article 5 countries – due to

the increased cost of meeting those obligations.) It is important for countries to set up their own dedicated LGA working groups, under the auspices of an industry association, institute or the NOU. This could be used to initiate changes to regulations and standards, develop guidelines and training schemes, set up workshops, identify producers of LGA refrigerants, systems or equipment and to work with suppliers. Consideration can be given to how to best overcome the potential conflicts arising as barriers are sought to be resolved.

A question may be posed, asking if the barriers that carry the highest significance were worked upon using the interventions proposed, would this result in the widespread uptake of LGAs? This is difficult to address, given the differing circumstances associated with each of the LGAs. However, the following somewhat simplified progression may be considered. Assuming that a given LGA technology is functional (in that it works in principle in a comparable manner to the existing technology) then the general barriers can be considered hierarchically, thus:

> *Firstly, legislation will either permit or not permit a particular technology. If no legislation blocks the technology, then one must consider the safety standards. Again, if these standards do not prohibit or inhibit the technology, then the market is essentially open to a given LGA.*
>
> *Assuming that there are no other legislative hindrances, the main issue is financial. If interventions by the government, implementing agencies, industry, etc., result in the cost of systems and refrigerant approaching parity or cheaper than the current options, then the perception of high cost will be mitigated. With certain LGAs in particular applications (such as flammable refrigerants in larger systems or R744 in high ambient climates), the ongoing research and development activities would assist with approaching this status.*
>
> *The introduction of some demonstration projects – which are well developed and for which information is widely disseminated – then the fear of technological immaturity and the safety risks (where applicable) would begin to dissolve. This would be complimented by the growing occurrence of dedicated training, awareness and experience with the LGA. Those involved with the phase-out of HCFCs and process of implementation of alternatives would also gain confidence in LGAs as viable options.*
>
> *Enterprises will posit that since the technology is (now) otherwise equivalent to the conventional technology, yet there is an environmental "selling feature" (i.e., the low global warming impact) and that this issue has received greater awareness due to actions of ENGOs, etc., they will identify the possibility to exploit the market. They see that the positive benefits are no longer dwarfed by the cost and legislative hindrances, and would therefore be motivated to invest in production of systems and equipment using LGAs. This would become accelerated in the knowledge that more HCFC phase-out projects are similarly following the same direction in a not insignificant proportion of cases.*
>
> *Consequently, an increasing number of products would become available within the market – and assuming that no systematic technical problems arose – the investment in production*

and output of products would gather pace. With the increasing number of products there would be a strong demand for (service) refrigerant and any refrigerant seller would satisfy this demand and thus become more widely available; the competition amongst retailers and the increasing volume would push down prices. Similarly, producers of system components, parts and service equipment would also recognise the demand for such items and invest in production. With this evolution, the amount, quality and extent of training and experience would also increase.

This description is of course simplistic and idealistic, however, it is not entirely inconceivable and it provides a distinct indication of the possible direction and evolution of the use of LGAs, were the necessary interventions put in place. Realistically, there are also a number of major assumptions which will vary in impact depending upon the matching of the particular LGA to the application. It is also evident from the sequence of events that there is a significant time factor involved, until the LGA technologies become as widespread as conventional technologies. This therefore highlights the importance of immediate and rapid action to begin addressing the barriers.

Final remarks

Many of the experiences from Article 5 country enterprises, as derived from the survey, were revealing, in terms of how they had managed to introduce LGA refrigerants into their products. Interestingly they reported that some of the barriers that they had experienced were different from those anticipated by other respondents (who do not currently use LGAs). These tended to be specific infrastructure-related items that would not normally be anticipated by anyone who had not been through the process. In other cases, the problems were associated with opening up supply chains for refrigerant and parts. They also found that many of the barriers described were practically fairly easy to overcome; the main issue was the time and persistence required to achieve that. This is evidence that the perception of the barrier is often a stronger force than the barrier itself, and that it is essential to have the willingness of all involved parties to work towards overcoming the barriers.

The natural progression of the market will result in some movement, but for significant changes to occur comprehensive action on the part of industry, national authorities, implementing agencies, decision-making bodies within the Montreal Protocol community, and ENGOs is necessary. Nevertheless, the subject of LGA refrigerants is a dynamic field, and their application is an evolving situation with many rapid commercial and technological developments. It is acknowledged that with the ongoing HPMPs, this is a critical time for addressing the barriers to the introduction of LGAs and this study is intended to lead to more active discussions and stakeholder activities on this issue in order to achieve a better understanding, clear defined targets and willingness to remove barriers. It is useful to revisit this type of assessment in subsequent years to see how it has changed, and whether any new lessons can be applied to accelerate further change.

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List of respondents

In total, there were 109 named respondents. An additional number of respondents did not offer their names. All whose contacts details were provided were invited to confirm whether they wished to be included within the list of respondents. The majority did not respond to this request therefore implying that they preferred not to be included in the list; those that responded positively were:

- Cesar Luis dL. Lim, Kilojoule Consultants International Co (Philippines)
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- Rotchana Prapainop, Kasetsart University (Thailand)
- Ruben Marchand, Consultant (Mexico)
- Samba Bajie, Ozone Unit (Gambia)
- Serdar Kocaoglu, PepsiCo Beverages (Turkey)
- Yasin Karim (Malaysia)

LIST OF ABBREVIATIONS

CDM	Clean development mechanism
DTIE	Division of Technology, Industry and Economics of UNEP
ENGO	Environmental non-governmental organisation
ExCom	Executive Committee of the Multilateral Fund
GEF	Global Environment Facility
GWP	Global warming potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Hydrofluorooelfin
HPMP	HCFC phase-out management plan
LGA	Low-GWP alternative[19]
LVC	Low volume consuming countries
MLF	Multilateral Fund for the implementation of the Montreal Protocol
MP	Montreal Protocol
NAMA	Nationally Appropriate Mitigation Actions
NGO	Non-governmental organisation
NOU	National Ozone Unit
ODP	Ozone depletion potential
ODS	Ozone depleting substance
RAC	Refrigeration and air conditioning
TEAP	Technical and Economic Assessment Panel
UNFCCC	United Nations Framework Convention on Climate Change

[19] The initialism "LGA" is used only in the context of this report to refer specifically to refrigerants with low-GWP that may be used as alternatives to HCFCs, in particular R22.

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

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- Sustainable Consumption and Production (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
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- Energy (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

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As the phase-out of ozone depleting HCFCs (hydrochlorofluorocarbons) progresses in line with the agreement decided on by the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, countries need to adopt alternative non-ozone depleting substances as replacement chemicals. If HCFCs are simply substituted by 'conventional' alternatives, such as hydrofluorocarbons (HFCs) which generally have significantly higher global warming potentials than the HCFCs they replace, the climate impacts could be considerable. Alternative options include refrigerants with low global warming potentials, such as hydrocarbons, ammonia, carbon dioxide, and new unsaturated HFCs. While these can be used across a wide range of refrigeration and air-conditioning equipment, they are not generally taken up as alternatives.

This report aims to identify and examine the barriers to the adoption of low global warming potential alternatives to HCFCS in developing countries, and to consider the various ways of overcoming these barriers.

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