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

United Nations Environment Programme

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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"

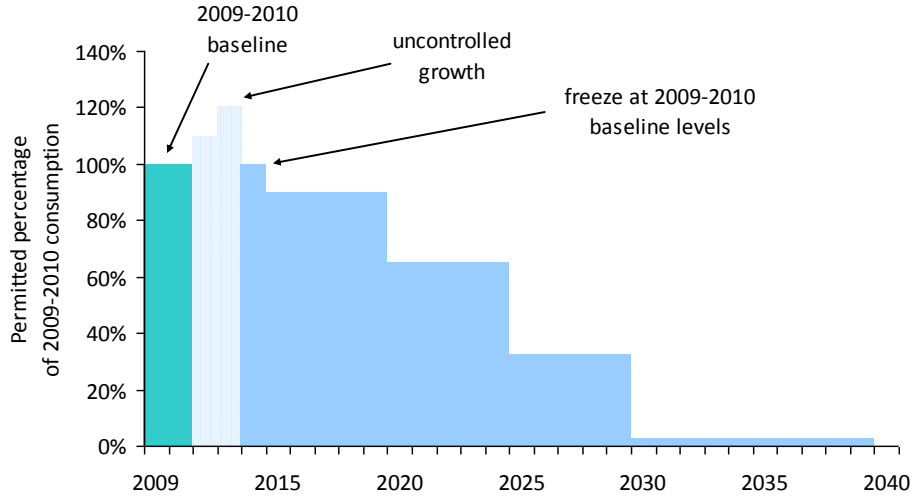

Figure 1: Current HCFC phase-out schedule for Article 5 countries

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.) 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.) 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 it. (These activities are described further in Sections 5 and 6.) The analysis using the initial

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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.

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.

2. CATEGORISATION OF BARRIERS AND STAKEHOLDERS

2.1 Types of barriers

In order to help classify and subsequently understand the various barriers, it was considered necessary to categorise the type of barriers. They may be separated into different types, of which the most relevant are described below.

- *Technical (refrigeration)* – where there are specific technical issues that will not allow the use of a certain refrigerant, for example, where the properties or a characteristic of a refrigerant mean that it cannot be applied to a specific type of system or application.
- *Technical (safety)* – when there are specific safety issues that will not allow the use of a certain refrigerant, for example, where the safety characteristics of a refrigerant are such that it cannot be applied to a particular application.
- *Supply and availability* – when a particular "part", be it material, equipment, component or fluid or even a particular service (or activity), that is necessary for the operation (in-use or service/maintenance) of a system is not physically available or will not be or cannot be supplied to the user, thereby preventing the use of a specific refrigerant.
- *Commercial* (investment, profit, financial incentives) – where an enterprise establishes that the cost of adopting a specific refrigerant will incur additional costs such that profit will be diminished beyond what is acceptable or where insufficient finding is available for investment or adequate financial incentives are unavailable.
- *Market* – where an enterprise believes that there is no customer demand for a product that uses a particular refrigerant, or where the end-user or consumer would not accept a given refrigerant, or where there are no such competing products.
- *Information resources* – when insufficient information, know-how, guidance, or technical data either in the form of literature or training, is available to enterprises or technicians that need the know-how before they can embark on using a particular refrigerant.

- *Regulations and standards* – where existing regulations prohibit the use of a particular refrigerant, where a necessary standard (such as for system or appliance design and construction) does not exist within the country, or where the requirements of a regulation or standard are very restrictive thereby physically or financially (through stringent demands) prohibit the use of the refrigerant.
- *Psychological and sociological aspects* – where individuals, management of an enterprise or broader industry organisations hold a general resistance to change for the use of a particular refrigerant on the basis of rumour, influence of peer groups, or unwillingness to change to alternative technologies.

Most of the barriers rarely fit neatly into any one of these types: they tend to cross-over to some extent. However, it is important to be able to allocate the identified barriers into each of these categories as it will assist with strategically developing ways and means of overcoming them.

2.2 Routes for placing equipment on the market

In order to understand where barriers may lie, it is important to understand the processes that enterprises may go through in order to introduce a new product – such as one using LGA refrigerants – onto the market, assuming that they do not already have such a product.

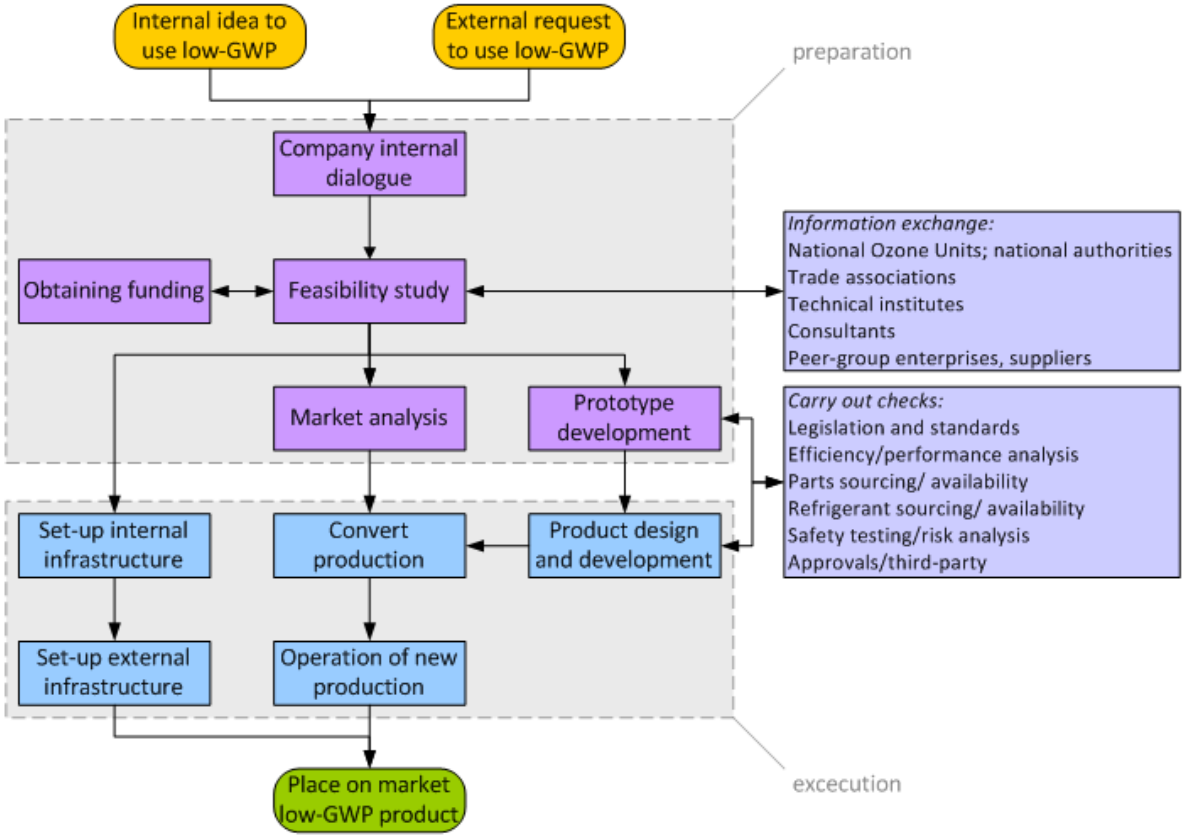

Figure 2: Flow diagram illustrating the general process that an enterprise may go through in order to place a new product on the market that uses low-GWP refrigerant

The flow diagram in Figure 2 is intended to provide a fairly general overview of the process that any enterprise – be it a manufacturer, supplier or contractor – may go through (where in some cases certain processes may not necessarily be applicable). Such a process may apply to any type of product, whether it is a mass-produced appliance (such as a refrigerator or room air conditioner), a large system assembled within a small workshop-type facility (such as a bespoke chiller) or a site-installed system (such as a coldstore or a centralised supermarket system). Of course the extent that the enterprise handles and deliberates on any one of the stages indicated in Figure 2 may vary widely depending upon the type of product and the size of the enterprise. However, a similar fundamental process will be (or should be) exercised in all cases, and within each of these stages barriers to the use of that LGA refrigerant may be experienced. For this reason it is important to be able to identify which barriers may occur at each stage, and options for overcoming them.

The various stages within the process in Figure 2 may be described as follows:

The possibility of using LGA refrigerants may arise within an enterprise either as an internal idea (i.e., from employees; sales and marketing staff, development engineers, etc) or it will have been an external request (or even demand) typically by a customer or end user. In the case of a service enterprise the external "request" may be in the form of the recognition that system(s) are more frequently operating with an LGA refrigerant. The consideration by any of these parties (internal or external) may have been motivated by current or foreseen changes to legislation or standards, new or existing incentives schemes, introduction of a competitor's new product or the availability of a new system component or new refrigerant.

Initially a preparatory stage will ensue, where the general groundwork is carried out:

- *Company internal dialogue* – First there will be an internal dialogue within the enterprise, primarily to give the possibility some consideration. Any barriers experienced here will be of a psychological or sociological nature, for example where the idea is rejected due to preconceived ideas, lack of information or resistance to change.
- *Feasibility study* – Secondly a feasibility study will be carried out, which will involve information gathering and consideration of this information with respect to the nature of the business and the types of products under consideration. At this stage, any of the types of barriers (identified previously) may act against the use of LGA refrigerants being considered any further
- *Obtaining funding* – Once an initial appreciation of the order of costs is known, the enterprise can begin to identify possible funding options, which may be both internal and/or externally sourced. It is therefore important to have a fairly realistic understanding of the costs; otherwise overestimation will result in blocking of the project.
- *Market analysis* – If the feasibility study and funding options are not prohibitive then a more detailed market analysis is usually carried out, essentially identifying the extent to which the product using a LGA refrigerant may be applied. Here market as well as psychological and sociological aspects may introduce barriers.
- *Prototype development* – Further to this, prototype development will begin, which requires consideration of a variety of technical and regulatory-type issues to be taken into account. Here

the likely barriers will relate to technical refrigeration and technical safety matters, information resources and regulations/standards issues.

In the case of a service enterprise, the same stages will be processed: company internal dialogue and feasibility study in order to determine whether or not they can handle the refrigerant; obtaining funding in case new equipment and training is needed; market analysis to determine the extent of use; and prototype development which may be perceived as confirming whether or not the refrigerant can be suitably handled in practice.

If the preparatory stage is broadly successful, then the execution stage will proceed where the enterprise finalises the development of the product (or service) and associated infrastructure:

- *Product development* – The development of a prototype is scaled up to complete the development of the relevant models within the product range to use the LGA refrigerant. Whilst most of the technical and regulatory type barriers are less likely to come into play at this stage, issues related to supply and availability of correct components may possibly arise at this stage.
- *Convert production* – With the product development, the specific requirements for the production line, workshop or working area will be better understood, so that the relevant equipment can be introduced. Again regulatory or supply and availability issues may present barriers here.
- *Set-up internal infrastructure* – The enterprise must internally be prepared to handle the new product, and this essentially requires awareness raising and training within the relevant parts of the enterprise. The main barriers here are largely related to psychological and sociological aspects.
- *Set-up external infrastructure* – All of the stakeholders associated with the enterprise must also be prepared to handle the new product. This will include suppliers, auditors, approvals bodies, distributors of systems and parts, service and maintenance technicians and so on. Depending upon the nature of the products and the business, barriers may well be experienced in terms of market-related issues, information resources and particularly psychological and sociological aspects.
- *Operation of new production* – This involves the active production line, workshop or on-site construction of systems. It is unlikely that any significant barriers would arise at this stage.

Finally, the enterprise will had over the products to the consumer or end user, thereby placing it on the market.

For the service enterprise, the same concepts apply in a similar manner: product development and converting production translates as the practical implementation of tooling and training; set-up internal infrastructure involves model risk assessments and management; setting-up external infrastructure relates to sourcing and availability of materials; and operation of new production is the carrying out of the servicing work itself.

2.3 Stakeholder implications

Stakeholders play an important part concerning both the imposition of barriers and also the removal of barriers. Figure 3 provides an indication of the main stakeholders that are implicated when a LGA refrigerant may be introduced, applied or used. In general there are two sets of stakeholders – those that are directly implicated in providing a product (that uses LGA refrigerants) into the market, and those who whilst having peripheral involvement in particular products do play a significant role in the general direction of the choice of refrigerants.

Across the group with direct involvement, there are considered to be a series of critical links established between the key stakeholders (as indicated within the dashed box). At any of these positions, barriers could be present that may prevent the intended product using LGA refrigerant from reaching the market. Whilst the peripheral stakeholders may not necessarily have a direct influence on a particular product or project using LGA refrigerants from reaching the market, they do have a strong influence over the broader barriers that can affect the acceptance of LGAs over the longer term.

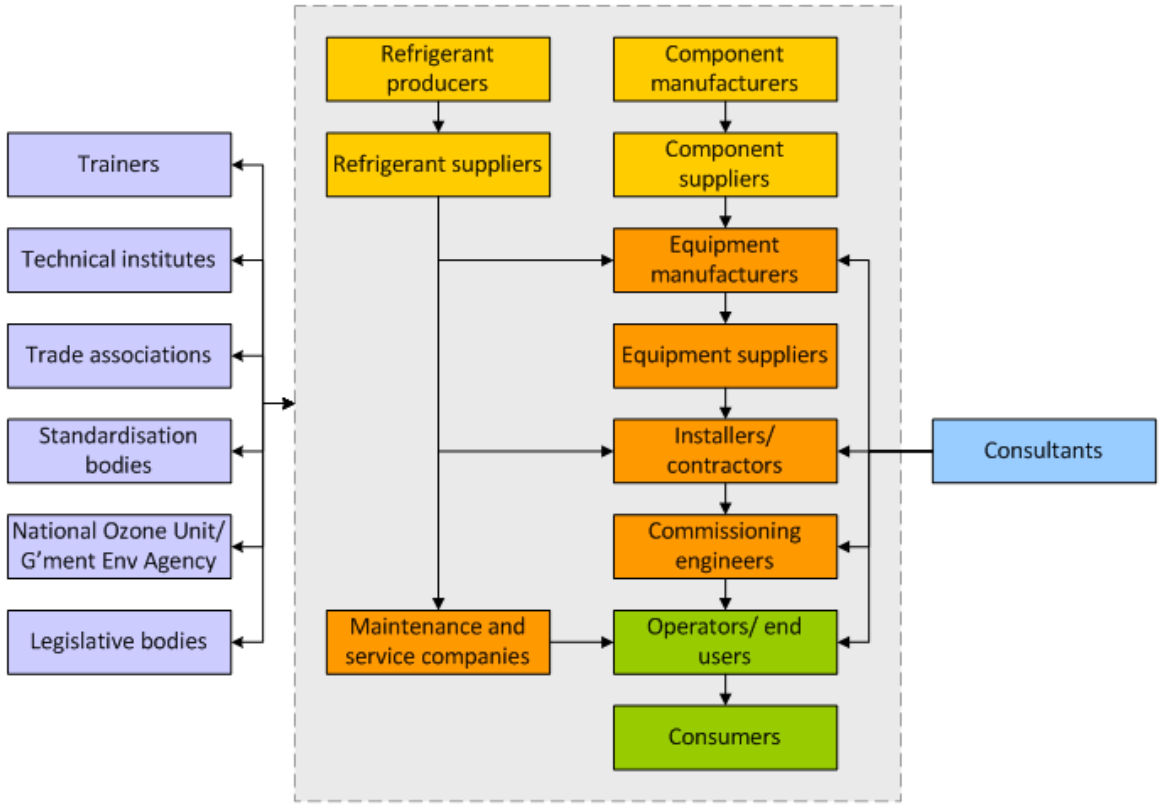

Figure 3: Flow diagram illustrating the main relevant stakeholders when introducing, applying and using low-GWP refrigerants

Amongst those stakeholders with direct influence on the progress of a product, the most significant types of barriers are those related to supply and availability of materials, components, equipment and systems. To a lesser extent, some of these stakeholders could impose commercially related barriers, especially if the use of a particular LGA was against their own business philosophy. Throughout all of these stakeholders, the psychological and sociological type barriers may also play a

significant part. Thus the supply and availability, commercial and psychological and sociological barriers present within this group of stakeholders can be considered to be more acute. Commensurate with the imposition of barriers, these entities may often also hold the key to assisting enterprises with overcoming them.

Some of the stakeholders that have a peripheral influence can of course strongly influence entire markets, in particular trade associations, standardisation bodies, NOUs and other authorities. Similarly, all of the peripheral entities are in a position to address matters related to markets, information resources, regulatory and standards and psychological and sociological barriers. Although they can rarely affect technical refrigeration and technical safety barriers directly, they may have the resources to providing means to overcome them.

It is also noted that the applicability of different types of barriers may vary according to particular types of equipment, such as:

- Size of equipment (large, medium, small)
- Sector (domestic, commercial, industrial)
- Types of equipment (mass-produced appliance, site-installed bespoke system)

Similarly, differing views may also be offered by companies of different orders of size.

3. SURVEY FORMS

3.1 Design of the survey

The design of the survey form was considered critical for drawing out the required information from the respondents. Essentially it was aimed at obtaining detailed answers for the following two questions:

- “If I wanted to have a low-GWP system tomorrow, what is stopping me?”
- “If I am determined to use a low-GWP refrigerant, what would need to be done?”

Further, it is also important to take into account the difference between what may be considered as an actual barrier as opposed to a cause of the barrier. (For example, “it is flammable” is not a barrier; it is a cause of the barrier- “the rules do not permit the use of a flammable substance”.) Similarly, the difference between a real barrier and an ‘excuse’ must also be accounted for. (For example, “I do not have time”” is an excuse, whereas “I cannot financially justify spending the time addressing the implications” is a barrier.) Therefore some guidance was needed to help indicate to the respondents how to differentiate between the terminologies used within the questionnaire. Integrating these considerations within the questionnaire was useful to be able to determine whether the submitted barriers were actual, tangible, personally experienced problems, or whether they were only perceived, fictitious or rumoured issues. In order to try to provide clarity of these issues, a specific sequence of questions was developed to help identify what the barrier is, what caused it and why it

exists, whom it impacts and what could be done about it. Table 4 provides the list of questions presented, and this set of questions was applied to each type of barrier. Also in Table 4 the reasoning for asking each question is explained.

Initially the questions were formulated as a comprehensive questionnaire, which also included background information, rationale for the questions and supplementary information. This comprehensive questionnaire is included in Appendix 1. It was also translated into Spanish for broader circulation around Central and South America. A second survey form was developed on the internet, which contained the same questions but the supplementary information was limited. This survey form is included in Appendix 2.

Table 4: Generic questions of the survey form

Question	Reasoning
Describe what the specific barrier is; do not give a general statement	To find out the barrier that is under consideration; it is important not to provide a basic statement such as "it is dangerous" since this provides no insight at all
What do you believe the causes/origins of this barrier are?	To find out whether the barrier is physical or perception, and what prior events have occurred that may have given rise to this barrier
Applicable to which refrigerant?	To find out whether it is a barrier generic to all refrigerants or one in particular
Which stakeholder(s) does it directly impact upon?	To find out whom the barrier causes a problem for
Can you do anything about it?	To find out whether the barrier could be overcome by the individual
If so, what action(s) would it be?	To find out how the individual (or any other party) may be able to overcome the barrier
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible)	To find out how whether the barrier is manageable and to rank the "severity" of the barrier
If you cannot do anything about it, which stakeholder(s) could?	To find out which other party may be able to overcome the barrier
Is there a way of by-passing the barrier, an alternative approach?	To find out whether the barrier is actually avoidable and the possible routes for doing this

3.2 Target groups

In order to obtain opinions from a wide perspective, a broad a range of stakeholders were targeted. These general categories were chosen since they are believed to encompass most elements of the RAC industry, so that the feedback would be as inclusive as possible:

- Service/maintenance technicians
- Component manufacturer
- Component supplier
- Refrigerant producer/supplier
- Equipment manufacturer
- Equipment supplier
- Installer/contractor/commissioning engineers
- Operator/end-user/consumer
- Consultant
- RAC Trade association
- Technical institute/university
- National authority/government (includes National Ozone Units)

In addition, the countries that were approached were intended to be as diverse as possible, ranging from low volume ODS consuming countries (LVCs) with a refrigeration servicing sector but with no refrigeration manufacturing, through to large ODS consuming countries with large amounts of manufacturing and industrial or institutional research and development activities, in addition to the servicing sector. Similarly all geographical regions were targeted.

4. RESPONSE TO THE SURVEY

4.1 Overview

For the initial "detailed" survey, respondents were approached using three different routes:

- Directly sent to the individual (via email)
- Presented to interested groups at workshops [18]
- Discussed during meetings [19]

Whilst initially a systematic approach was taken (i.e., directed at selected individuals within specific countries and regions), this was found to be inappropriate due to the difficulty in receiving sufficient replies. Therefore the survey forms were subsequently cast across a wider audience. Throughout the period from April to August 2010, this yielded a return of 29 completed (or partially completed) questionnaires.

At the beginning of June 2010, the internet survey was published and this was emailed to all of those whom had been sent but not responded to the first questionnaire, and additionally to a further group. In addition to this, it was included as an article on the UNEP "Jump Start" internet site and the-various Shecco[20] internet sites[21], and subsequently the articles were emailed to their circulation list which totals some 5,500 recipients. From the time of publication to 30th July 2010, this yielded a return of 81 completed (or partially completed) questionnaires. (It should be noted that 12 of the survey forms were completed by people from non-Article 5 countries; Australia, Belgium, Denmark [×2], France, Italy, Sweden, Switzerland, UK [× 2], USA [×2]. Whilst the survey was targeted at Article 5 countries, it is understood that the respondents have had experience within Article 5 countries and therefore their statements were taken into consideration.)

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

[19] Meetings of various types, that the author or other members of the project team participated in

[20] Shecco is an integrated marketing and communications consultancy supporting climate friendly technologies and which operates a number of internet sites specialising in natural refrigerants; www.shecco.com

[21] www.r744.com/articles/2010-07-05-call-for-input-on-unep-survey-how-to-overcome-barriers-for-r744.php, www.hydrocarbons21.com/content/articles/2010-06-30-call-for-input--unep-survey-on-barriers-of-hydrocarbons-uptake.php, www.ammonia21.com/content/articles/2010-07-01-how-to-overcome-barriers-for-ammonia---unep-needs-your-input.php

Considering the extensive distribution of both of the survey forms, the response rate was expected to be much higher than it was. If there is a further study of this type, the approach should be improved to try to achieve a larger number of responses. For example (as seen in Section 4.2) the higher number of responses appeared to be from those regions where a workshop had taken place and the audience had the project explained to them and the staff at the regional office centre (in this case ROLAC[22]) had followed up the request with the attendees. Conversely, where a large number of people were emailed and expected to read through large amounts of material, fewer responses were received.

In total, 109 named individuals provided responses and another 11 did not volunteer their names. Assuming these were provided by different people, a total of 110 different individuals provided response to the survey. In addition, a further unrecorded number of individuals provided statements during discussions.

Amongst the entire set of returned survey forms, a total of 257 "statements"[23] had been provided, from 42 different Article 5 countries (51 including the non-Article 5 countries).[24] During the discussions within workshops and meetings, a further 86 statements were recorded. In total, this is considered to provide a total of 343 statements relating to barriers.

4.2 Breakdown of the responses

In order to characterise the types and level of detail within the statements, the responses were analysed. This included distribution by country, stakeholder type, barrier type, refrigerant, and so on. It is noted that the details of the statements recorded during the discussions in workshops and other meetings were not necessarily recorded, so the overview below only covers those from the survey forms (both the detailed forms and the internet survey). The following analysis also represents the raw responses – in other words, where it was subsequently deemed that a part of a statement had been filled in erroneously, the analysis here represents the unaltered responses. (As discussed in Section 5, in certain circumstanced, selected statements were subsequently re-categorised in order to make better sense of the material.) It is observed that for a number of questions, the respondents did not provide answers (for example, when asked about cause of the barrier, the impacted stakeholders, the impacted stakeholders, how to overcome and the action of others). It is believed that the absence of answers was typically due to time restrictions, the level of interest the respondent had in the question or the lack of clarity of the question, rather than implying any unexplained implication.

Distribution by country

The distribution of responses according to country is shown in Figure 4. A generally wide distribution amongst Central and South American, Eastern Europe and Central Asian regions is seen. However, considering the current consumption of HCFCs according to geographic location, it is believed that

[22] UNEP's Regional Office for Latin America and the Caribbean

[23] A "statement" refers to the partial or entire response for each barrier listed, i.e., for each set of questions as detailed in Table 4

[24] Non-Article 5 countries included Belgium, Denmark, France, Italy, Sweden, Switzerland, UK and USA

the sample drastically under-represents East and South East Asia (for example, China, India, Indonesia and surrounding countries). This is a disappointing finding given the significance of HCFC consumption in those regions. Very few responses were received from Africa and the Middle East. It is important not to interpret the graph as an indication of the number of barriers existing within a given country in an absolute sense; instead it is more representative of the location of known contacts of those involved in distributing the survey forms and the location of the workshops and meetings that were attended. Also, the number of statements from one country may comprise many single statements from a number of different people, whereas there may have been only one person providing several statement from other countries.

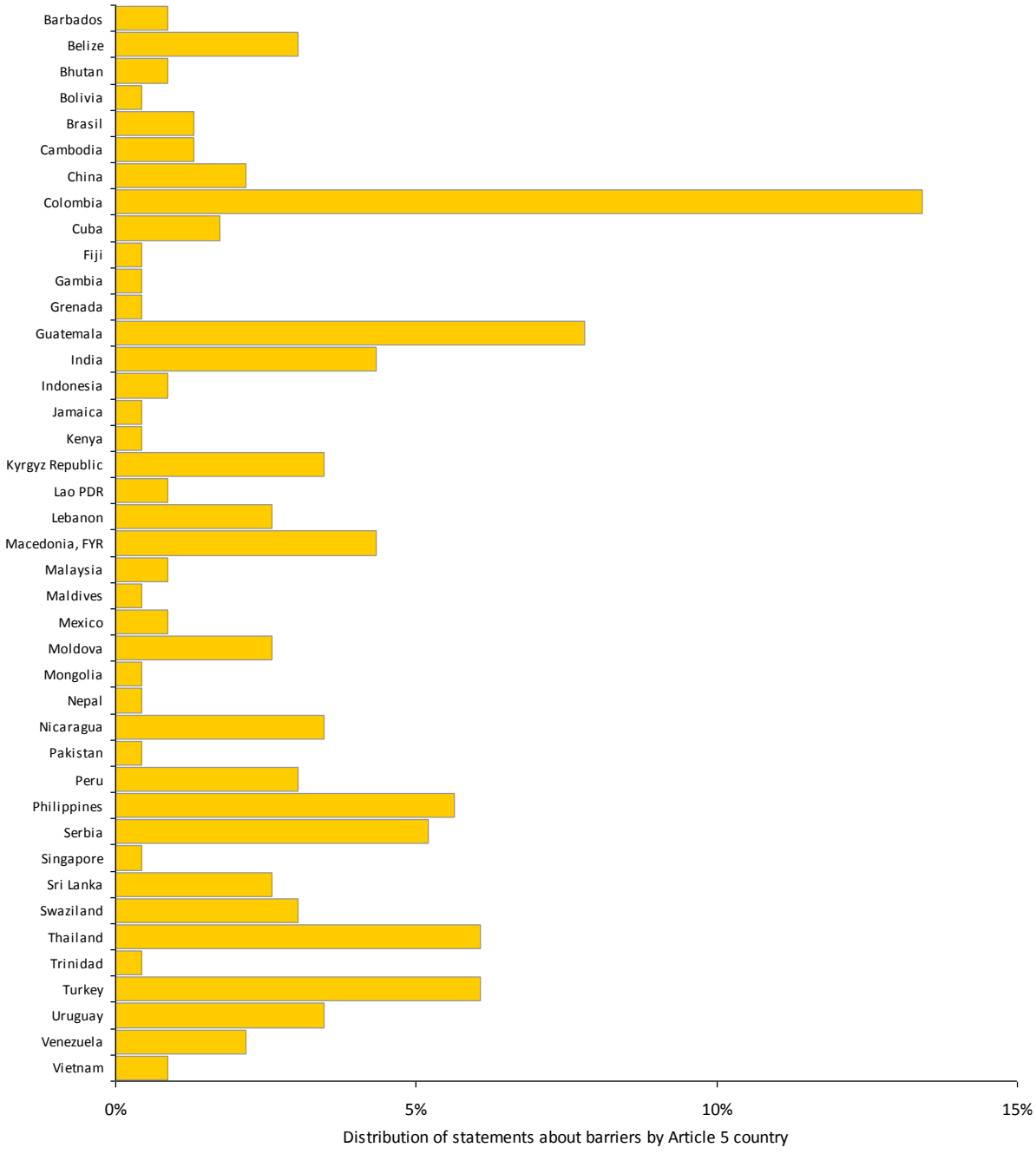

Figure 4: Distribution of the portion of the 257 statements from the questionnaire about barriers coming from Article 5 countries

Distribution by stakeholder category

Figure 5 indicates the distribution of responses given by different stakeholder categories. Some of the initial sub-categories have been grouped for ease of handling, for example, "manufacturer" includes manufacturers of both components and systems, "refrigerant supplier" includes both refrigerant supplier and producer, "equipment supplier" includes component, system and service equipment suppliers. In many cases, the individual respondents indicated two or more occupation types (for example, a wholesaler may sell refrigerant, systems and components, and a consultant may also be affiliated with an institute). The first stakeholder category indicated in the response was used (in order to avoid double counting). Figure 5 shows there is a fairly even distribution amongst most stakeholder groups, which suggests that a reasonable overview has mostly been achieved. However, the stakeholder groups that gave the greatest return were government (mainly NOUs), consultants and those from universities/institutes. This is possibly because these groups represented a higher proportion of those attending the workshops, and also are in more direct contact with the UNEP regional staff. On the other hand, there were relatively fewer responses from one of the more critical (i.e., according to Figure 3) stakeholder groups – equipment suppliers– from whom a greater response would be desired. It is also considered that more input from refrigerant suppliers, end users and contractors would be desirable since they are also key stakeholders and represent those with significant involvement in the implementation of new refrigerants.

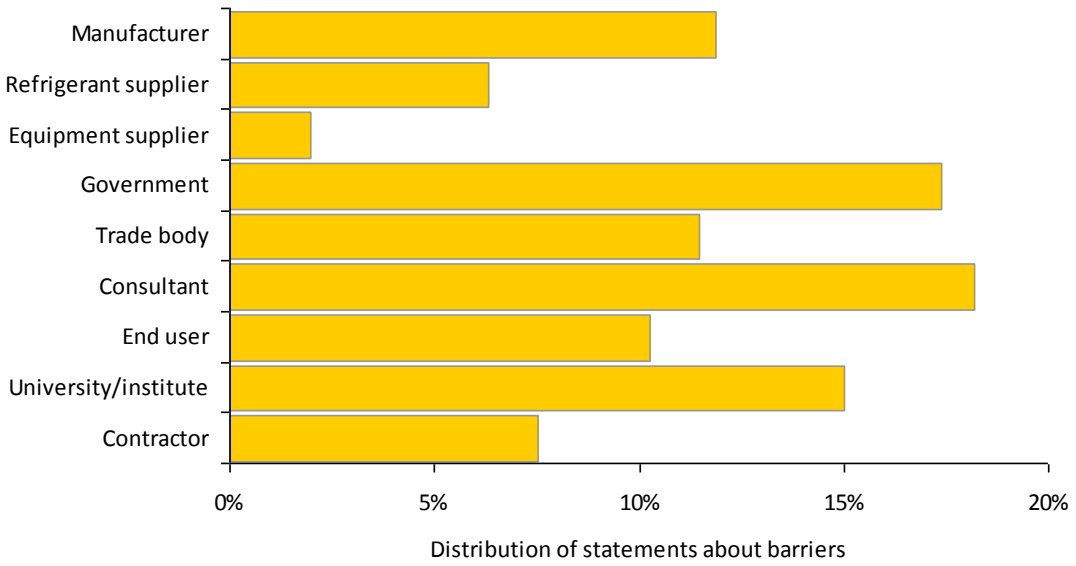

Figure 5: Distribution of the portion of the 257 statements from the questionnaire about barriers coming from different stakeholder groups

Type of barrier

Figure 6 shows the distribution amongst the type of barriers between the statements which indicates that a fairly even distribution amongst the different types was received.[25] Nevertheless, this apparent

[25] It was considered that some of the barriers described were mis-assigned by the respondent (for example, assigning a barrier described as "no availability of compressors" as a "technical refrigeration" barrier, whereas it was deemed to fall under the "supply and availability" category) and therefore discretion was used to more closely assign the categories where necessary.

even distribution should not be interpreted as there being roughly the same number of barriers amongst the barrier types. This is because in the case of the detailed questionnaire, respondents were asked to provide a description of a barrier for each type regardless. (In fact, the tendency for the proportion of statements to diminish from the start to the end of the survey is indicative of the general unwillingness of respondents to complete the questionnaire in its entirety.)

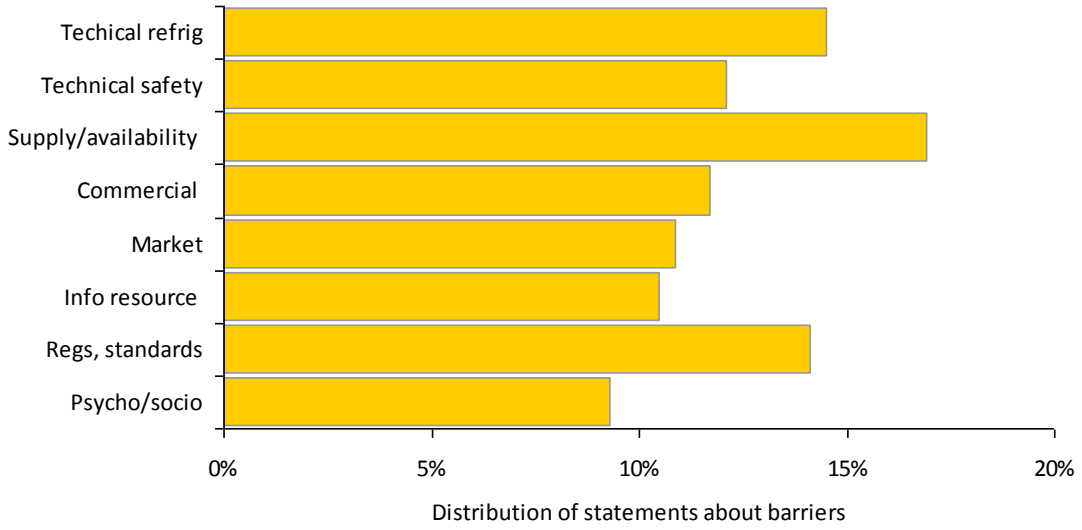

Figure 6: Distribution of the portion of the 257 statements from the questionnaire about barriers of a particular type

Cause of the barrier

Figure 7 shows the proportion of respondents that identified (one of the) causes of the stated barrier. The high rate of responses is believed to imply that most stakeholders are aware of what the causes are, i.e., that they understand the barrier to some extent. However, in some cases the given cause was too vague to be of use.

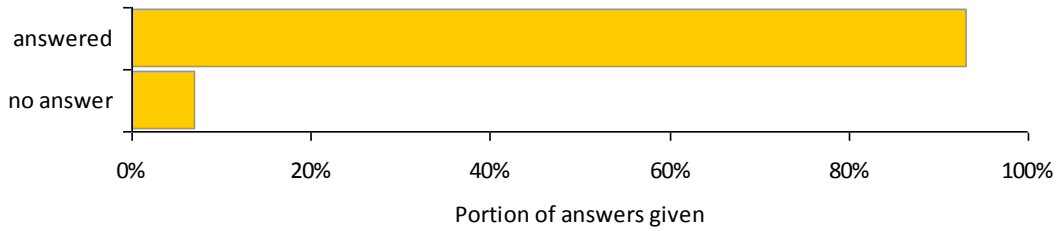

Figure 7: Portion of the 257 statements from the questionnaire including the causes of the barrier

Type of refrigerant

Figure 8 shows the distribution of responses according to refrigerant type. In absolute terms (for each refrigerant type) the total does exceed 100% because many of the barriers applied to more than one refrigerant category. Overall, HCs tended to be included in twice as many of the statements as the others, and this is believed to be an indication of the familiarity that the respondents have with that technology. Whilst the figure indicates that unsaturated HFCs were included in a large number of the responses, this is primarily when the statement referred to “all” LGA refrigerants; only five statements referred to these specifically. Again, this level of response is deemed to be due to the

unfamiliarity of most respondents to unsaturated HFCs, which is particularly the case in Article 5 countries.

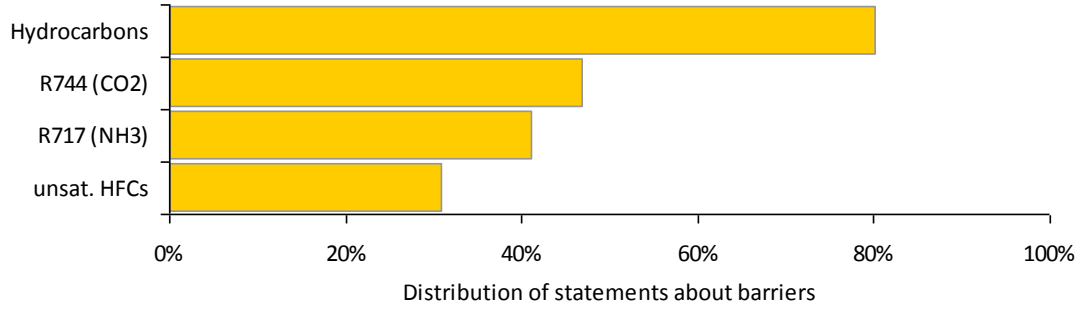

Figure 8: Distribution of the portion of the 257 statements from the questionnaire about barriers according to different low-GWP refrigerant categories

Impacted stakeholders

Figure 9 gives the proportion of respondents that identified the stakeholders who they believed the barrier impacts upon. The high number of responses to this suggests that the respondents are fairly well aware of whom such barriers affect.

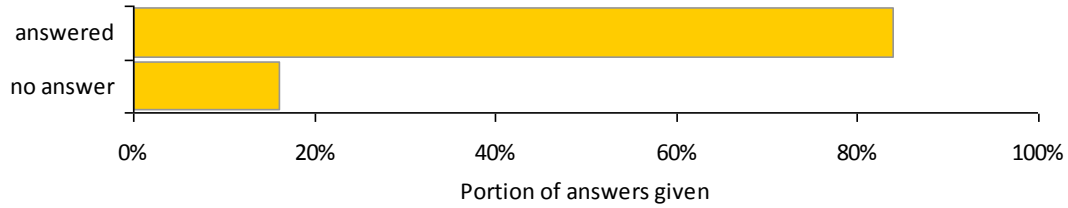

Figure 9: Portion of the 257 statements from the questionnaire including who the barrier impacts upon

Possibility of resolving the barrier

Figure 10 shows the distribution between those who believe they could help with resolving a barrier and those who could not. Whilst a small fraction did not respond, it seems that the majority believe that the barriers they described could be overcome. A further breakdown revealed that of those that responded positively, there was no general trend in terms of the stakeholder group that could or couldn't resolve the barrier, and neither was it related to any particular type of barrier.

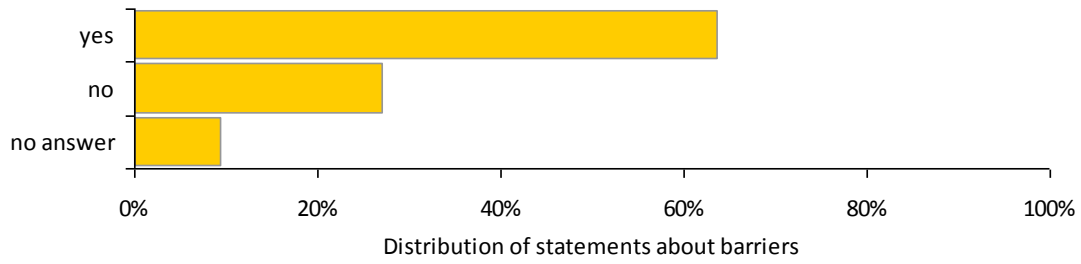

Figure 10: Distribution of the 257 statements from the questionnaire identifying whether or not the individual could help with overcoming the barrier they identified

How to overcome

Figure 11 gives the proportion of respondents that offered a means of overcoming the barrier that they identified. A similar proportion of respondents who said that the barrier could be overcome, explained how it could be achieved. In fact 90% of the respondents who said that the barrier could be overcome gave an explanation. The depth of the suggestions varied, with some providing a detailed explanation and others giving a basic remark (e.g., "training").

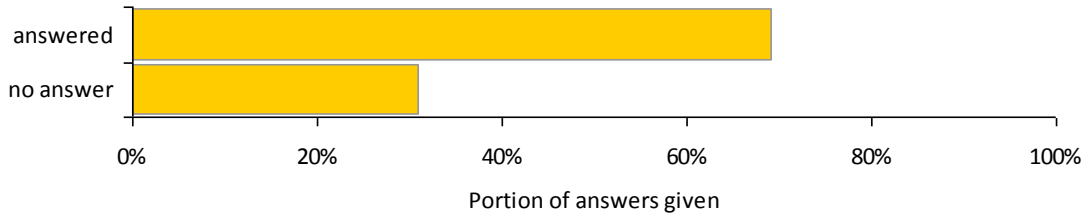

Figure 11: Portion of the 257 statements from the questionnaire including how to resolve the barrier

Achievability of overcoming

Of those that proposed a means of overcoming the barrier, the achievability of this was rated, from "easy" to "impossible". From Figure 12 it can be seen that most respondents believed it would be "feasible"/"difficult" to overcome these barriers. Only about 10% believed that it was an easy task, which seems reasonable considering that the barrier exists. On the other hand, very few believed that the task would be "impossible", which is a positive sign. Again, it must be recognised here that these responses are largely subjective and also vary broadly by country, and therefore these answer must be considered more in terms of the opinion of the respondent.

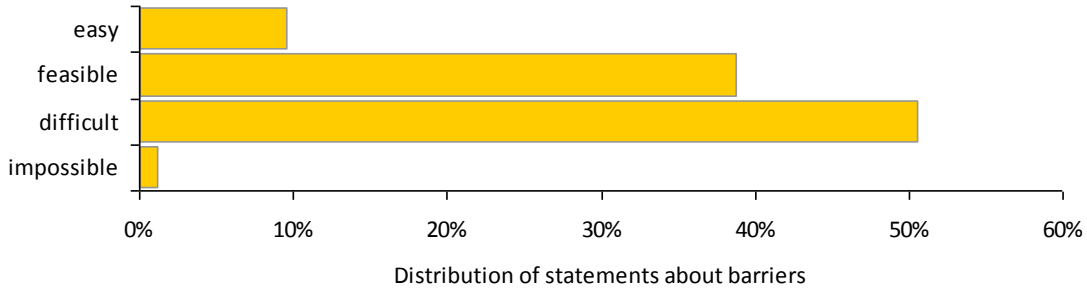

Figure 12: Distribution of the 257 statements from the questionnaire identifying how achievable it is to overcome the barrier that was identified

Action of others

A number of respondents proposed other stakeholder who they believed would be better placed to help overcome the barriers. Figure 13 show that about half of the respondents offered suggestions. Interestingly, the majority of those proposed were government departments, training institutions and trade associations. This suggests that most people look towards the national authorities to resolve many of the issues.

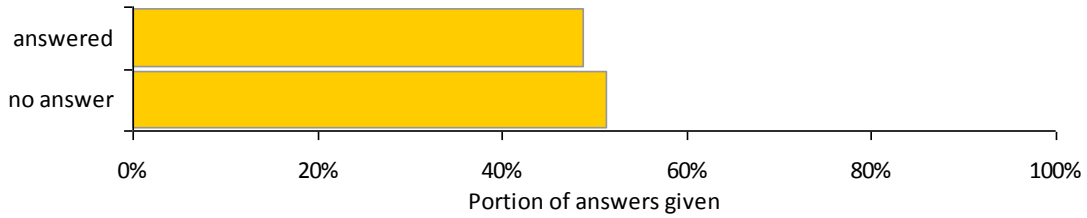

Figure 13: Portion of the 257 statements from the questionnaire suggesting others to help resolve the barrier

5. ANALYSIS OF RESPONSES

NB: The statements and associated views expressed in Section 5 below are those of the respondents to the survey and do not reflect the views of the author or of UNEP.[26]

5.1 Approach of analysis

From the two survey forms, a large amount of material was complied and therefore a means to analyse the information was needed. The general approach for analysing the responses to the survey was as follows:

- Initially the responses were categorised in terms of the types of barriers as detailed within Section 3. In doing this it was observed that within these types, there were many distinctly separate barriers that were identified. As a result, within each type of barrier, several distinct barriers are listed. (It should also be noted that some of the statements were reassigned to different barrier types when it was deemed that were not originally relevant.)
- For each of these separate barriers, the corresponding information was also compiled, such as applicable refrigerants, causes, stakeholder(s) affected, means to overcome, and so on. Where applicable, brief statements and phrases were formulated into discussion points.
- Based on the distribution of the range of responses to a particular barrier, an average "severity rating" was arrived at to indicate how problematic that specific barrier is. Similarly, an "unachievability rating" was also determined broadly according to the responses, which indicates how unachievable overcoming the barrier is.[27]

Many respondents gave specific examples for their country, but they have been generalised here to make them more broadly applicable. Table 5 summarises the general statements relating to the different types of barriers identified, according to the categorisation.

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[26] 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 offense. Very rarely, remarks were omitted where they were deemed factually incorrect or completely irrelevant to the topic under consideration.

[27] Both of these ratings are based on the strength of the responses and in some cases required further judgement of the author to interpret how severe or achievable overcoming a particular barrier is. Furthermore these ratings must be seen as approximate indications, since their relevance will vary widely according to country, enterprises and individuals.

Table 5: Breakdown of generalised statements to describe the barriers

Type of barrier	General barrier statement
Technical (refrigeration and safety)	"Some systems have poor efficiency"
	"The design of systems using flammable refrigerants is not fully established"
	"There is an additional level of complexity involved with working with low-GWP refrigerants"
Supply and availability	"There are no systems using low-GWP refrigerants available to buy"
	"There problems with obtaining the correct servicing equipment and the use of improper servicing equipment"
	"There are no parts/components for systems using low-GWP alternatives"
	"The refrigerant is not available"
	"The industry is insufficiently trained to handle these refrigerants"
Commercial	"There is a significantly greater cost for setting up for production of systems"
	"The products/systems using LGAs demand a greater cost"
	"The service equipment and spare parts needed for a system using an LGA cost more"
	"The LGA refrigerant is priced higher than conventional refrigerants."
	"There is nothing to incentivise enterprises to invest in LGA technology"
Market	"There is no demand for products using LGAs"
	"There is a fear of market acceptance of systems using these refrigerants"
	"No one is willing to invest in production of systems, parts, components and refrigerant"
Information resources	"The industry is unaware of LGA refrigerants and their use in systems"
	"There is a broad absence of general technical information"
	"There are no demonstration projects or installations to learn from"
	"There is no experience in using LGA refrigerants within the local industry"
	"There is a lack of local experts on LGA refrigerants"
	"Consultants developing HPMPs are not recommending LGA refrigerants for projects"
Regulations and standards	"There are no suitable rules to direct users how to use the LGA refrigerants properly"
	"The rules for using low-GWP refrigerants are too restrictive to allow their use"
	"Some stakeholders are unaware of the existence of the rules"
Psychological and sociological aspects	"Lobbying activities in favour of the use of LGA refrigerants in insufficient to influence decision-makers"
	"There is a natural fear of change to use something notably different"
	"There is a fear that the cost of systems and equipment will be very high"
	"There is a general fear of the safety risks"
	"One cannot rely on technicians and others to handle the refrigerants responsibly and according to the rules"
	"Enterprises consider embarking on the production or installation of LGA refrigerants too risky"
	"It is not necessary to use these refrigerants"

Below, a general overview of these specific issues associated with each type of barrier is provided. Subsequent to the general description, the specific barriers are presented individually with the following information:

- A general statement to identify the barrier
- A brief explanation as to why the barrier is a problem
- An overview of the various causes of the barrier
- Suggestions on how to resolve the barrier
- Any additional remarks that were submitted
- A table summarising the applicable refrigerants, system/application types, those stakeholders most impacted and the severity and unachievability rating.

For the "severity" rating, the higher the rating out of five, the more significant the impact of that barrier is considered to have on the adoption and use of a LGA. For the "unachievability" rating, the higher the rating out of five, the more difficult it is considered to remove that specific barrier.

Whilst information was also compiled regarding how viable it was that the respondent believed the barrier to be resolved, the specific responses have not been included in the sections below. This is because for nearly all of the barriers listed, there was nearly always a broad span of views, thereby rendering any conclusion rather meaningless. (i.e., where one respondent believes it to be "easy" and the other "difficult", it cannot be concluded to be "feasible".)

The order within which the specific barriers are listed is random and has no significance.

5.2 Technical (refrigeration and safety)

Since the number of statements addressing technical refrigeration and technical safety issues was relatively small, they have been combined here. This limited number may be due to the respondents' inexperience in designing and working with these LGA refrigerants. Commensurate with this, the statements identified that there is a lack of knowledge and experience in all sectors with the use and application of the LGA refrigerants. Handling some of these refrigerants is considered to be too complex for some engineers', technicians' and operators' current levels of knowledge and basic refrigeration training. This is due to limited experience, especially with HCs, CO_2 and low-GWP HFCs, relating to safety matters, design issues, general expertise, and knowledge of availability of parts and equipment; in general, a lack of specialists. Furthermore, there are little or no research and development activities within the countries to build up (internal) confidence in working directly with the LGA refrigerants, specifically in larger and more complicated types of systems.

The causes of this type of barrier is simply related to there being little or no need to develop such knowledge and experience (as a result of few systems in the market), and also due to the fairly basic level of refrigeration training in many countries.

Ultimately this type of barrier impacts on virtually all stakeholders within the supply chain and therefore it is an important issue to resolve. The means of overcoming this was common amongst all respondents who stated that the only way to build up the knowledge and experience was to steadily evolve a wider use of these refrigerants, whilst simultaneously providing the necessary information

resources (described later). Many of the respondents indicated that overcoming these types of barriers was achievable.

Barrier: "Some systems have poor efficiency"

This barrier is considered a problem because in principle end users and therefore those that supply them the equipment are concerned about energy costs.

Overview of barrier

It is generally believed that R744 has a relatively poor efficiency compared to most other commonly used refrigerants, particularly under higher ambient temperatures. The climatic conditions for many of the Article 5 countries often exceeds 30°C (the temperature at which R744 performance begins to degrade relative to other refrigerants) and as such it is of concern.

Causes

This is largely related to the thermodynamic properties of the refrigerant, but also to some extent the design and construction of the system and associated controls.

How to resolve

Many studies within the literature indicate that systems using R744 can in fact be designed to match the performance of conventional refrigerants up to ambient temperatures approaching 45°C, provided that the appropriate design and control measures are taken. Furthermore there are numerous other studies describing new developments that enable R744 systems to be designed with improved efficiency, and this remains to be a major focus of international research. Manufacturers considering this refrigerant can approach a variety of experts to help assist with the design of such systems.

Refrigerant types	R744
System/application types	All, mainly air conditioning, low temperature refrigeration
Impacted stakeholders	End users, manufacturers, suppliers/retailers
Impact of barrier	Research and development activities are ongoing and with sufficient will many of the efficiency issues can be (partially) overcome
Severity rating	
Unachievability rating	

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

If uncertainties are present with regards to the means of ensuring a high level of safety of systems using flammable refrigerants, those who build and use the systems will be hesitant to do so.

Overview of barrier

It is well known that flammable refrigerants and in particular HCs can pose a risk of fire and explosion if designed and used improperly. Whilst safety standards are available, they do not necessarily contain material suitable for addressing certain important matters such as techniques for reducing refrigerant charge, design and operation of safety systems and methods and results for risk

assessment. Elsewhere, there is a deficit of relevant information within the literature on these matters. Manufacturers of parts and particularly systems, as well as end users require such information to be able to assist with determining and improving the levels of safety.[28]

Causes

The flammability issue is fundamentally a result of the chemical properties of the substance. However, the more "traditional" widespread use of HCs has been in domestic appliances (such as refrigerators and freezers) where charge sizes are fairly small and the need for more comprehensive risk reducing measures has not been necessary.

How to resolve

In general, the various needs for risk reducing measures can be achieved through more research and development activities. Techniques for reducing refrigerant charge are the focus of some research groups and within some companies, but further improvements can always be made, especially with regards to heat exchanger design. Further work or dissemination of findings is also required for system design and construction strategies, such as mechanisms to reduce the amount of refrigerant that could be leaked from the system, preventing leaked refrigerant form accumulating, leak detection schemes and so on. Manufacturers considering this refrigerant can approach a variety of experts, universities and technical institutes to help assist with the design of such systems and the techniques made widely available to all enterprises throughout Article 5 countries. Similarly, collective efforts are needed to carry out risk assessment studies of different types of systems and circumstances and to demonstrate when certain designs have negligible risk.

Refrigerant types	Mainly HC
System/application types	Non-domestic and larger refrigeration and air conditioning systems
Impacted stakeholders	End users, manufacturers
Impact of barrier	Without a clear means of achieving a low risk, manufacturers and end users will hesitate to use
Severity rating	
Unachievability rating	

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

This barrier is problematic since those involved with the design, installation, servicing and operation of the systems are necessitated to deal with more complicated issues than usual, which implies additional risk, cost and responsibility.

Overview of barrier

Using low-GWP refrigerants generally does involve considerations not normally applicable to conventional refrigerants, including conformity to different regulations and safety standards,

[28] Recently a comprehensive new handbook by GTZ-Proklima and TÜV SÜD has been published, "Guidelines for the safe use of hydrocarbon refrigerants" (www.gtz.de/proklima) which addresses many of the issues raised with regards to safety of flammable refrigerants.

different circuitry, training and so on. Overall, it is more difficult to design and construct systems with LGAs compared to conventional refrigerants. Being involved with something deemed to be very different is seen as too much additional effort. In particular, many enterprises within Article 5 countries are too small to be able to handle the subsequent significant changes to systems and infrastructure. In these cases, management will often lack the confidence in designing complex systems and designing systems safely.

Causes

Compared to conventional refrigerants, this observation is often true, but enterprises and supporting infrastructure is rarely present to help overcome these barriers. For example, refrigeration design software rarely includes low-GWP refrigerants, the level of RAC technical training is often too basic or there are too few suitable training courses available, there is no local experience and there are no other comparable systems locally to learn from. The absence of such aspects gives rise to too much scope for mistakes which could result in costly consequences. For manufacturers and contractors, developing systems that have smaller (flammable) refrigerant charges and suitable (non-sparking) electrical components can be challenging and demanding of resources.

How to resolve [29]

The primary means to overcome this barrier is to for enterprises to receive support in terms of technical training at all levels, including design engineering, production and at technicians level. There should be improved basic level of training and also specific training for the key issues. However, it is important that the training is targeted both at existing engineers and technicians as well as for those just entering the industry. The benefits of allowing employees to attend extended training courses must be emphasised to managers, as the loss of a large portion of employees even for a few days can impact on the smooth operation of a small business.

Additional remarks

It was generally considered that the authorities should take responsibility for introducing training. Also, it was proposed that the authorities can “require” the relevant people to learn the key skills through regulation.

Refrigerant types	All
System/application types	All systems, but mainly site-installed systems
Impacted stakeholders	These problems largely impact on manufacturers, installers and service technicians
Impact of barrier	The complexity is often misinterpreted as a different way of doing things and greater familiarity over time minimises the impact.
Severity rating	
Unachievability rating	

[29] As noted previously, it is noted that the Executive Committee of the Montreal Protocol has already decided to provide up to 25% additional funding for LGAs in order to address the need to overcome such barriers; however, this is not available to non-manufacturing enterprises/countries that do not have manufacturing. Also, it must be recognised that many respondents may not have been aware of this decision.

5.3 Supply and availability

The statements relating to supply and availability issues were extensive and therefore considered to reflect a strong feeling. They mainly apply to inability to obtain systems/appliances, components, the refrigerant itself and service equipment. Similarly there is a lack of awareness for handling LGA refrigerants due to an absence of available training.

Of course the causes for these problems are almost always the lack of large-scale demand. In most cases, the suppliers of components, refrigerant and service equipment can endeavour to source them, but the resulting cost will often be prohibitive. There is also a perception of contractors and system manufacturers that there is a reluctance of component and equipment suppliers to readily provide items for use with hazardous refrigerants due to general safety concerns, a mistrust of customers to use them safely and associated liability issues. Also, since many of the contractors and servicing enterprises are small, there are insufficient internal resources to justify employing or training up high level experts in the use of LGA refrigerants.

These barriers impact on many of the stakeholders, but mainly on contractors and servicing companies. There are mixed views as to who has the ability to push for the barriers to be overcome, and in most cases it is considered to be a difficult task. In general it is seen as the task of the authorities to somehow develop incentives to encourage the use of the LGAs and disincentives to limit the use of existing products.

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

It is obvious that if there are no systems available to purchase then these refrigerants are unlikely to be used.

Overview of barrier

Except for a few specific sectors in some countries, new systems using LGAs are not commercially available. Those systems that are available are for a specific market sector (such as domestic refrigeration using HCs and large industrial refrigeration using R717). In many Article 5 counties there are few system suppliers and they rarely supply systems using LGAs. Similarly producers of equipment also rarely market such products in Article 5 countries.

Causes

The cause for the absence of suppliers of these systems is two-fold. In most cases it is because there is no market demand or even awareness of such systems. For some cases it is also because products are not knowingly manufactured by any companies. Where products are manufactured, suppliers may not be aware of them or they may be very remote (globally) or the products may have a "premium" price attached meaning that they are not viable for sale in certain Article 5 countries. Within an Article 5 country where environmental issues have less of an impact than other more critical social issues, there is often sparser knowledge of the technology, and therefore the interest in LGA will be limited.

In countries where import duty is high, importing “premium” low-GWP products may introduce further costs, thereby making products even less financially attractive, than say locally sourced products or mass-produced HCFC/HFC products. For local producers, switching refrigerant implies a high investment cost.

Where countries are located geographically close to larger non-Article 5 nations (such as Central America in relation to North America), there is typically “product-spillage” where products intended for the non-Article 5 countries also go to the smaller Article 5 countries for convenience and cost reasons. Subsequently conventional technologies – such as those using high GWP HFCs from North America – become established, rather than low-GWP products that may be more commonplace in Europe, for example. Another issue for certain countries is that second-hand systems from non-Article 5 countries are reused in Article 5 countries (which may be more than ten years old) and may be based on HCFC or even CFC technology.

How to resolve

There are two main ways to tackle this barrier. The “softer” approach is to raise awareness of the possibility of the alternatives within the industry particularly amongst end-users, especially targeting those sectors with high refrigerant consumption. This could include advisory roles to the industry, as well as seminars and workshops. From a longer-term perspective it would be useful to try to institutionalise the interest in LGAs by informing younger engineers and technicians to be more aware of the refrigerants and the implications. In order to assist with enabling the introduction of systems using LGA, a database of producers of such equipment may be set up so that the links between these companies and local suppliers can be made, that is to open up the supply stream. A slightly more structured approach could be to formulate national policies to stimulate demand for LGA systems, such as financially orientated incentives (for low-GWP) and disincentives (for high-GWP) alternatives. This may include sales tax, import duty or subsidies.

Additional remarks

To contribute to addressing this barrier, technical colleges and other training establishments should be encouraged to contribute to the awareness raising. Also equipment suppliers should be encouraged to source systems using LGAs. It was considered by many respondents that national authorities (Ozone Units and others) should be developing incentives to encourage these activities.

It often happens that individual end users or suppliers may enquire about the purchase of a small number of systems from a manufacturer; these requests are often turned down. The reason is that most manufacturers are set up to carry out large scale production and cannot cope with making similar systems or equipment on a small scale with the variations necessary to accommodate a different refrigerant.

Whilst awareness raising and other forms of encouragement are essential, it is also important to retain some realism in terms of what ranges of systems are available and what the constraints are for using particular alternatives. For example, all of the stakeholders should be aware of which

refrigerant can be used in a given type of systems and what the most applicable capacity and temperature ranges are.

In some respects, it is important that LGA designed systems are available for safety reasons; there is a growing desire within many Article 5 countries to use HCs in systems that are designed for non-flammable refrigerants and this has safety consequences. If systems are designed specifically for use with HCs their use will be inherently safer.

It has been reported that some Article 5 countries receive a lot of second-hand systems from non-Article 5 countries. These will typically be designed for CFCs, HCFCs or HFCs, and therefore local technicians and engineers will gain greater familiarity with these refrigerants, rather than LGA ones.

Refrigerant types	All
System/application types	Mainly air conditioning
Impacted stakeholders	This barrier ultimately impacts on the end-user, since they are unable to make the choice of using a low-GWP refrigerant in their systems. To a lesser extent, system suppliers are impacted since they cannot offer such systems.
Impact of barrier	Without systems being available, nobody can install, work on learn from them or have any need for peripheral parts and equipment.
Severity rating	
Unachievability rating	

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

Contractors will be less eager to work on systems without the proper service equipment and therefore end users may struggle in having their systems maintained. There are also safety implications when improper equipment may be used as a short-cut.

<u>Overview of barrier</u>

In most Article 5 countries the relevant service tools and equipment are unavailable. This may include gauges, comparators, gas detectors, recovery machines and so on. In some places, the proper equipment may be sourced, but service shops and especially smaller enterprises cannot justify the purchase of new or separate sets of equipment.

<u>Causes</u>

As with systems, the main reason for the absence of service tools and equipment is largely related to the lack of demand. Also, much of this service equipment for LGAs is produced and supplied within Europe so there is additional cost premiums associated with transportation to other parts of the world. When it comes to the purchase of equipment through funding opportunities, the limited funds mean that the cheaper (more widely produced) CFC/HCFC-based products are purchased.

<u>How to resolve</u>

At a basic level, specific requests could be made to importers to import the appropriate service equipment. Other more involved strategies would include local enterprises developing their own

service equipment products that could be sold to the local industry. (This would have the added advantage of being better suited to the local conditions, rather than, say, the European or North American market). Lastly, implementing agencies could routinely specify that only dual purpose servicing equipment be purchased under HPMPs (i.e., that is compatible with both fluorocarbons and HCs) or that a certain proportion of the purchased equipment be suitable for LGA. Similarly, an arrangement could be made where implementation agencies subsidise the cost of any service equipment for LGA whenever needed, outside the constraints of HPMP funding. Other suggestions included the contractors importing the equipment directly themselves.

Additional remarks

It was also noted by some respondents that most technicians do not want to have to carry around more items than is necessary (such as two sets of gauges, recovery machines, vacuum pumps, etc), and therefore dual-purpose service equipment would be most desirable.

Refrigerant types	All, but mainly HC
System/application types	All
Impacted stakeholders	This problem mainly applies to contractors involved with installation, service and maintenance of systems, but ultimately impacts on end users.
Impact of barrier	Although the lack of parts makes use of LGA refrigerants difficult, the presence of systems would open the flow of equipment
Severity rating	
Unachievability rating	

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

This barrier poses a problem in two regards – first when manufacturers want to build systems some essential parts are not available (thereby making the construction of the system not possible) and secondly existing systems cannot be repaired properly and may have to then be converted to high-GWP refrigerants (where possible).

Overview of barrier

In many countries there is no availability of system components, especially compressors. Otherwise parts are sometimes available but are from a limited number of manufacturers and therefore subject to a high price. These problems are exaggerated when considering smaller countries or rural areas. A similar issue applies to suitable electrical components for use with flammable refrigerants for the construction of new systems (and for conversions of existing systems). The same applies to sophisticated safety control systems as needed for larger systems.

Other issues related to this are where certain component producers only sell components to selected system manufacturers subject to legal agreements and the associated limits applied to these. In other cases, component suppliers refuse to supply parts if they believe they will be used for HCs or other such refrigerants.

Causes

As is the case with the supply of systems, the overriding reason for the absence of components is there being not enough demand. Especially if there are few existing systems, there will be no need to import the components in the first place making it even more difficult for the manufacturer to obtain parts. Again, certain components may only available from distant countries (thus incurring transport costs, sourcing time, etc) thereby increasing their cost. Of course some parts may be available, but these are only suitable for a limited range of system types (e.g., domestic fridges/HC, industrial/R717).

With regard to the philosophy of the suppliers, the reasons for this is quite straight-forward, in that they often have a concern over safety and by adopting a default doubt over the conduct of the customer they are ensuring that their components are used in a safer manner. This also helps to protect them with regards to liability and technical failures.

How to resolve

Apart from stimulating the supply of components through greater use of systems, there are few other options available to help overcome this barrier. One option is to encourage local producers to develop suitable components; this may apply more suitably to electrical components. In order to satisfy the larger manufacturers of components, the national authorities could develop the infrastructure to improve the safe working practices of the local industry. A registration and certification scheme (for both technicians and enterprises) is one means of achieving this. They should also involve manufacturers' association in the process. Also manufacturers of systems could set up their own sales outlets for the supply of spares to the technicians.

Additional remarks

It was noted that when such components are not widely available, this can result in longer repair lead times and this strongly affects customer's views and thus the reputation of the refrigerant under discussion; the customer similarly looses faith with the manufacturer and the contractor.

Manufacturers that have been through the process stated that the problem was overcome, but it took around one year to set up the relevant distribution chains.

It is also important to emphasise the importance of ensuring good availability of parts and components for technicians, since technicians will often use ingenious means to improvise parts and components which in some cases could lead to more hazardous situations (through incorrect use and unauthorised modification of parts).

Refrigerant types	All refrigerants, mainly HC
System/application types	All
Impacted stakeholders	This barrier applies to a large segment of the industry including manufacturers, installers, service and maintenance technicians as well as local component importers/suppliers.
Impact of barrier	Although the lack of parts makes use of LGA refrigerants difficult, the presence of systems would open the flow of parts.
Severity rating	
Unachievability rating	

Barrier: "The refrigerant is not available"

It is evident that if there is no refrigerant available to purchase then it cannot be used.

Overview of barrier

Local suppliers do not stock the refrigerants. Often they are unaware as to where to source the refrigerant. In other cases, the supply of the refrigerant is very limited. For some types of refrigerant, the quality of the product (in terms of the composition, contaminants, etc) being sold is poor and this leads to reliability and performance problems. On the other hand, conventional refrigerants are widely available and pose few of the problems described.

Causes

From the suppliers' perspective, if the demand is low then they are not likely to source and sell the product, which is the case in many countries. If the product can only be sourced at a high cost this is a further inhibition to prevent them from stocking the refrigerant. So long as a given refrigerant is not being used within equipment installed locally then there is little specific need for stocking the refrigerant. For refrigerant producers, these reasons are amplified – given the high cost of setting up a plant for cleaning and decanting product, as well as the investment in cylinders, there must be a significant demand within the region. One further hindrance is the more complex requirements associated with storage and transportation of flammable, higher toxicity or high pressure substances, thereby demanding additional consideration on the part of the supplier and often greater costs. This issue is frequently experienced by those trying to import flammable refrigerants who find that the transportation costs are prohibitive.

It was also noted that in many cases the refrigerant importers and retailers do not have the information on where to source the LGA, what the cost is and also what the market potential is.

How to resolve

At a fairly basic level, the stakeholders may request wholesalers and suppliers to import and stock the refrigerant, thereby indicating a notable market demand. A more difficult approach would be for contractors or manufacturers to import directly from foreign countries, although this is likely to be particularly demanding in terms of time and resources (for example, for sourcing the correct types of cylinders or tanks). The situation associated with additional rules for storage and transport of the product could be eased by the national authorities developing industry guidance (based on national legislation) for handling the relevant substances. Furthermore implementing agencies can also help

to overcome this barrier by including measures to improve supply of refrigerant adequately into their HPMP project proposals, thereby obliging the necessity to develop easier supply routes.

In order to assist potential importers and retailers of LGA refrigerants, there is a need to provide commercial information such as the potential size of the market and sources within the region and elsewhere where the LGA can be obtained.

Additional remarks

The national authorities could assist with encouraging the competitiveness of the LGA by imposing some sort of limit on the import and therefore the availability of more environmentally damaging fluids, and at the same time introduce financial incentives for the importation of LGAs. They could also establish refrigerant replacement programmes whereby old systems/refrigerant are replaced with LGAs. A database of regional and international suppliers of the relevant refrigerants could be developed so that local dealers could more easily source the product and at the same time competition would be improved (thereby driving down prices). Lastly, if a country has its own production of raw product (such as ammonia, CO_2 or HCs) then there may be an opportunity for developing a cleaning and decanting facility to provide a locally-sourced refrigerant supply.
One respondent stated that the import of HCs is currently restricted by their countries' Ministry of Defence due to possibility of using HC by terrorists.

Refrigerant types	All, but mainly HC
System/application types	All
Impacted stakeholders	This barrier impact on most of the industry, from refrigerant importers, wholesalers and retailers, to installation, service and maintenance contractors, service shops, manufacturers and to end users.
Impact of barrier	LGA refrigerants cannot be used if they cannot be bought, but if greater number of systems is present, they will be made available.
Severity rating	
Unachievability rating	

Barrier: "The industry is insufficiently trained to handle these refrigerants"

If design engineers, service, installation and maintenance technicians and system operators are not trained to use the LGA refrigerants, they will either be uncomfortable with working on such systems and will therefore refuse to use them, or they will use them with the possibility of undesirable consequences.

Overview of barrier

There is a general lack of training of service, installation and maintenance technicians to safely use HCs, but also R744 and R717. This applies to a various equipment types ranging from domestic to commercial refrigeration and air conditioning. It has been stated that businesses cannot find local technicians that are able to deal with LGA natural refrigerants. Similarly, design engineers are also not adequately trained such that they may not be aware of the possibilities of using a given refrigerant and how to apply it safely and efficiently. In many cases, the depth and quality of training courses is limited and insufficient, sometimes the cost of attending the courses is prohibitive or the

technicians or employers are not prepared to lose money through absent working hours and otherwise the training courses are simply not available. Ultimately this means that there are insufficient numbers of technicians to be able to work on systems. In the case of larger systems (such as those that would use R717) the shortage of plant operators is also a significant problem.

Causes

Generally the need for training arises with the observed introduction of a particular technology. Since the introduction of some of the LGAs in certain countries is in embryonic stages, then the need and demand for the relevant training is not yet recognised. Where training does take place, if a technicians has limited direct hands-on experience with the LGA under consideration, after some time their confidence in using the product may wane. It was also reported that in many countries there is an absence of knowledge about the use of the LGAs at a senior level, rendering the country unable to properly train the field technicians and design engineers. Of course if there is a lack of awareness of LGAs in colleges and training institutions, it may not occur to them to include training for these refrigerants. In other cases, there may be insufficient funds available to provide the proper training, especially if it is considered to be peripheral or non-essential in nature. Similarly, the education within further and higher education establishments (colleges, polytechnics and universities) is often known to lag behind the most recent technological developments. In Article 5 countries many service technicians are from the informal sector which makes it even more difficult to encourage them to become involved in improved training.

How to resolve

The means of resolving this barrier is largely to extend and elaborate current training practices. That is, to set up workshops and seminars on the subject, that – where relevant – should encompass both theoretical and practical aspects. However, it is important to ensure that these events are dedicated to specific LGAs under consideration. (For example, many current workshops may address "refrigerants" as a whole, and only dedicate a small proportion of the time simply mentioning that LGAs; considering the additional complexities the focus must be on specific LGAs.) It is also suggested that the refrigerant producers or suppliers of the LGAs and the system manufacturers participate so that they can gauge the level of interest and acceptance of their products. There should also be promotion of teaching programmes at senior level in the appropriate use of LGAs; national authorities should review the knowledge of teachers and lecturers to identify if and where the gaps are. Where trainers of those from other institutions have a deficit in the knowledge on the use of a given LGA, it may be advisable to send them to other regions of countries to receive intensive high level training such that they can impart the knowledge more widely back in their own country. When dealing with refrigerants that are notably different from the conventional ones, and especially during the evolution of use of those refrigerants within a country, it may be necessary to have regular "re-training" where technicians have their understanding topped-up to ensure that the critical elements are not forgotten or that they do not become complacent.

This also provides a strong case for why servicing sectors have to be involved in HCFC phase-out from an early stage as introduction of LGAs requires the capacity of the service sector to handle them.

Additional remarks

It is also noted that such training should be combined certification schemes.

Where a country anticipates the increasing use of a particular LGA within their country, it would be wise to try to lead this with extensive training in order to help the industry embrace the technology and also to lessen the risks of untrained technicians handling more hazardous substances. It is also important to ensure that a little training does not result in excessive immediate use of alternatives, and some form of staged introduction is applied. Such intentions could be supported with the development of national legislation and "phase-in" programme.

A country may also wish to set up dedicated (national) consultancies with experts who may liaise with training institutions to impart the latest and most comprehensive knowledge to them.

It was also noted that engineers unskilled in the use of certain LGAs (such as R717) may not have the knowledge to exploit the properties of the refrigerant to achieve the potentially very high efficiencies that would normally be expected.

It has also been proposed for certain countries to set up mobile training resources, so that the trainers can go directly to the companies.

Refrigerant types	All
System/application types	All
Impacted stakeholders	Training issues broadly apply to the entire industry, encompassing suppliers, manufacturers, contractors, operators and end users, as well of course as schools, colleges, universities and other technical institutes.
Impact of barrier	No knowledge means that individuals cannot design or work on systems, but training is easy, albeit time consuming and costly.
Severity rating	
Unachievability rating	

5.4 Commercial

Commercial issues appear to be amongst the more significant barriers. There were a variety of statements in the survey that reflect the various commercial issues that enterprises would have to deal with if adopting any of the LGA refrigerants. These include the (current) price of systems, components, service equipment and refrigerant being too high, and at the same time an absence of financial stimuli or incentives for importers of systems and equipment or producers to adopt the alternatives. Due to these and the additional time and resources required for internal training, investigation of the technology, research and development, etc (especially for smaller companies), there is no additional profit seen to offset these complications as well as the potential increase in business risk associated with the unknown.

These issues generally impact on all enterprises involved within the manufacturing, supply and contracting sectors. This is especially relevant where much of the components, systems and refrigerant come from non-Article 5 (more affluent) countries, rendering the costs more exaggerated

than in Article 5 countries. It is especially relevant to servicing and contracting enterprises that are often individuals or comprise a very small number of employees and therefore do not have the financial resources for handling major changes, improving practices and investing in the capability for using more than a couple of different refrigerant types. Another contributing factor is the fact that because the market for such alternatives is (currently) small, volumes are low and therefore few suppliers sell related products which results in an absence of competition. A further financial implication is the existence of too many new refrigerants and the uncertainty of which direction refrigerant choice will follow in the future, thus the risk of investing heavily in one particular LGA is considered to be great. Lastly there is also a belief (whether true or not) that the funding process under the MLF is institutionally directed against natural refrigerants.[30]

Amongst the respondents, few stated that they could do anything to resolve the main issues since the cost of supplying an atypical system or appliance or an item with additional technical implications will always cost more. Since many of these barriers may be perceived rather than actual, it may be pertinent to present studies to show what the real cost is (likely) to be for a particular technology. In any case, many of these are tangible problems and therefore some entity would have to accept that cost differential. Ultimately it would be left to national authorities or agencies to apply financial interventions to help offset the differential costs until a critical mass is achieved for cost parity. In many cases it was proposed that this could be done through incentives such as lower tax, import duty, etc. Other proposals included using the clean development mechanism of the Kyoto Protocol could be use to make the use of LGAs more commercially attractive.

Barrier: "There is a significantly greater cost for setting up for production of systems"
Greater costs, resources, time and effort in the short term is a disincentive for adopting LGAs in the production of systems.

Overview of barrier
In order to produce systems using LGA refrigerants, there are greater costs involved for the manufacturer. Therefore enterprises must be prepared to invest more in order to produce those systems. Also handling additional refrigerants within the production process (especially for small and medium-sized enterprises) increases operating costs and therefore reduces competitiveness. Many enterprises have already invested in conversion of their production line from CFC to HCFC or HCFC to HFC and are therefore not keen on being subject to the entire process again, especially with greater incurred costs. Even though it is not necessarily financially quantifiable, management within enterprises also cite the anticipation of additional effort as a disincentive.

Causes
The reasons for these additional costs are fairly obvious. The origin of these costs, depending upon the type of production, the type of systems and the LGA under condition, include:

[30] For clarity, the decision of the Executive Committee of the Montreal Protocol to provide additional funding of up to 25% for investment projects for the introduction of low-GWP alternatives is reiterated here.

- Additional resources are needed to modify the production area in order to safely handle flammable or higher toxicity substances, since the relevant equipment and safety systems are generally more costly and/or additional equipment are normally needed.
- There is usually a greater cost for production line equipment suited to use flammable, corrosive and very high pressure refrigerants.
- There may be greater cost of transportation (or at higher prices from freight companies) for systems containing flammable substances.
- More time and resources are necessary for internal training, such as for production line workers, factory maintenance staff, managers, design engineers, etc. If the enterprise has its own or contracted field technicians, the retraining costs also apply to these.
- During the development phase, it is necessary to spend resources for complying with standards.
- In some countries, there may not be local contractors that could supply the production line that meet the necessary requirements (qualifications, quality systems, safety standards) to adequately facilitate a safe installation thereby necessitating the use of foreign contractors and components.
- Local testing laboratories may not have the experience or testing equipment for relevant safety standards, so they will charge more for the service or will have to contract it out elsewhere.

As with most other items, the cost of the hardware for implementing LGA refrigerants may be relatively higher with the initial implementation projects due to the current demand being low.

How to resolve

A number of different approaches may be taken to help minimise the costs associated with converting the production facilities and to minimise the complications associated with it, such as:

- Develop and promote financial incentives (such as tax benefits) for companies that adopt these technologies.
- Tax rebates for import of production line equipment used for LGAs.
- Authorities to provide complimentary promotional activities for the products and/or enterprises that use LGAs.
- Identify specialist companies (or encourage potential companies) to provide turn-key packages for carrying out all the necessary activities for converting the production area, training internal and external personnel and sourcing the necessary tools and equipment.
- Implementing agencies could provide additional funds for conversion, for example according to the decision of the ExCom to provide an additional 25% of funding[31] (although it must also be mentioned that in some cases this amount could be insufficient)
- Implementing agencies could develop conversion guidelines for manufacturers, specific to each LGA refrigerant.
- Implementing agencies could draft in experts to work with the manufacturers to assist with interpretation of rules, production modification/development, specialist training, etc.

[31] Ibid.

- Manufacturers could offer to help train the laboratories or the implementing agency may supply needed equipment and systems to be tested at the production facility under the supervision of an external laboratory.

It is important that countries become fully aware of the possibility obtaining additional funding from the MLF for investment projects when introducing LGAs so that additional costs may be offset through this scheme.

Additional remarks

In some cases, it must be recognised that it is unlikely that the cost can be minimised or offset. Also, in certain circumstances where a manufacturer already produces equipment using two or more other refrigerants, the addition of a further refrigerant will increase the operating costs of the business and will subsequently add to the unit price of the products using the new (LGA) refrigerant.

One country has developed several consultancies to determine the needs of refrigeration equipment maintenance sector to boost the use of HC, as well as training activities for technicians. They have developed a full package for service facilities together with a supplier.

The output and the efficiency of the manufacturer will also influence the impact of the cost – if the output is sufficiently high then the on-cost for individual systems or appliances may be negligible. In some cases where the system is cheaper to manufacture because of improved thermo-physical properties (i.e., less metal) then this can actually offset the average manufacturing costs (over the investment period). One manufacturer found that the conversion from HFC to HC resulted in significant financial benefits as a result of the leaner production process and better trained workers and lower material costs for systems and higher efficiency due to the need for redesign.

Refrigerant types	All
System/application types	Mainly appliances
Impacted stakeholders	Manufacturers of systems and their service and maintenance infrastructure.
Barrier impact	This is sensitive to the size and output of the enterprises involved, and overtime the impact of the barrier diminishes.
Severity rating	
Unachievability rating	

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

The purchase of refrigeration and air conditioning systems is broadly based on lowest first cost (or lowest cost for a given efficiency) and if LGA systems have a higher cost they will not be purchased.

Overview of barrier

Enterprises that manufacture RAC systems or construct systems using LGAs state that the cost can be to some extent greater than those using conventional refrigerants. For smaller enterprises this cost may be significant, whereas the larger international manufacturers often shy away from using LGA

technologies for more political reasons and therefore the attractiveness of lower cost mass-manufactured products will be absent. In the majority of cases, the client prefers the cheaper alternative, namely the one that implies lower initial investment irrespective of environmental impact or even lifetime cost. The majority of end users have (or can only afford to have) a short term policy.

Another issue is that if the customer believes the refrigerant to be more hazardous (flammable, higher toxicity) they are even less likely to pay a higher price for a product. In the case of a new technology, the confidence of the seller in the reliability of the product may be low, which will further dissuade the customer from investing.

Causes

The reasons for this barrier vary between factual and perception. In general, systems need to be redesigned both in terms of the refrigerant circuit and ancillary parts (to achieve safety requirements when flammable refrigerant are employed). The time associated with this introduces more staff time and resource costs. Particularly if a company has a large number of different products the time taken to analyse and redesign each model can be very onerous.

Depending upon the product type, enterprises may have to invest significant time and funding to investigate the technical aspects of the LGAs and to carry out development activities. Again, smaller enterprises often cannot afford to investigate the technology options in this way. Further time and effort is required to launch the new products and ensure that the supply chain is familiarised and comfortable with them. A further cost impact (for the manufacture of some types of appliances) is the cost for purchasing and installation suitable production equipment (charging, strength testing, tightness testing, etc). Depending upon the LGA, there may be a higher cost associated with the actual construction of the equipment due to the materials used and the installation methods.

Given these increased costs, smaller companies may suffer liquidity problems when having to make a significant investment. Alternatively, the enterprise may consider that not enough profit is to be made using the LGA.

How to resolve [32]

There is no straight forward way of overcoming this barrier (where it exists). A number of options are proposed.

In order to offset the higher costs, authorities may opt to introduce financial incentives, such as reducing either import duty or sales tax on systems that use LGAs in order to develop some momentum in terms of encouraging the market. Simultaneously they could raise duty on systems that use conventional refrigerants to offset the loss of duty on the LGA systems. For manufacturers who would have to make a considerable investment, the authorities could offer to provide tax rebates on the relevant purchases necessary for the production, or to provide interest-free loans.

[32] Ibid.

Implementation agencies may provide additional funding for production line equipment, expert consultancy, research and development programmes and liaising with technical institutes that could assist specifically with the technology.

General awareness-raising programmes could be encouraged to advise typically end users of the environmental and energy related benefits of certain systems and to approach purchasing on a lifecycle cost basis rather than on first cost only. In particular, adopting or joining energy efficiency labelling programmes can have a beneficial impact.

Additional remarks

In order to overcome the initial barrier of the cost of systems, both governments and implementation agencies should be obliged to take large steps to make strong commitments in terms of supporting the introduction of LGAs, mainly from a financial incentive point of view. Political action and commitment is needed.

Although it may be considered as a draconian approach, it is also proposed that authorities develop regulations to prohibit types of systems that use conventional refrigerants, where technology is available that use LGAs. It has been stated that without appropriate regulations, it would take a long time before cost parity is reached.

Lastly, it is reiterated that in cases to date, manufacturers have found that the production costs significantly reduce for reasons of improved designs, leaner production methods and better thermophysical properties of the refrigerant itself.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This applies primarily to end users and system manufacturers equally, and to a lesser extent system suppliers.
Barrier impact	New products (regardless of refrigerant type) can have a higher price but as sales volumes increase parity is more likely to be achieved..
Severity rating	
Unachievability rating	

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

A large proportion of systems need to be subject to service and/or maintenance during their lifetime, and if the necessary parts and equipment are not available then technicians cannot carry out the work properly and are therefore discouraged from working with systems using LGA refrigerants.

Overview of barrier

The equipment and spare parts necessary for working of systems using LGA refrigerants are different to those used for conventional refrigerants and therefore it is necessary to purchase an additional set, which requires considerable expenditure and is therefore prohibitive. Also the price of these

items are sometimes more expensive than the conventional types. Because of these reasons, contractor and service shops are reluctant to invest in such equipment.

Causes

The reason for these equipment and spare parts being so expensive is largely due to there being a small market and thus a limited need for them. Establishing service facilities for LGAs requires large investment and training of personal. Also the culture in some countries may not be identical to what is considered to be "best practice" so any demand for items such as recovery machines, gas detectors, and so on is limited anyway. Another issue is that the majority of components from ODS-reliant equipment come from centres of mass manufacturing and are thus very cheap, whereas parts used for LGA systems tend to originate from Europe and therefore have a higher cost associated with them. Ultimately if the costs for equipment and parts are high, then enterprises will not see enough profit and bypass the correct servicing approach. This is particularly pertinent in Article 5 countries where the cost of labour is relatively much less than those in non-Article 5 countries, whereas the cost of hardware is at a comparable level. Thus the impact of the higher prices for LGA refrigerant equipment and parts is amplified.

It is noted that the opportunity for receiving up to 25% additional funding available through the MLF is not available for the service sector.[33]

How to resolve

There are a number of ways of helping to overcome this barrier, although it involves some commitment to investment.

Implementing agencies could make a commitment to purchase a certain quantity of equipment for certain countries/regions from suppliers. The same could apply to LGA systems, to encourage the system manufacturers to make adequate spares available. Similarly, governments should offer subsidies to those that purchase these equipment and parts.

Another approach could be for local or regional enterprises to begin to manufacture equipment and parts, although the range may be limited depending upon the core activities of a given enterprise. Similarly, wholesalers could encourage manufacturers to produce equipment and parts for LGA systems. In these latter cases, it would be wise to develop equipment and parts that are universally suitable for the most common LGA refrigerants as well as the conventional ones, so that technicians only need to carry around and stock one set of items.

The ExCom may consider the possibility of additional funding to subsidise the supply of service equipment for LGAs.

[33] Under Decision 60/44 in UNEP/OzL.Pro/ExCom/60/54

Refrigerant types	All
System/application types	All
Impacted stakeholders	This applies largely to the contracting and servicing sector, and to some extent the end users, since they may not be able to get their systems service. Equipment and parts importers, wholesalers and retailers are also involved.
Barrier impact	This is prohibitive with small system population but does not necessarily strongly inhibit use of LGAs.
Severity rating	
Unachievability rating	

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

Depending upon the type and size of the system, the refrigerant can represent a notable portion of the cost and therefore especially during servicing it is preferred to use cheaper products.

Overview of barrier

Some LGA refrigerants have a high price (per kg). Whilst R717 does not normally suffer from this high cost, it is generally HCs and R744 whose price is normally relatively high. Although R1234yf is not widely available as yet, it is anticipated that it will also demand a very high price. The higher price of LGAs is often amplified when comparing against the very cheap price of mass produced refrigerants such as R22.

Causes

In principle HCs should be cheaper than conventional refrigerants, which they are, in bulk quantities. However, the high cost is largely due to the fact that the market is small and the number of competing companies is limited. In particular for HCs, because the refrigerant is often sold in smaller (one litre disposable) containers, the price is significantly greater than one would expect for any refrigerant within a usual sized cylinders (such as 11 litres, 27 litres or 60 litres). The small scale production of HCs means that the economies of scale cannot be reached. Furthermore, it is often reported that shipping companies (over-) charge for transportation of flammable refrigerants due to adherence to the rules for transportation of dangerous goods.

R744 in principle should also be very low cost. However, the quality of the product must be of high purity and the cleaning process therefore adds on extra cost. It addition, due to the high pressure it requires cylinders that are significantly different from conventional refrigerant cylinders, which also adds on cost.

Also much of the conventional refrigerants (HCFCs) come from large scale producing countries where the sheer volume of production enables very low prices to be achieved, along with subsidies from emissions reduction of R23 which is produced as a by-product. An additional problem highlighted is that in certain locations, the restricted refrigerants are still (illegally) available, which again dissuades companies from considering alternatives.

How to resolve

There is little that can be done to improve the competitiveness of these LGA refrigerants other than using regulatory instruments. The most draconian approach would be to ban or cap conventional refrigerants, thereby forcing the market open for the LGAs. A less aggressive approach would be to introduce import duty on high-GWP refrigerants, and again lessen the duty on LGAs. It is expected that if or when the sales volume of the LGAs began to approach those of the conventional refrigerants, the price would also begin to approach parity or even less.

Additional remarks

Most respondents believe that government authorities have the possibility to control the price of LGA refrigerants.

It is stated that high GWP refrigerants do not reflect their true "environmental" price – assuming the cost of carbon credits – \$15 per tCO_2eq, HCFCs and HFCs should be around \$20 to \$60 per kg (in addition to the actual cost). It was proposed that with a significant increase of the price of conventional refrigerants (to say, \$40 per kg), there would be a migration of technicians and manufacturers towards the more cost effective LGAs.

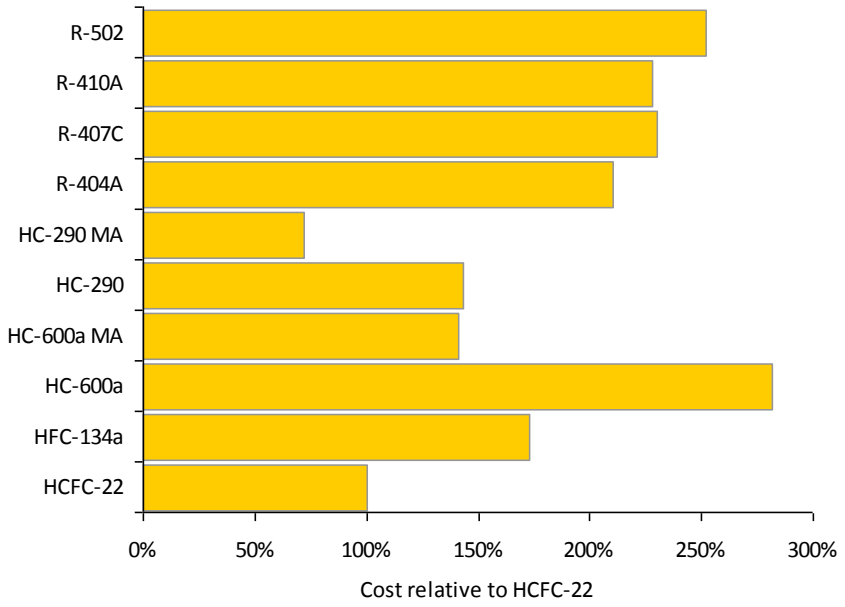

Figure 14: Average price (over years 2007 – 2009 and various countries) for certain alternative refrigerants relative to R22 (\$7 per kg); for HCs, the term "MA" refers to the mass-adjusted cost which accounts for the lower charge for a system of the same capacity

Contrary to a number of statements submitted, according to work by UNEP tracing prices of refrigerant [34], the average price of ODS and substitutes indicates that HCs are not so much more expensive than R22 on a per-system basis, and are in fact cheaper than most of the high-GWP alternatives (see Figure 14). However, the price of R717, R744 and unsaturated HFCs is not included.

[34] See Table 11 of UNEP/OzL.Pro/ExCom/61/6, 9th June 2010

Refrigerant types	Mainly HC, R744 and unsaturated HFCs
System/application types	Medium and large charge systems
Impacted stakeholders	The high prices mainly impact on the service and maintenance contractors, system manufacturers and end users.
Barrier impact	As volumes increase this barrier will cease to exist, also where systems are present they must (normally) use the designated refrigerant.
Severity rating	
Unachievability rating	

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

If the current price of parts, materials, systems and service equipment is high, there is no incentive to use LGAs and more money can be made from continuing with the conventional refrigerants.

Overview of barrier

There are no financial stimuli for producers or importers of RAC systems using LGAs, whether it is from government authorities, implementing agencies or any other entity. Similarly, there are no incentives for installers of systems to accept LGAs or for end-users to buy them. Without any viable financial gain to be made, investors are equally reluctant to provide funds to produce refrigerant, change manufacturing or to purchase systems on a large scale.

In fact it is frequently stated that from a business perspective there exist mainly disincentives, such as greater risk in terms of reliability of technology, safety implications and typically a greater first cost; end users are not likely to pay extra solely for the knowledge that they are cooling with a LGA refrigerant.

Causes

The primary reason for this is that most countries operate an open market that permits competition, regardless of one of the inherent environmental impacts. Whilst there is encroaching regulation to force use away from ODSs, there is no legislation for force usage away from high-GWP refrigerants to LGAs. As such the extent of future use of LGAs remains uncertain in most countries.

How to resolve

First it is necessary to identify who could provide incentives and it appears that ultimately it is left to government authorities to do this, and to some extent implementing agencies; rewards are needed for producing, working with or purchasing systems using LGA refrigerants. These ought to be given long-term certainty rather than being perceived to apply for short periods. In general this could involve developing rules to make the use of conventional refrigerants more onerous or to have finite lifetime, whilst providing financial or in-kind support aimed at LGA projects to help entrain external funding. Programmes such as the clean development mechanism (CDM) which provide carbon credits that have some financial value for avoiding emissions could be considered, although this is known to be a resource intensive exercise and is therefore difficult for small sectors. Lastly, many of the vested interests could aim to promote wider awareness of environmental and any economic potential that the use of LGAs may offer.

Additional remarks

International organisation and natural refrigerant associations could play a fundamental role. Manufacturers of products sharing the common use of LGAs should aim to work together to promote LGA-based systems to major end users and other stakeholders. This working together to promote a common message will indicate it as a major regional or even global trend where many enterprises are developing systems in a similar direction and thereby emphasising the certainty of the technology to investors.

It should be recognised that often the life-cycle cost of systems of certain LGA refrigerants – particularly R717 and R744 – is considerably lower than the use of conventional high-GWP refrigerants. This is widely accepted in most non-Article 5 and also in some Article 5 countries, and is due to lower operating (energy and maintenance) costs. However, it is evident that this incentive is currently insufficient for many consumers to justify the higher first cost.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This barrier largely impact upon all stakeholders within the sector, although most directly upon manufactures, refrigerant producers, wholesalers and end users.
Barrier impact	Without there being any financial incentives, no enterprise will consider using LGAs.
Severity rating	
Unachievability rating	

5.5 Market

There were relatively few statements relating to the potential market barriers. The main issue is that there is little or no customer demand specifically for systems using these alternatives. Furthermore, there is in some cases a concern that the market may refuse to accept such products (because the refrigerant is typically more hazardous than conventional ones) and therefore there may be a severe risk of financial loss of investment. On the other hand, consumers may consider that the higher price (at least initially) does not justify the environmental benefits.

The causes of these are primarily due to the lack of awareness of the benefits of new technology, or the problems (such as climate or “non-green” issues) associated with existing products. There is also a concern that other companies may market against the negative characteristics of the products using alternatives (i.e., flammable and/or higher toxicity).

Handling these issues is considered to be fairly difficult to overcome, again, because it demands the involvement of the authorities to introduce a broad information campaign as well as educating sales staff on such issues.

Barrier: "There is no demand for products using LGAs"

If there is no market demand for a particular type of product, then the enterprises cannot draw any profit from such products, rendering them with little interest.

Overview of barrier

In general, there is little demand for LGA systems by customers or end users, and this then subsequently applies to parts, components and servicing equipment. If LGA systems were available, the potential market is unknown.

Causes

Fundamentally, the end user is not concerned about the type of refrigerant that their system uses; all they are concerned about is whether it does what it is intended to do. If products using LGAs are not available, they will not be used. Were the end user aware of the possibility of using LGA refrigerants in their systems, it is unlikely that they will push suppliers or manufacturers to make them available since they have no interest to create additional complications for themselves. If LGA systems were available but end users are unaware of the availability of such systems, they are unlikely to specifically request them. An end user that is familiar with a conventional product that serves them satisfactorily has little interest in changing to a different product for fear of introducing difficulties. A supplier of systems will also favour retaining the reliability of existing systems that are provided to their customers, rather than taking a risk with a new technology and loosing the client. If the existing brands do not shift from conventional to LGA refrigerants, the end users will not switch on their own accord. If the only difference between an existing and a new product is that the new one utilises an LGA refrigerant, the end user many not be aware of the environmental benefits the new product offers and therefore not have the motivation to switch. The end user may be aware of the green credentials of an LGA product, but the ecological benefit is often insufficient to justify the shift to a technology that probably has a lower level of maturity. There is nothing to force end users to choose an LGA technology.

How to resolve

This barrier could be overcome by imposing or forcing a need to adopt systems that use LGA refrigerants. At one end of the scale this could be achieved by awareness-raising and thus encouraging a *moral* obligation to use LGAs or at the other end, introducing legislation that permits only systems using LGA refrigerants in particular situations (where the technology is suitable). Between these approaches there are financial incentives which could be introduced where applications that use conventional refrigerants are penalised and those that use LGA refrigerants are offered benefits. A softer approach could be to introduce schemes such as a "green building" rating where points are achieved for using LGA refrigerants instead of conventional ones. Sub-sectors or specific industries (that are in the public light) may be encouraged to develop a collective sense of needing to "green" their sector, and using LGA refrigerants is one way by which this can be achieved. Pressure on end users should be applied by environmental NGOs, as well as raising awareness of the public. For these latter approaches, they are likely to be more successful if LGA products are already available.

Additional remarks

Major manufacturers and suppliers should be encouraged by government and industry associations to participate in the activities. Manufacturers with well developed and robust LGA refrigerant technologies should focus on specific countries, and aggressively target the market. Currently, such technologies are often presented by sellers or industry commentators as "curious alternatives" or as “novel but niche European oddities”, or marketed as "super-green" but also "super expensive", whilst having questionable energy efficiency. Thus a certain perception of these technologies is formed by the industry and the end users, so the confidence in the attractiveness of such products may be correspondingly low.

On the other hand, it is also observed that in many countries there really is a desire to use systems with LGAs, but there are no local manufacturers to provide such products. It is therefore important to be able to relay this demand from one location to the manufacturers in another so that they become aware and can recognise that a notable market exists.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This primarily impacts upon manufacturers and suppliers of systems, and consequently on importers, contractors, technicians and component suppliers.
Barrier impact	The barrier impacts upon different equipment sectors – more severely on consumer appliances and less so on large end users
Severity rating	
Unachievability rating	

Barrier: “There is a fear of market acceptance of systems using these refrigerants”

System manufacturers and suppliers are concerned that products utilising LGA refrigerants will not be acceptable and therefore any investment will be wasted.

Overview of barrier

Enterprises have a concern that there will be a negative market reaction and non-acceptance to the new LGA refrigerant technology, for example, due to the fact that the refrigerant is flammable or of higher toxicity. Furthermore, these enterprises have additional concerns over the reaction of competing companies (that do not use LGAs) and that they may use the negative characteristics to market against them.

Causes

The main causes of this fear are that there may be a general lack of awareness of environmental issues and the commensurate benefits that the LGA technology has in this respect, whilst the enterprises involved may have little confidence in the potential for deigning-in higher levels of safety to the LGA systems. This type of barrier is also common when there are none or only a small number of other enterprises involved with such technology.

How to resolve

There are several approaches for helping to overcome this issue. NOUs, consultants and implementing agencies may try to encourage a number of enterprises to enter the market with LGAs at the same time, thereby spreading the perceived risk. In addition, those enterprises could be made aware of and familiar with comparable products being developed and sold in other countries or regions. Lastly, sales and marketing staff ought to be well orientated with the relevant issues such that they can adequately respond to concerns and questions raised from customers.

Additional remarks

For any business, their need to achieve market share exceeds the desire to integrate other features such as environmental benefits that would benefit the wider society. Therefore the use of LGAs must be consistent with achieving that market share. Also, it is easy to claim that a competitor's systems are unsafe/unreliable/inappropriate/etc., without having to be responsible for the statements or the consequences of the statements.

Refrigerant types	All
System/application types	All, but mainly appliances
Impacted stakeholders	This is primarily applicable to manufacturers and retailers of systems, but also to end users.
Barrier impact	For the first enterprise to introduce an LGA product, there is a considerable impact, but thereafter it is a minor issue.
Severity rating	
Unachievability rating	

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

If enterprises or individuals are not prepared to invest in new production lines, development or large-scale purchase of systems and equipment, then products will not become available.

Overview of barrier

It is not possible to obtain funding for investing in production plant for refrigerant or systems and there is insufficient funding for research and development activities.

Causes

The general reason is that it is not obvious which direction the refrigerant markets are going – there is no strong trend towards one particular technology in one particular type of system. This has partly been contributed to the lack of Multilateral Fund funding of virtually any projects involving LGA (except in domestic refrigeration). As a result there is little interest from industry as a whole. Furthermore, so long as LGAs are seen to be for niche applications, major manufacturers will not seriously consider them for mass production. This is accentuated by the continual development of newer refrigerants.

How to resolve

It was posed that it needs to be demonstrated that there is greater certainty that LGA refrigerants will not only be used, but also demanded by end users. Thus, clearer direction would need to be indicated to countries and manufacturers in terms of which refrigerant should be used in which type of system for which climatic zone. This would require consistent messages to be passed on.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This largely impacts on system, parts and components manufacturers and refrigerant producers.
Barrier impact	This is a major circular problem for the use of LGAs that result in a deadlock between manufacturers, suppliers and customers.
Severity rating	
Unachievability rating	

5.6 Information resources

This is another type of barrier where an extensive number of issues have been raised. Most of the remarks can be generalised by the limited appreciation of the technical and safety aspects associated with the use of LGA refrigerants, along with limited availability of technical data, design guides, instructions for carrying out and using servicing and maintenance equipment, etc, specific to LGA refrigerants, compounded by the absence of dedicated, in-depth training. As a result there is insufficient confidence in designing complex systems safely and no experienced peers to discuss with. On a more fundamental level there is often little or no awareness of the existence of LGA refrigerants, and where there is, no guidance exists as to which LGA to use for a given system and application. Finally, it is also felt that the absence in knowledge and understanding of LGA alternatives extends into those consultants working on HPMPs.

These barriers are considered to apply to all LGAs, and generally apply to all stakeholders involved in the design, construction, servicing and operation of systems as well as national and international consultants. The general absence of technical know-how tends to be an issue with smaller enterprises; the larger more developed enterprises possess knowledge and have access to new technologies and informational recourses, whereas the small workshops – that represent the larger portion of the sector – do not have such possibilities.

The causes of these barriers may not necessarily be due to the lack of information resources as such, but more to do with the extent of the distribution of material and the ultimate “embedding” of the knowledge within the enterprises. Major causes of these barriers are deemed to include: the overwhelming majority of the material is in the English language or is of low quality; no interest to have the knowledge because of it being irrelevant; too few training courses; and no local experience to learn from. For the majority of these issues, the respondents deemed them feasible and fairly straight-forward to overcome, although it should be the responsibility of NOUs, implementing agencies, technical institutes, industry associations and also components and equipment suppliers.

In general the approach to overcome these issues should be to focus in a more localised manner. For example, more literature in native languages, the building-up of expertise locally (i.e., not only inviting foreign experts to "preach"), have more in-depth dedicated training courses for design engineers as well and technicians, and ensure that there are real example installations locally for people to gain direct experience from.

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

If large parts of the industry are unaware of the possibility of using LGA refrigerants, their uptake is highly unlikely.

Overview of barrier

In some regions there is a general ignorance of LGA refrigerants and the possibility of their use in systems. Even where there may be some extent of awareness there remain a lack of understanding about what the significance is of their environmental characteristics and, where relevant, their safety (e.g., flammability) implications.

Causes

The causes are largely attributable to inadequate information dissemination. In parts of the industry where training is not applied (typical outside the technician sector and higher education) the less mainstream information (such as on LGAs) does not diffuse. For example, end users may not be aware of the possibilities of using LGA refrigerants, since their suppliers and contractors have not made them aware of the issues and options.

Conversely, whilst those who are trained may be subjected to extensive lists of all type of R-numbers and other detailed information, they may only recall those that they are familiar with during their daily work, that is, the refrigerants within the equipment they work with; if there is little or no market penetration of a particular refrigerant, it will remain in obscurity.

Another issue frequently raised is that the majority of the literature is in the English language, and therefore much of the important information does not reach the elements of the industry who can only communicate in local languages. Since an increasingly large proportion of the information is published on the internet, those who are not computer literate or do not have access, will be unable to find the relevant information.

How to resolve

General awareness-raising of the LGA refrigerants and associated advantages could be increased, but such awareness raising activities should be dedicated to these fluids so as not to dilute the focus. This applies in particular to seminars and workshops which may be directed specifically at individual LGA refrigerants. The information ought to be focussed and the amount of information optimised so that the key data and messages are not lost. Technician training sessions may equally be devoted to changing the culture of the workforce to understand the unique characteristics of LGA refrigerants (such as safety issues) and the necessity for obeying the modified rules. Focussed awareness-raising

schemes could be targeted towards end-user sub-sectors (such as catering, leisure, food processing, and so on).

Concise information ought to be published in local languages as well as being printed and widely distributed rather than relying on English only material and internet-based resources.

Additional remarks

It was also deemed that refrigerant and refrigeration equipment distributors and wholesalers should raise awareness in this sense, since they come into contact with a large portion of the industry.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This barrier applies to many parts of the industry, but is of particular relevant to the smaller scale enterprises and sole traders, end users but also in some cases training institutions.
Barrier impact	Whilst there are immediate implications, in the longer term awareness will easily increase.
Severity rating	
Unachievability rating	

Barrier: "There is a broad absence of general technical information"

If large parts of the industry only have limited knowledge about the use of LGA refrigerants, any significant uptake is unlikely.

Overview of barrier

A variety of subject areas were identified as being deficient:

- technical data on LGA refrigerants
- basic safety information
- selection and use guidelines
- proper working instructions
- information on economic impacts
- information on environmental impacts
- conversion guidelines
- design guides

Specifically it is not widely known which of the LGAs should be used for which type of systems and application.

Causes

The causes are broadly attributable to inadequate information dissemination, but also a lack of focus on what information to target to particular stakeholders. At the same time, if LGA refrigerants are not in common use, then the need for information will not be there. It has also been observed that because of the rapid change in the focus of refrigerant usage over recent years, much of the earlier

literature rapidly becomes out of date and redundant. In some cases, the relevant information may actually be included within the literature but it is "hidden" amongst the volumes of information relating to other refrigerants.

How to resolve

This barrier may largely be overcome by disseminating information in a targeted manner. For example, carrying out training, seminars, workshops, etc, dedicated to specific stakeholder groups. These could be dedicated specifically to the LGA refrigerant under consideration to avoid dilution. It is important to highlight specific advantages such as energy efficiency, environment and technical benefits. Similarly, such information ought to be provided by respected authorities on the matter.

Additional remarks

National authorities should engage technical institutes, universities, colleges, training institutes, etc, to disseminate the relevant information to those attending training and seminars. The authorities should also be encouraged to publish positive outcomes of any studies or trials that are carried out.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This issue applies to all stakeholders: end users, installers, technicians, suppliers, sales people, design engineers, operators, service and maintenance technicians, manufacturers, funding agencies, authorities/regulators.
Barrier impact	Whilst there are immediate implications, in the longer term technical data will become more widespread, especially since there is ample already in circulation.
Severity rating	
Unachievability rating	

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

Whilst information can be supplied to the industry through literature and training, confidence in a technology can largely be gained from seeing the LGA refrigerant in use; without such demonstrations the use of LGAs may always be considered as a theoretical option.[35]

Overview of barrier

There are no demonstration projects within the industrial and commercial sectors, either in terms of production lines for smaller systems (appliances), no workshop conversions (for the production of larger systems) and no installations of site-constructed systems. Without direct observation or even knowledge of LGA refrigerants in use locally, they will not be considered as realistic viable options. In other words the theory of their application has not been tested locally. Therefore the risk for any one enterprise doing this as a first attempt is great.

[35] It has been stated by one reviewer that recent discussions of the Executive Committee of the Montreal Protocol have yielded agreement to fund a small number of projects that use LGAs; however, no further information was provided to verify this.

Causes

The main reason for this is that no organisation has opted to invest in such a project. Most enterprises do not want to take the risk, and there are no encouragement by project consultants and implementing agencies.

How to resolve

In general it was felt that the responsibility for initiating demonstration projects is with the implementing agencies and ExCom. Funding should be made available for production line conversions as well as the installation of larger systems; in all cases additional funding should be provided to enable monitoring and testing as well and organising regular site visits for other stakeholders and broader dissemination of findings (such as successful experiences guides). Furthermore, the ExCom could consider approaches such as allocating a minimum proportion of projects, or proposing a minimum quota system for the number of LGA projects to be funded.

Additional remarks

Technical institutes could be drafted in for evaluating the projects and providing guidance on improvements were the project to be replicated elsewhere.

The use of R744 for supermarket refrigeration is a notable trend but there is little competition. In particular countries, only one or very few companies are promoting this option. In general, enterprises are waiting for the first application with (or without) success before taking any decision. No one is willing to invest in cases (like joint-ventures between manufacturers and customers) in order to prove the results and the success. Manufacturers are trying to convince customers based upon the European experience, but the customer (within the Article 5 country) knows that here there are other considerations to be accounted for (such as after sales support, components availability, maintenance people with comprehensive training, etc).

Refrigerant types	All
System/application types	All
Impacted stakeholders	This barrier applies to all stakeholders since they could all learn from such demonstration projects.
Barrier impact	Until stakeholder have seen something work with their own eyes, under local conditions, it is difficult to convince using theory only.
Severity rating	
Unachievability rating	

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

If engineers and especially technicians have no experience of using LGA refrigerants then they and their peers will have less confidence in choosing to use them.

Overview of barrier

Too few engineers and technicians have any direct experience of using LGA refrigerants. Most of their know-how is from reading literature and attending seminars. They do not feel sufficiently comfortable to work with these refrigerants and consequently will not choose to use them.

Causes

The main cause of this is that there may not be any LGA-using products in the field for them to work on. In addition, either within the company or at local training establishments there is not the possibility to practice on systems using LGAs.

How to resolve

It was proposed to ensure that local training institutes have set up trial equipment for technicians to practice on. Larger companies could set up similar types of trail systems in-house. For more complex applications, engineers, consultants and technicians could spend a limited amount of time with other enterprises who have already embraced the technology (in different countries or regions) to gain direct experience. One possibility may be to develop exchange schemes where technicians from one country spend hand-on time at expert enterprises in other countries, so that they can gain direct experience with using LGA refrigerants, especially with more complicated situations.

Additional remarks

In addition to the industry stakeholders, if the enforcement agencies within a country have no knowledge or experience of the use of a particular substance in a particular application, they will have less confidence in permitting its use and may impose stricter requirements. For this reason it is also sensible to engage these authorities in training or at least awareness sessions.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This mainly applies to technicians particularly from smaller enterprises or sole traders), contracting companies involved in the installation and servicing of systems. To some extent it applies to design and consulting engineers, and smaller systems manufacturers.
Barrier impact	This is an immediate barrier but will lessen in impact as the use of LGA refrigerants evolves locally.
Severity rating	
Unachievability rating	

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

As a new technology begins to be used more widely, unknown issues may arise that can demand the guidance of a specialist, but without their aid unresolved problems could inhibit the development of the technology.

Overview of barrier

There are often none or very few experts within the country that can assist with design, installation and maintenance matters. This is more of an issue when considering larger more complex systems

that may demand extensive safe design features and require emergency safety systems. The need for external expertise is more relevant to smaller enterprises, that don't have resources to fund development of internal specialist. In general, it is useful to have experienced peers to discuss technical issues with, in order to feel comfortable and therefore gain confidence with a particular technology.

Causes

In general, if a technology is new to a country there will not have been sufficient time for experts in a particular topic to evolve. In smaller companies, the number of employees is often too few to necessitate the employment of higher level experts. Also in smaller countries there may be an absence of research and development activities (which often help evolve such expertise) – be it within enterprises or technical institutes.

How to resolve

A couple of options exist for resolving this problem. One may be to set up collaborative efforts between the industry and technical institutes to carry out research and development programmes to address the application of LGAs under local conditions, thereby growing expertise within the country. Another approach could be for implementing agencies to fund specialist intensive educational sessions, drawing in expertise from countries where the LGA refrigerants are used more extensively.

Additional remarks

The industry has to rely on government authorities, trade associations and equipment suppliers to develop experts.

Refrigerant types	All
System/application types	Larger capacity refrigeration and air conditioning
Impacted stakeholders	This barrier applies to many within the industry, ranging from contracting companies, manufacturers, supplier and consultants.
Barrier impact	This is an immediate barrier but will lessen in impact as the use of LGA refrigerants evolves locally.
Severity rating	
Unachievability rating	

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

If consultants that are advising governments and developing HPMPs do not recommend them as options or do not present means of addressing NOU's concerns regarding LGAs, they will be neglected.

Overview

Currently, and for the next few years, Article 5 countries will be developing and revising their HCFC Phase-out Management Plans. These will form the basis of a country's strategy to reduce and eventually eliminate the use of HCFCs. In order to achieve this, the industry within a country must adopt the use of refrigerants with a zero ODP, and this may include conventional refrigerants and/or

LGA refrigerants. National and international consultants are used to assist Article 5 countries in preparing HPMP and are expected to provide the best advice as to how to replace HCFCs. However, in many of the HPMPs already submitted or under preparation, there is a broad neglect of the use of LGAs.

Causes

The causes of this are several-fold:

- There is (considered to be) insufficient funding to fully account for all the components necessary for implementing LGAs.
- It is easier for consultants to follow a basic template that does not encourage innovative (LGA) approaches.
- HPMP consultants are not aware of how to address the concerns of the industry stakeholders when it comes to discussing LGAs.
- There is often no desire or will from the NOUs to consider LGA options.
- A general lack of understanding of the technology exists and how to implement LGAs.
- A position seems to exist amongst industry representatives and consultants that says "let us first focus on the phase-out of ODS and low-GWP substances can be considered at a later stage" which has resulted in a polarisation in favour of conventional high GWP HFCs.

Another major problem is that information and recommendations within their toolkits, such as the reports of the TEAP are deemed by some respondents to downplay the application of LGAs.

How to resolve

The best way to affect the development of an HPMP (at this late stage) may be to educate those in the process. Possible means of doing this could include identifying assistants (experts from institutes, companies, etc, who are experts in LGAs) to work with consultants on developing HPMPs. Similarly, the agencies could enable LGA experts to attend HPMP stakeholder meetings so that they can address specific issues and provide recommendations of particular technologies and applications. On a broader scale, agencies may provide dedicated training and workshops for HPMP consultants on the application and implementation of LGAs in order to broaden their understanding and present the extent of the possibilities available to countries. To support this, specific booklets could be developed, which are targeted towards NOUs to encourage and explain where and how LGA alternatives could be applied to replace HCFCs. Lastly, an assessment report that is dedicated to individual LGA refrigerants could be developed such that the competition with conventional refrigerants and the consequent negative comparisons or downplaying of the technology can be avoided.

It was considered that whilst implementing agencies can really help with the adoption of LGAs, they do not get much funding (and therefore time) for preparation of HPMPs, which is necessary to go into more depth of considering LGAs. Many consultants are more familiar with HFCs, so in order to save time they may advise in favour of "the easiest" option. Therefore there is a need for more

funding for HPMP preparation but also a need to employ consultants with good understanding of LGAs.

Additional remarks

In his paper, R. Ciconkov[36] has identified a catastrophic situation within the activities under the Montreal Protocol: "Some ammonia cold stores in developing countries are renovated using HFC-404A. In 2000-2001 [Ciconkov] contacted the MLF of MP and UN implementing agencies to support renovation of ammonia cold stores as ammonia is ozone and climate friendly refrigerant. The MLF and UN agencies answered that they support only replacement of ODS, and not climate change projects. The answer of GEF was that they are not involved in ozone portfolio projects suggesting to contact the MLF." This suggests that an overly mechanistic approach is taken without further considering the peripheral issues.

It was also noted that there is insufficient pressure from the non-Article 5 donor countries for Article 5 countries to use LGAs. Donors may be very concerned about financial budgets so if HFCs are chosen, they may be approved simply on financial grounds. Ideally donor countries should be imposing stronger disagreements when HFCs are selected and insisting on seeing sufficient justification for these choices; however this is currently not happening.

Refrigerant types	All, but mainly HCs, R744 and R717
System/application types	Large refrigeration, air conditioning, systems that would normally use R22
Impacted stakeholders	NOUs, implementing agencies, industry stakeholder groups
Barrier impact	The wider use of LGA refrigerants is highly dependent upon HPMPs being produced with them in a favourable light.
Severity rating	
Unachievability rating	

5.7 Regulations and standards

The issues associated with regulations and standards may be separated into two main groups. The first group is where the regulations and/or (national, regional or international) standards exist but they are excessively strict and thereby prohibit or effectively prohibit the use of such refrigerants – this is considered to be the most serious barrier. To a lesser extent, it is considered that some of the existing (international or European) standards are overly complex and cannot be applied with confidence, or they have not been written to account for the differing conditions within Article 5 countries. The second group refer to there being no regulations and/or standards that apply to the use of LGA refrigerants, whereby the requirements are inadequate or non-existent, such that designers and technicians cannot apply the refrigerants with confidence. Similar to this is where legislation – that is not specifically applicable to the use as refrigerants – accidentally indirectly affects use of certain refrigerants. In some cases, enterprises are unaware of whether any applicable standards or regulations actually exist within their country. Regulations and standards in Article 5

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

countries are less rigorous and less strongly enforced and therefore (may be considered as) less effective, leading to a greater possibility of accidents. Somewhat unrelated to the previous issues, is that often regulations are not present that impose licensing and registration of service technicians such that they must be somehow approved to be competent to use LGA refrigerants safely.

These barriers are evidently applicable to all LGA alternatives, although more so on HCs, R744 and to a lesser extent R717. They impact significantly on all stakeholders involved in the design, construction, servicing and operation of systems. The causes of these barriers are evident. In many respects the existing legislation and standards – or absence thereof – is due to the fact that better rules were not previously needed because the market for LGAs did not exist. On the other hand, as markets have begun to develop, there was a belief that there was a lack of initiative from the relevant national authorities or industry associations. However, this could also be put down to the fact that the importance of health and safety issues may be a low priority compared to other local and national issues. More recently, the problems with some standards is seen to have occurred through the actions of commercial interests within the standards making process, imposing requirements such that if the standards are applied the use of certain LGA refrigerant would be very difficult or not cost-effective to use.

There is a consensus that some of the issues can be resolved fairly easily, but only under the initiative of the national authorities and with the cooperation of the wider industry, such as through industry associations and standardisation bodies. Actions could include carrying out national studies to look into what regulations and standards apply, and to subsequently modify them to suit and to enhance the market. Furthermore, agencies should develop "model" standards to be adopted by Article 5 countries that are more directly applicable to the local conditions.

Barrier: "There are no suitable rules to direct users how to use the LGA refrigerants properly"
Standards and regulations normally assist enterprises in applying technology safely, and without such an infrastructure in place, stakeholders will not have the confidence to apply the technology.

Overview of barrier
Depending upon the country, there are not the appropriate regulations and standards to cover the application of LGA refrigerants in certain applications. Without these rules, the use of certain refrigerants may be prohibited or it would open the door to very dubious application of the refrigerants, which could lead to undesirable outcomes in terms of safety and other problems. Regulations and standards may cover issues such as transportation and storage of flammable or higher toxicity refrigerants, authorisation of sales, handling, certification and licensing, design and construction of systems, installation and refrigerant handling.

Causes
The main reason for this situation is that there has been to date no need to modify existing regulations or develop new standards to account for the use of LGA refrigerants. (Standards normally lag behind technology.) In some cases, the development of a standard may be ongoing, but it is normally a laborious and drawn-out exercise resulting in a long delay before it is published.

Alternatively it could be due to the fact that a countries' standardisation process is awaiting the output from an international standard.

How to resolve

In terms of developing the regulations, it is normally the responsibility of the government authorities to initiate the process of reviewing the current legislation and thereafter developing new legislation where needed. The latter part of this process ought to involve the participation of the industry stakeholders. The means for addressing the lack of standards differs by country, in that the responsible authority for developing and/or publishing standards may be governmental or private. In either case the fastest route is to aim to adopt an international or another country's standard (of which there are many), and modify it to suit the national situation if and where relevant. Alternatively, the standards can be developed from a more basic level, but this often takes considerably more time. Whichever approach is taken, it is important for the industry to encourage a good pace of development of the rules and moreover to be very careful that the rules are not written in a way that they end up being more prohibitive than constructive and thereby imposing a new barrier.

Additional remarks

It is important that NOUs take an active role in pushing the development of regulations and standards through, with good cooperation with regulatory and standardisation bodies and trade associations.

Refrigerant types	All
System/application types	All, especially larger systems
Impacted stakeholders	This barrier impacts on a range of entities, most directly upon manufacturers and contractors/installers and consultants.
Barrier impact	The absence of regulations or standards imposes a softer barrier, and can normally be resolved.
Severity rating	
Unachievability rating	

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

If the rules are too restrictive, then it is either impracticable to use the LGA refrigerant in most situations, or following the rules would make the exercise highly uncompetitive.

Overview of barrier

The regulations that apply to flammable substances and higher toxicity substances are too restrictive to allow the handling, storage, transportation, use within systems and handling as refrigerants. Similarly, many standards include the use of these LGA refrigerants within their scope, but do not permit their use (apart from in limited circumstances) or the requirements are restrictive such that they cannot be applied in most types of systems. These (European, North American and International) standards do not take into consideration Article 5 country conditions. It has been stated that the requirements within some regulations and standards are "opposed" to the use of

some LGA refrigerants; especially HCs. Reference was made specifically to the refrigerant charge size limits prescribed for HCs in air conditioners. Building codes treat refrigerants in an inflexible way, whereby if the refrigerant is flammable it is disqualified. Another problem identified is that some of the standards are particularly complicated, meaning that many engineers and technicians cannot easily understand the requirements, apply them to unusual situations or misinterpret them potentially leading to mistakes.

Causes

The causes of this barrier are several-fold. Some of the rules relating to flammable and higher-toxicity substances were originally developed for the industrial and the oil/gas industry, and therefore do not given consideration to the use of such substances on a smaller scale (such as R717 and HCs in the RAC sectors). Trying to squeeze an industrial sector requirement into a domestic or commercial setting can have undesirable (and unnecessary) complications, particularly in terms of cost.

Building codes and consumer safety certification bodies traditionally looked at refrigerants with an approach that if toxicity or flammability exists it is an automatic disqualifier of their wider use, since at the time there was no need to use such refrigerants. In this respect many regulations and codes may be considered as out-of-date since there has been no prior necessity to evaluate and reconcile existing legislation that may conflict with the needs of the industry that opt to use LGA refrigerants. The governmental systems in many countries may be bureaucratic which means that changing such rules can be a laborious and a long-winded process.

It has been stated that there is manipulation of standards by existing vested interests in order to prevent the application of LGAs in existing markets. There is a view that large enterprises for commercial reasons expend resources in influencing the development of such standards such that the requirements become prohibitive for some LGA refrigerants. Once an (European or International) standard has been finalised, it is often accepted by default in other countries, and becomes established. National standards organisations are normally hesitant to modify the standard because they have not the experience, resources or inclination to justify any significant changes.

How to resolve

Overcoming this barrier may be achieved in a number of ways. For regulations and building codes, it is necessary to get the rules changed as it is often not possible to conform to them. The correct routes must be taken, although it may be appropriate for the NOUs to advise the relevant department or authorities of the need to do this. One approach may be to get the regulation amended to account for the characteristics of LGA refrigerants and applications. An alternative approach could be to aim for exemptions in regulations for “commercial and domestic application” and handle the requirements for these situations within an annex or as a separate regulation. Building codes need to be amended specifically as they are already dealing with commercial and maybe domestic applications.

There are several approaches for handling the restrictions present within standards. One option is to develop a national code of practice or a national standard instead of relying on international ones, or develop a dedicated standard for the specific refrigerant and type of equipment. Alternatively, or even at the same time, make a collective effort amongst other interested countries to revise the international standards. In doing this, it is essential that a number of countries put forward their objections/revisions at the same time. They must communicate with the relevant committees expressing concern over the restrictions, providing evidence to support the case for an amendment or modification. It is important to note that when revising, ensure that the end product is not technology prescriptive, that is it defines performance criteria for achieving safety (such as "concentrations cannot exceed x%", rather than stating that the use must be limited to a certain quantity or type of system.) It is important to engage government in assisting with the adoption or changes to standards as they normally can provide more weight in this respect. This may be more effective in those countries where the government oversees the standardisation process. Draft regulations and standards also need to be reviewed by independent bodies free from undue influences, to avoid the problems associated with the strong involvement of large dominating enterprises.

It must be emphasised that carrying out the activities described here requires significant resources, time and long term determination.

Additional remarks

It is essential that national authorities, Ozone Units and national and regional trade associations coordinate to assist with changes to regulations and standards. Without such assistance efforts to change them will often be diluted.

It must be recognised that regulations are not normally intended to be technology prohibitive, but it is normally a symptom of regulators being unaware; their purpose is not normally to restrict trade or inhibit environmental technology. It is important that national authorities develop guidelines or relevant legislation with specific interpretation to the industry. On the other hand, standards are primarily trade instruments written by industry, or at least the enterprises within the industry that wish to impose specific requirements upon the wider industry.

Larger enterprises can use research and development activities to help find novel ways of designing systems to overcome the restrictions imposed by standards (such as charge size reduction). The current limits on HCs are seen as a "soft prohibition", i.e., they do not say "you cannot use", but the requirements effectively do prohibit.

The success of R600a in domestic appliances is partly due to the flexibility of requirements, in that they can be placed anywhere without any concern of whether or not it is possible to put them in a particular location.

Whilst the restrictions apply mainly to HCs and to a lesser extent R744 and R717, the sectors directly involved with the development of unsaturated HFCs are currently developing requirements within

certain international standards and therefore this problem is unlikely to exist for these refrigerants in the future.

Refrigerant types	Mainly HC and also R717, and to a lesser extent R744
System/application types	Mainly air conditioning, larger refrigeration systems
Impacted stakeholders	The impact of these regulations and standards largely impacts upon the entire industry, particularly manufacturers and suppliers, contractors, system designers, installers, end users, and LGA refrigerant producers and retailers.
Barrier impact	So long at the restrictive rules persist, the use of many LGA refrigerants can never achieve broad use and never approach cost parity with other technologies.
Severity rating	
Unachievability rating	

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

If stakeholders involved with the production, supply, specification, installation and servicing of LGA refrigerants are unaware of the rules then the application of systems could be unnecessarily prevented or carried out erroneously.

Overview of barrier

Whilst regulations and standards may exist within a country to enable the safe and efficient use of LGA refrigerants, certain stakeholders may be unaware of their existence or have a proper interpretation of the main element of the rules. Accordingly, the application of LGA refrigerants may be unnecessarily restricted or applied incorrectly.

Causes

The main causes of this are simply that those individuals may never have had the need to study the rules, or they have relied upon assumptions or what other parties have said. In many smaller countries there may be less awareness of regulations and standards and it is therefore not something that is normally considered.

How to resolve

The most basic means for overcoming this barrier is to adopt an awareness campaign. Even though the detail of the rules is not necessarily essential in most cases, providing an indication of its existence and a brief overview of the general theme of the rules would be important. Prior to carrying out the awareness-raising, it is advisable for at least one entity to carry out a thorough review of the national regulations and standards so that the entire set of relevant rules can be summarised. Once the information has been collated, it could also be included within training sessions, seminars, workshops and guidance notes.

Additional remarks

It has been reported that in certain countries "the authorities" have advised the industry not to use flammable refrigerants. Upon further investigation it was revealed that this was the advice from the

fire services. This example highlights the importance of industry associations within countries embarking on the use of the relevant LGA refrigerants to liaise with all relevant national workers and industrial safety, public health, fire and other departments to explain the implications and the measures that are being put in place in order to achieve broader consent.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This barrier impacts on a range of entities, most directly upon manufacturers and contractors/installers and consultants.
Barrier impact	This is not considered to be a major restriction since simple advice can often resolve the matter.
Severity rating	
Unachievability rating	

5.8 Psychological and sociological aspects

Whilst few psychological and sociological barriers were identified by the respondents, the discussions revealed a considerable number and the significance and strength of these were also highlighted on numerous occasions. Barrier may come in the form of negative recommendations and advice from peer groups, industry association representatives, consultants, etc., recommending against use of certain LGA refrigerants, or reporting on “bad” experiences. Such fears are often compounded by natural resistance to change, such as technicians preferring to work using their traditional methods and activities, or the unwillingness to tolerate additional complications and efforts just to be involved with something different and the anticipation that the additional cost will be significant. Other psychological and sociological barriers include stakeholders not considering global warming as a reality, that addressing it is not their or their businesses’ responsibility, that it is considered to be a “premium” issue, that the currently used HFCs are already “green” or “eco-“, and that the concept of LGA refrigerants is too “distant” and an industrialised country issue.

These issues were largely directed towards all of the natural refrigerants and are considered to apply to all stakeholders, ranging from small service companies to government departments.

The causes are widely known. In many cases it is solely attributable to the way in which persons react to a changing situation and in particular an enterprise’s reaction to the potential loss of profit. Often such fears and concerns – whether realistic or not – can be fuelled by lobbying and marketing activities on the part of a small number of parties (enterprises, interest groups, etc) who would be set to lose financially from a shift to LGAs. However, the building of such a consensus amongst the industry stakeholders can flourish in absence of high quality guidance, insufficient knowledge and lack of awareness-raising in the first place.

Most respondents felt that it was feasible to overcome most of these psychological and sociological barriers. Since individual or other entities tend to follow the crowd, if a consensus view on the necessity to adopt LGAs can be been established then this will ordinarily be sustained. This suggests the need to promote the view that it is advantageous to adopt LGAs. This may include informing and

educating customers, wider promotion of the equipment using such refrigerants, introducing demonstration projects in industrial and commercial sectors and developing national campaigns to characterise only LGAs as “green”, “eco” etc.

Barrier: “Lobbying activities in favour of the use of LGA refrigerants is insufficient to influence decision-makers”

Whilst there is a strong commercial lobby favouring conventional refrigerants, the lobby for the use and adoption of LGA technologies is insufficient to positively affect the views of decision makers in government and enterprises, thereby improving the perception of acceptability of LGA refrigerants.

Overview of barrier

It is stated that lobbying in favour of conventional refrigerants – and as a consequence against LGA refrigerants – is believed to be carried out by producers of high-GWP refrigerants[37], although large manufacturers of RAC systems also carry out such activities. Often much of the lobbying of this type is carried out by trade associations representing the interests of both of these groups of enterprises. Due to their commercial prowess, the larger enterprises and thus dominant trade associations will have effective lobbyists and will therefore be able to have a strong impact upon government and industry. Conversely, the industry surrounding the use of the most common LGAs is comparatively smaller and rarely carries out such wide scale lobbying activities that may counter-balance the arguments against the use of LGAs. The lack of such activities typically results in a mindset within sector of the industry and peer groups that sees some LGAs in a negative light.

Causes

The main reason for disparity in lobbying exercises is that enterprises which currently to profit from the dominant technology do not wish for alternative products to displace their financial opportunity. On the other hand, the enterprises which aim to gain financially from LGAs are smaller in size and have less financial power to support the counter lobbying (although this argument does not apply to the manufactures of unsaturated HFCs). Moreover, most LGAs – specifically HCs, R744 and R717 – have less intrinsic value (i.e., they are commodity products which are comparatively easy to produce) than conventional refrigerants and therefore yield less gain.

To a lesser extent, the wider industry may be uncomfortable with the prospect of change and the financial and other inconveniences associated with this and will therefore warm more to the negative messages about LGAs than to the positive ones. Manufacturers of equipment using conventional refrigerants prefer to conserve their existing investments and avoid the need to embark on a possibly extensive research and development process in order to handle the LGA refrigerants. Other aspects can feed-in to the negative messages generated by lobbyists, for example, the case of a rare incident, fault or other such event occurring involving LGA refrigerants can stand out and will much more visible than common events.

[37] It is noted that some of those manufacturers are also developing the low-GWP unsaturated HFCs.

How to resolve

It is not possible to prevent the negative lobbying activities. However, actions can be carried out in order to increase the impact of lobbying that favours LGAs. Because of the relative absence of enterprises that have a commercial interest in LGAs, any entity organising refrigerant related activities could consider the following as options for aiming for a better balance:

- Where possible, use speakers with considerable experience and knowledge of LGAs to events on refrigerants
- Try to invite figures of authority to speak out in favour of LGA refrigerants
- Encourage authoritative entities (such as implementation agencies, trade associations, etc) have a common positive position on the use of LGA refrigerants
- Develop positively-orientated literature targeted at policy makers, end users and investors

It has also been stated that many of the hindrances would be overcome if the representatives of the conventional high-GWP refrigerants did not have a constant presence in the political, scientific and regulatory arenas.

Additional remarks

Sometimes those with interests in one LGA refrigerant often use negative statement about other LGA refrigerants, in order to promote their own preferences. This is a broadly self-destructive approach since it emphasises the messages of the lobbyists of the conventional refrigerants.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This barrier applies to all those that are involved in adopting LGA refrigerant technology, such as manufacturers, suppliers, contractors, Investors and government authorities.
Barrier impact	This is more of a "deterrent" and it is hoped that most decision makers would be subject to both sides of the discussion.
Severity rating	
Unachievability rating	

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

If there is an overriding fear of change of shifting from a well known refrigerant to a less known one with considerably different characteristics, it would demand considerably greater effort to convince decision makers to embrace that change to LGA refrigerants.

Overview of barrier

Management within enterprises often fear the possibility of changing to a new refrigerant. On one hand there is a "mistrust" of the LGA refrigerants, whilst on the other hand there is good familiarity (almost dependence) on the use conventional refrigerants. Similarly, there exist traditional alliances between system manufacturers and contractors and refrigerant suppliers.

Causes

This fear of change largely originates from the perception of something unknown and different. This is exemplified by a lack of knowledge and understanding of the characteristics of the LGA refrigerants, inexperience of engineers and technicians in using them and a general lack of specific examples of LGA refrigerants already in use. This sense may be exaggerated due to a bad experience in the past during a trial with some other a new refrigerant (maybe during a shift from CFC to HCFC or HCFC to HFC). This in itself may have been due to insufficient good quality guidance in the first place. Also after many years of using the same refrigerants, purchasing from the same suppliers, liaising with the same individuals, habits and familiarities evolve and breaking away from these is often a difficult task

How to resolve

In order to allay people's fears, the usual approaches may be taken; this typically involves distribution of general and technician information targeted to the relevant categories of individuals, as well as seminars, workshops and training. Particularly useful information would be to provide case studies of demonstration and pilot conversions to LGAs, emphasising the successful aspects and how the problems were overcome. A more powerful approach may be to organise site visits and discussions for those decision makers to the completed conversion projects. It was also stated that the only way to properly address this is through legislation; whilst people may complain about phase-outs; they are seen to work.

Additional remarks

Provide orientation programmes to consultants who have previously recommended against the use of LGA refrigerants. Also, the introduction of legislation imposing a need to adopt LGA refrigerants will create the necessity to overcome these fears.

Often certain refrigerant options become psychologically "too established" within particular sectors, and therefore do not get realistically considered for wider application. Prime examples of this are the use of R717 in industrial refrigerant (when it can suitably be used in many commercial applications) and R600a in domestic refrigeration (when it is also broadly applicable in many other types of systems). It is therefore important to develop awareness-raising on these issues to avoid the perception that they only "belong" in these more traditional situations.

Refrigerant types	All
System/application types	All
Impacted stakeholders	This barrier primarily applies to most decision makers within manufacturers, suppliers, contractors and consultants, and to a lesser extent NOUs and trade associations.
Barrier impact	This can be a significant barrier, but it can be offset with the opportunity of financial gain.
Severity rating	
Unachievability rating	

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

If there is a pre-existing fear that the cost of systems and equipment will be prohibitively high, then enterprises will automatically dismiss the possibility of investing in LGA systems even before considering them in detail.

Overview of barrier

There exists a belief that the price of systems using LGA refrigerants will be considerably greater than that of conventional refrigerants. The same fear may also apply to enterprises looking at converting production lines. There is a general fear of greater set-up and investment costs for any projects.

Causes

In some cases, this belief is of course correct, whereas in other cases it is not. Many published documents "estimate" or use very approximate calculations for the cost rather than actually finding the true costs. These values get passed on from one report to the next and become established. Alternatively they may be based on prices offered by smaller or niche product ranges, where prices are artificially inflated due to a "green premium". There is information that provides realistic cost information, but this may not be widely distributed.

How to resolve

Implementing agencies could develop informative cost analysis of certain generic projects for LGA refrigerants and provide the information to manufacturers and end users. Particularly for end users, these ought to include life cycle cost comparisons (between LGA and conventional refrigerants). Example case studies may also be developed. Such information could be fed into assessment reports (such as UNEP Technical Options Committee reports) so the more realistic values may be published and widely read.

Whilst the decision of the ExCom to provide up to 25% additional funding for LGAs may be applicable (for factory conversions), if this possibility is not known about – as appears to be often the case – then the belief of prohibitive cost implications will persist. Therefore it is essential to raise awareness of this option for manufacturers and other stakeholders.

Additional remarks

Manufacturers and end users should be made well aware of any subsidies and other financial incentives that are available.

In cases where this belief is held true, individuals are unaware of other important benefits. An example of this is the use of R717 in large systems; whilst the cost may be known to be greater than conventional HCFC systems, the efficiency and extended lifetime normally greatly offsets the initial high cost.

Refrigerant types	All
System/application types	All
Impacted stakeholders	Manufacturers of systems, distributors, contractors, installers, end users
Barrier impact	The impact can be significant if no further information is available, and of course in some cases it is a factual barrier.
Severity rating	
Unachievability rating	

Barrier: "There is a general fear of the safety risks"

If the fear of safety is sufficiently severe and the sense of the potential risk is overly exaggerated then any enterprise will shy away from seriously considering the use of LGA refrigerants.

Overview of barrier

It is widely known that some refrigerants are flammable and/or have a higher toxicity than existing substances. There has been existing a mantra that "flammable" is not acceptable or "toxicity is not acceptable". In many cases, the national authorities may lack confidence in the use of flammable or higher toxicity refrigerants, and therefore do not necessarily condone with its use. From a commercial point-of-view, management within enterprises may suppose that there is a high risk that major failure that could result in collapse of company.

More specific statements included:

- In some regions, end users will not contemplate the use of a substance that is not used in North America on the basis that the market there will not accept an "unsafe" refrigerant.
- Since many of the cities in Article 5 countries are more densely populated than in some other parts of the world, a higher number of products in very populous areas increase the absolute risk.
- It is recognised that many systems have very high leakage rates and consider it is not possible to address the leakage problem sufficiently to handle certain LGAs.
- General fire regulations may be less stringent and therefore the consequences of the risk are greater.

Such considerations amplify the concerns over safety.

Causes

People are aware of the flammable, higher toxicity and high pressure characteristics of LGA refrigerants, which directly leads to anticipation of the possible consequences. Because most only register the "headline" information, the lack of detailed explanation leads to negative assumptions. In a lot of cases, stakeholders jump to an easy assumption and over-anticipate the risk of using these refrigerants, particularly within the context public areas and residential spaces.

The main problem is that there is a lack of understanding about the safety risks, how they are normally handled, systems design options for mitigating the risk and the safety record of these LGA

refrigerants in other countries. The decision makers are often unaware that design and technology options exist that can be applied to improve safety. Similarly, at a technician level, there may well be an absence of training in safe working practices.

Individuals may also have come across news reports about incidents that have involved LGA refrigerants, which may solidify their views on the safety risks.

How to resolve

The general approach to overcoming this problem of fear is by means of informing and educating stakeholders, but in a way that helps explain why they may hold preconceived views and how to think about the issue in a rational manner. Further to this, special workshops, seminars and training may be applied, which specifically address safety issues. Design and installation guides should be made available, but also for different levels (for example, a simplistic yet robust design and installation strategy type guide for management and end users, but a more comprehensive detailed version for design engineers). Any guidelines and training type activities should be complemented with a focus on leak minimisation and containment measures.

Additional remarks

Respondents believed that NOU, standardisation bodies, implementation agencies, relevant government departments should also assist.

It is important to involve the fire services to some extent so that they understand the possible implications of the use of LGA refrigerants and how they should be handled in a fire situation in order to avoid over reaction.

Often a single report of an incident will create a fearful mindset. However, this can be considered to be disproportionate. For example, there may be a report of an incident involving an R600a refrigerator, which could be interpreted as R600a refrigerators being “dangerous”. However, considering that there is normally one incident per 50 million appliances per year, the risk is less by several orders of magnitude than the number of times that a domestic refrigerator (or any other domestic appliance) may cause a house fire for other (electrical) reasons. It should be recognised that news reports are rarely reported on these other types of incidents because they are not newsworthy; the rarer event receive more attention. The same situation applies to R717 where the pungent smell makes people aware of a small leak, which is not hazardous, yet news reports often citing language such as “massive chemical spill” are often referred to.

Refrigerant types	All
System/application types	All, but mainly those of larger capacity (charge size)
Impacted stakeholders	Mainly to manufacturers, suppliers, contractors and end users To some extent national authorities/regulatory bodies and trade associations.
Barrier impact	There is a range of perception of safety risk, and where this is exaggerated it can act as a severe barrier.
Severity rating	
Unachievability rating	

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

Sometimes in there is a tendency for technicians and management not to follow the rules as closely as would be preferred, giving cause for concern about whether the safety requirements would be suitably followed.

Overview of barrier

It has been stated that there is often a lack of respect of safety rules. The proper procedures may not be followed as closely as would be necessary to ensure adequate levels of safety. It is difficult to "force" the technician to handle hazardous refrigerants when installing or repairing systems, even though they may have attended the relevant training. Such behaviour is exaggerated in many Article 5 countries where regulations may be less rigorous and also less strongly enforced and is therefore less effective.

Causes

Whilst in many developed countries, the health and safety culture may be strongly enforced by regulations, awareness and high-profile prosecutions, there is a general lack of awareness of the importance of such matters in many Article 5 countries (indeed, compared to the importance of other local and national issues, conforming to health and safety rules is often a much lower priority). This leads to an absence of following proper procedures. Such a characteristic is a habitual issue where technicians will follow the more direct route to getting a job done regardless of whether or not they are aware of the rules.

Often the level of training is fairly limited. Whilst general instructions – "dos" and "don'ts" – are given, the more in-depth knowledge on safety parameters, flammability issues, etc, may not necessarily be taught. This deprives the technicians of a deeper understanding of the reasons to follow particular rules and instructions.

Most technicians may have spent the majority of their career using the same working practices, some of which may not be transferrable to handling flammable, higher-toxicity or higher pressure refrigerants. In the case of some technicians, there may be a sense of resistance to change.

Within many of the enterprises in Article 5 countries that carry out installation and servicing of systems, there is less likely to be an infrastructure and internal directives that demand they follow rules, let alone the existence of quality control systems. Thus, the enforcement of rules – be it within enterprises or even by the authorities – occurs far less.

Another cause is simply due to the fact that existing training on LGAs in some cases may be poor, inadequate or factually incorrect, resulting in incorrect procedures being followed or poor reasoning. Similarly, if the correct tools are not available or are faulty or inadequate, this may also preclude them from following procedures correctly.

With conventional refrigerants the safety implications are less severe and the cost of the system is less for smaller applications (say, < 100 kW). Therefore there has historically been a tendency to allow technicians of limited competence to work on such systems. For larger systems companies may employ specialist technicians from elsewhere within the region or other countries for design, installation, commissioning, trouble shooting and maintenance of such systems. As a result there exists a distinct hierarchy in skills between technicians that work on smaller, more basic systems and more complex applications.

How to resolve

A number of approaches may be adopted in order to help overcome this problem:

- Improve the scope and depth of technician training, for example by establishing training centres dedicated to LGAs.
- Introduce legislation to necessitate that technicians follow the prescribed rules and practices.
- Introduce certification schemes for technicians, where they may only practice, purchase refrigerant, etc., once they achieve a certain level of competence.
- Set-up an inspection scheme where random checks and inspections are carried out and the results fed-back to the certification scheme.
- Encourage enterprises to introduce quality control systems, way-of-thinking training, ethics and etiquette.
- Re-educate the existing refrigeration technicians and to train a new generation of professional refrigeration technicians.
- Improve the quality, level of rigour and “competence criteria” of local training centres.
- Develop simple, easy to follow instruction cards and issue to all technicians.

Additional remarks

Respondents remarked that the relevant government authorities, educational/occupational-training institutions, Ozone Unit and trade associations should assist.

It is necessary to improve the level of knowledge and competence and this has to start with more thorough training regimes. This requires a greater commitment to funding and also perseverance.

Until someone has actually experienced an accident, their appreciation of the hazard is not normally fully comprehended. Therefore their motivation to avoid an accident is only theoretical. Were training courses to include a physical demonstration of, for example, ignition of a flammable refrigerant, it would be a memorable and useful reminder as to the reasons to follow the prescribed procedures.

An example was provided from an African country. It was stated that they had already identified all the field technicians, created a database and already begun preliminary training in the major centres. The factory had set up proper HC workshops in these centres which include service equipment and ventilation systems. Technicians are trained by the factory engineers at these centres on both theoretical and practical aspects. The trainees themselves retrofit or change compressors and re-charge using hydrocarbons. It is envisaged to supply the technicians with evacuating, charging and servicing equipment.

In many Article 5 countries HC retrofitting had been introduced during the time of CFC phase-out. These training infrastructures are therefore available for HCFC phase-out as well. Therefore it may be helpful to establish partnerships between industry and these training partners.

Refrigerant types	All, but mainly to flammables
System/application types	All
Impacted stakeholders	This applies largely to all those involved with the handling of refrigerants – installers, service and maintenance technicians and general contractors, and to some extent system owners and end users.
Barrier impact	This is a major barrier to achieving good levels of safety, but may not necessarily restrict wider use of LGAs.
Severity rating	
Unachievability rating	

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

Enterprises may consider the possibility of working with LGA refrigerants, but if they consider it to be too risky in terms of return on their investment, they will not pursue the option.

<u>Overview of barrier</u>

Enterprises may believe that the risk of failure within market is too high, especially if they expect the end users to be reluctant to purchase and apply such systems. This type of perception has largely evolved because most enterprises have experienced various changes in refrigerant over the past few years, and whilst the changes were initially considered to be permanent, it gradually transpired that many of the refrigerants were transitory. Therefore enterprises have become more and more cautious of claims that a given refrigerant will be "permanent". With each refrigerant that is offered, there is now doubt that at some point they will be proposed for phase-out. As such there is broad uncertainty as to which direction refrigerant choice will go in and if the enterprise chooses the "wrong" refrigerant, then it is likely that they will have to go through the same process again in a few years, demanding further investment. It is also stated that LGA technology in many applications is

not a sufficiently mature technology, and therefore any conversion, installations or purchasing of systems will be considered as being at developmental stage or under trial.

Causes

The cause of this barrier is largely due to the uncertainty associated with which direction refrigerant use will proceed. This is exaggerated by not just the plethora of alternatives that are presently available, but also the ever increasing number of products that are introduced to the market and the associated promotional literature surrounding them. Many large enterprises, especially those from non-Article 5 countries will advertise that a specific refrigerant is "the" refrigerant, whilst another enterprise from another region will promote their products which use another refrigerant, whilst a consultant or adviser from some institution may argue for a different refrigerant again. Similarly, different enterprises or advisers will put forward technical arguments in favour of one option, but then there will be counter arguments against their use, followed by other perspectives from different parties stating pitfalls or problems. Such conflicting views create confusion and to some extent, distrust. In many cases, manufacturers and end users will make a decision to simply wait until a "final" option has been converged upon, which of course rarely happens due to the now dynamic nature of the refrigerant market. Otherwise, they will choose the option that appears to require the least complication and which is subject to the least amount of controversy (such as high-GWP alternatives). Depending upon the concentration of particular arguments for or against a particular refrigerant, end users or manufacturers may develop an aversion against that refrigerant – whether the arguments are realistic or not. Often politically-motivated cases are misconstrued for technical problems.

How to resolve

In general, this barrier can only be overcome by creating a sense of greater confidence in particular LGAs. This may be achieved by better informing of the industry about specific LGA options, through a number of approaches:

- Presenting robust case studies and experiences from other countries and enterprises.
- Exemplifying comparable projects in other (similar) countries, demonstrating its maturity.
- Those in authority (NOUs, implementing agencies) providing firmer direction to the industry.
- Publication of robust guidelines as to what refrigerant to use, when to use and how.
- Environmental organisations should carry out stronger activities within countries.
- Conferences and seminars should be designed to focus on the benefits and methods for particular refrigerants.
- The industry must have it explained to them the importance of longer-term perspectives and that accepting slightly higher cost and complications now can pay off in the future.

Additional remarks

NOUs and national authorities, trade associations and implementing agencies can be involved with encouraging enterprises to be more comfortable with embarking on a conversion.

Contractors and technicians are well aware that the systems they look after leak and that they may be leaking severely. But, the amount of effort necessary to find and repair the leak is excessive compared to the ease and convenience (and in some situation greater profit) of topping-up the system. This is frequently supported by the customer who would rather frequently pay smaller amounts for adding refrigerant, rather than one large amount for a repair job. Knowing that this culture of persistence of leakage exists makes contractors and users more hesitant about using flammable or higher toxicity refrigerants whose consequence of leaks are more significant.

Refrigerant types	All
System/application types	All types of systems, especially those of larger capacity
Impacted stakeholders	Manufacturers, installers, end users
Barrier impact	Although making a change to an LGA refrigerant may pose risks, so would any change to the business and therefore is not seen as a major problem.
Severity rating	
Unachievability rating	

Barrier: "It is not necessary to use these refrigerants"

If there is a consensus that it is not necessary to use LGA refrigerants then decision makers will not find any need to do so.

Overview of barrier

Whilst in certain sectors and the general public in many (non-Article 5) countries, the issue of global warming is taken seriously, in other countries or sectors this view does not prevail. Therefore if there is no appreciation of the need to take responsibility for avoiding emissions of greenhouse gases, then the choice of refrigerant will largely be based on non-environmental and often short-term issues. Thus, where existing options are well known that work reasonably well and impose no additional complications, then there is no need to consider other refrigerants that pose additional difficulties, are considered less safe and are not already well established within the market.

Causes

It is part of human nature to be resistant to changes and novelties, especially if they cannot see how they may benefit from it. Specifically, where the consensus view is that global warming is not a reality there is no obligation to use refrigerants with a low GWP – either morally or legally. Enterprises are relatively satisfied with what they currently use and therefore they have no incentive to change or even look for alternatives. There is no need to cease using what is convenient for them and to go with the more efficient but more expensive technology. Enterprises would question the reasons to make their business less competitive by trying to develop new products that use a different refrigerant which demands greater cost and resources, yet at the same time may pose greater risk.

Regardless of the view of the enterprise(s), if the market is unaware of the climate impact of existing refrigerants, then there will be no consumer demand for climate-friendly products. Thus it could be argued that there is insufficient awareness-raising on the issue of global warming (or at least the

impact that high-GWP refrigerants has on it), and that the issue of the "urgency" of using LGA options has not been imposed upon the relevant stakeholders.

If enterprises are aware and open to the view that high-GWP refrigerants do contribute to climate change, then they may still deem it unnecessary to actively respond to it. For example, they may not consider addressing global warming as their own, or the company's "responsibility". Similarly they may consider that addressing global warming issues is a "premium" issue that consumers in Article 5 countries are unlikely to pay for, or that the concept of LGA refrigerants is too "distant"; it is an industrialised country issue.

Moreover, due to the widespread marketing of various companies, there exists a belief that high-GWP HFCs are already "green", "eco-", etc., and therefore no additional benefit can be gained from adopting (genuinely) low-GWP refrigerants. This is exaggerated by many producers of systems and refrigerants by adverting high-GWP – but also ODS – refrigerants as "environmentally friendly", "climate friendly", "ecological" and so on.

How to resolve

As is seen in other fields, convincing decision-makers and stakeholders of the importance of climate change and the necessity to address it is very difficult. Possible approaches to help overcome this barrier may include:

- Active promotion of systems using LGA refrigerants.
- Financial incentives for systems using LGA refrigerants.
- Broader awareness-raising of the benefits of LGA refrigerants.
- Environmental NGOs playing a greater part in making consumers more aware of these climate issues.

National authorities could also develop rules to prevent the widespread use of "green" marking and claims unless it can be proved to meet acceptable criteria. Any such rules should of course be enforced.

Refrigerant types	All		
System/application types	All		
Impacted stakeholders	This applies mainly to manufacturers and suppliers, but also to installers, service contractors and end users		
Barrier impact	This barrier does not have a major impact because the environmental reason is not one of necessity for decision-makers.		
Severity rating			
Unachievability rating			

6. CONCLUSIONS

6.1 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.

6.2 Summary of barriers and ways and means [38]

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.) 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.

[38] Again, the statements and associated views expressed below – as consolidated from those in Section 5 – 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 15 to help indicate the most important barriers.

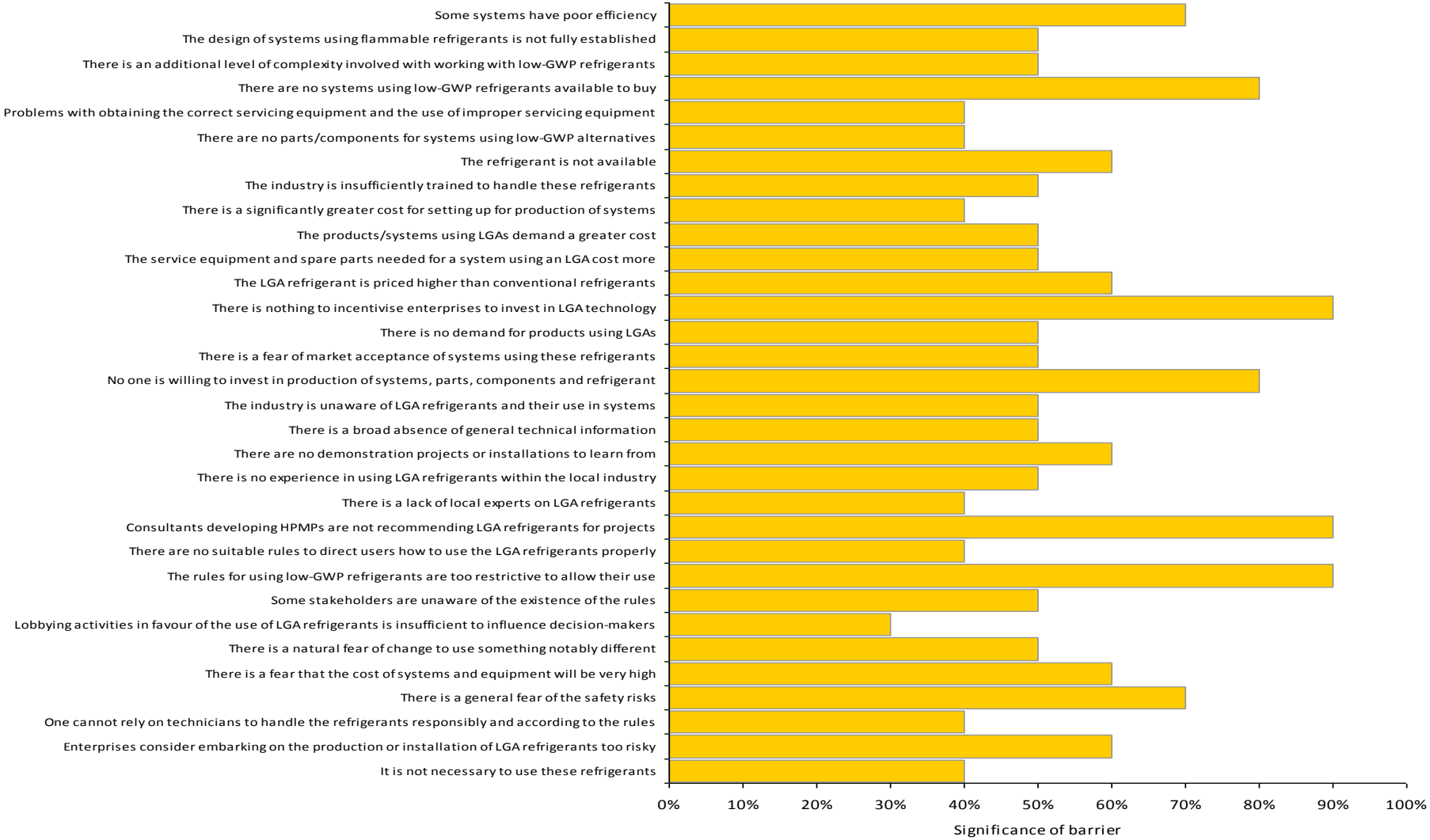

Figure 15: Summary of the significance of the various barriers

6.3 General recommendations

It can be seen from the list above (as well as the discussion in Section 5.3) 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.

6.4 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"

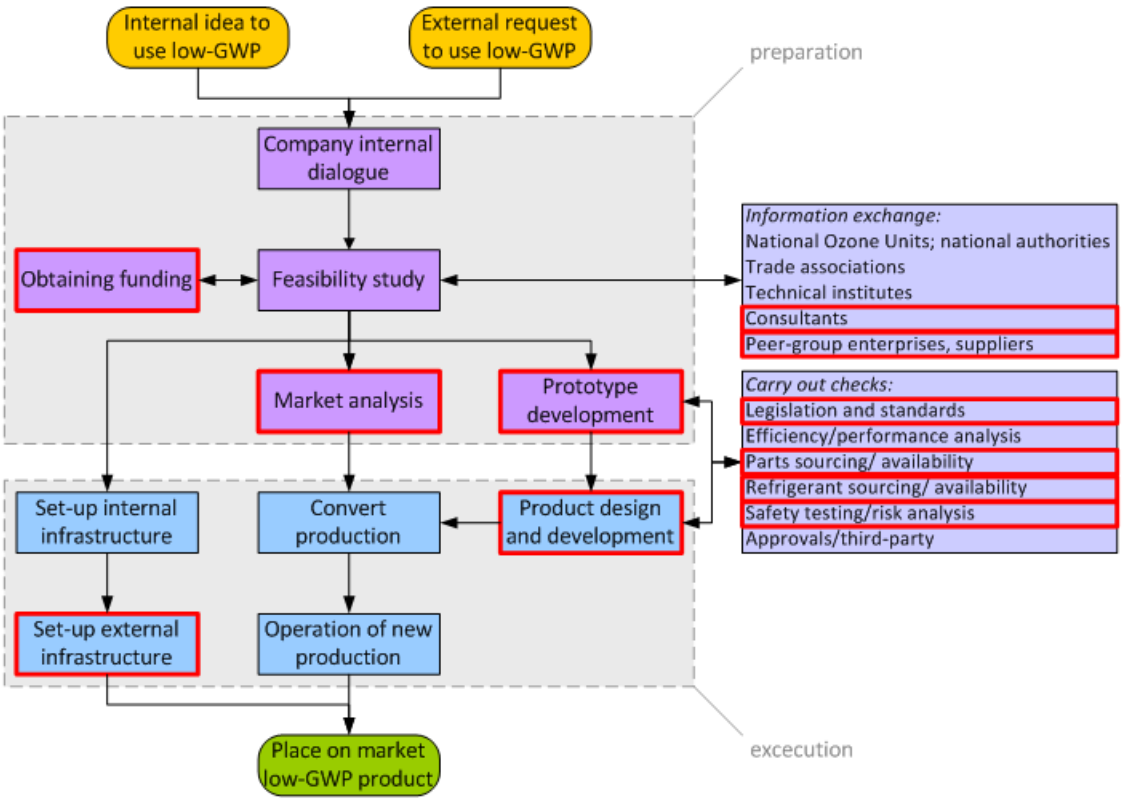

Figure 16: Identification of the stages (red boxes) likely to experience the most significant barriers during the general process for placing a new product on the market

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.

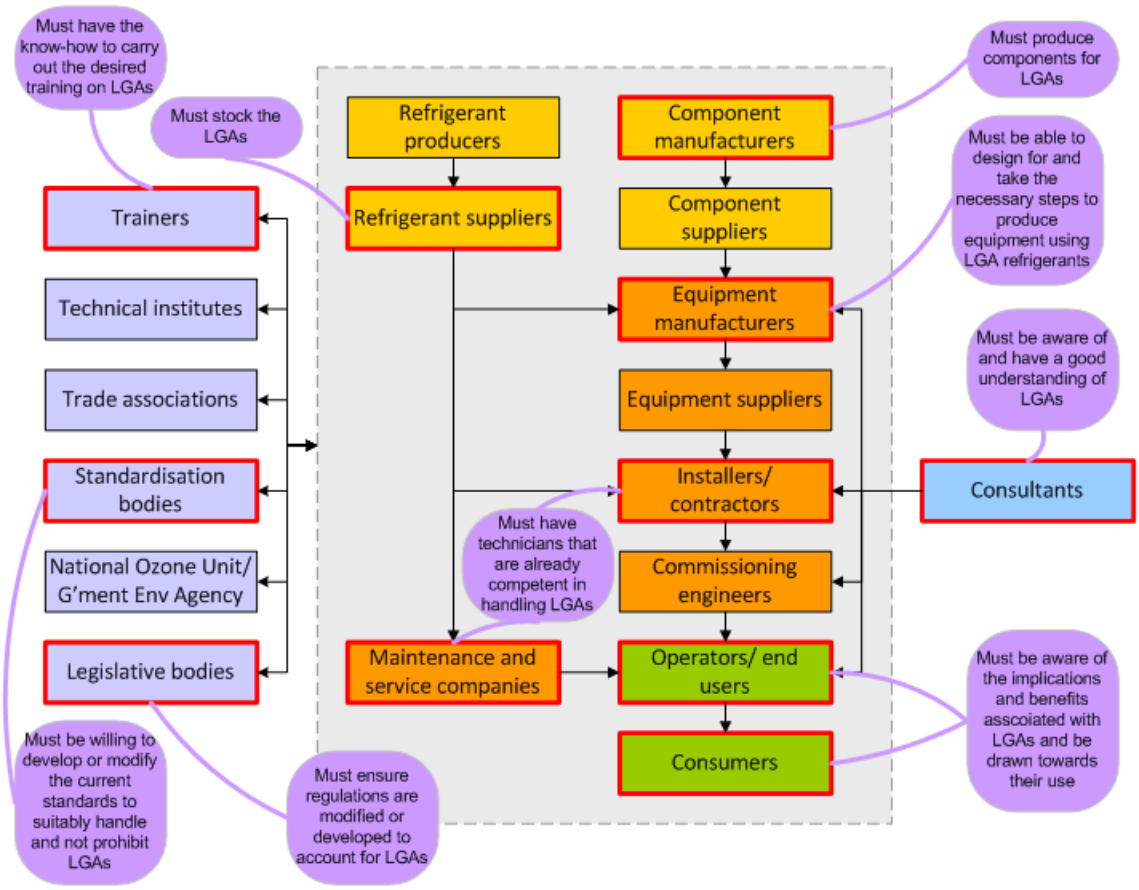

Figure 17: Identification of the stakeholders who have greatest impact on the existence of dissolution of barriers when introducing, applying and using LGA refrigerants

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 16 repeats Figure 2 but highlights the stages, sources of information or work items where barriers are most likely to occur (as identified in Section 5.3). 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 17 builds on the information within Figure 3 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 17. 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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- Ruben Marchand, Consultant (Mexico)
- Dilip D Rajadhyaksha, Godrej & Boyce Mfg. Co. Ltd (India)
- Markus Wypior (GTZ Proklima)

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)
- Dilip D Rajadhyaksha, Godrej & Boyce Mfg. Co. Ltd (India)
- Germán Arturo Orrego Muñoz, Servicio Nacional de Aprendizaje (Colombia)
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- Paul Lefèvre, Asian Green Fluids Company Ltd (Thailand)
- Prasai Chalidapongse, King Mongkut's University of Technology Thonburi (Thailand)
- Rafael Quintero, Universidad de Oriente (Cuba)
- Robert Nunez, ARIA (Trinidad and Tobago)
- 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[39]
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

[39] 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.

APPENDIX 1: COMPREHENSIVE SURVEY FORM

PLEASE RETURN BY MONDAY 10TH MAY *26th April 2010*

UNEP DTIE JUMPSTART PROJECT

QUESTIONNAIRE ON

THE BARRIERS TO THE UPTAKE OF LOW-GWP ALTERNATIVES TO HCFC REFRIGERANTS

INTRODUCTION

As part of the "jump-start" project UNEP has initiated a study to look at barriers to the up-take of low global warming potential (GWP) refrigerants in A5 countries. This is primarily aimed at low-GWP alternatives to HCFCs, particularly R22. Thus, it is intended to aid the acceleration of HCFC phase-out in Article 5 countries. The focus is also on the use of alternatives within new equipment, rather than for the purpose of converting existing systems.

PLEASE RETURN THE ANSWERED QUESTIONNAIRE BY MONDAY 10TH MAY 2010

OBJECTIVE

The objective of the study is to identify the various barriers to the introduction and use of low-GWP refrigerants, which may relate to different stages in the development, marketing or servicing of systems and equipment, or which may relate to different stakeholders within the industry. Further to this, the intention is to determine ways and means of overcoming such barriers.

As a general guide, one may ask:

"If I wanted to have a low-GWP system tomorrow, what is stopping me?"

"If I am determined to use a low-GWP refrigerant, what do I need to do?"

When referring to low-GWP refrigerants, those under consideration primarily include:

- R-717 (ammonia, NH3)
- Hydrocarbons (HCs) – R-290 (propane), R-1270 (propylene), R-600a (iso-butane)
- R-744 (carbon dioxide, CO2)
- Unsaturated HFCs – e.g., R1234yf, etc

GUIDANCE INFORMATION

In order to help guide one's thoughts for the proceeding questions, it may be worth considering the types of process that an enterprise may go through in order to introduce systems using alternative refrigerants, as well as the possible stakeholders involved in the possible introduction of a new refrigerant; examples are provided in Figures 1 and 2, respectively, below.

1

Barriers may be separated into several different categories, as follows:

- Technical (refrigeration engineering)
- Technical (safety engineering)
- Supply and availability (materials, equipment, components, fluids)
- Commercial (investment, profit, financial incentives)
- Market (customer, consumer, competing products)
- Information resources (know-how, guidance, technical data)
- Regulatory and quasi-regulatory (legislation, standards)
- Psychological and sociological aspects (rumour and influence of peer groups, personal desire to see or to not see barriers, etc)

Barriers may also be relevant to particular equipment or situations, such as:

- Size of equipment (large, medium, small)
- Sector (domestic, commercial, industrial)
- Types of equipment (mass-produced appliance, site-installed bespoke system)

It is also important to consider whether barriers are actual, tangible, personally experienced problems, or whether they are only perceived, mythical or rumoured issues.

CONTACT

If you have any questions that relate to this questionnaire, or would like clarification on how to respond to it, please contact:

Daniel Colbourne, d.colbourne@re-phridge.co.uk

PLEASE RETURN THE ANSWERED QUESTIONNAIRE BY MONDAY 10TH MAY 2010

FIGURES TO ASSIST WITH INDICATING THE CONTEXT OF BARRIERS

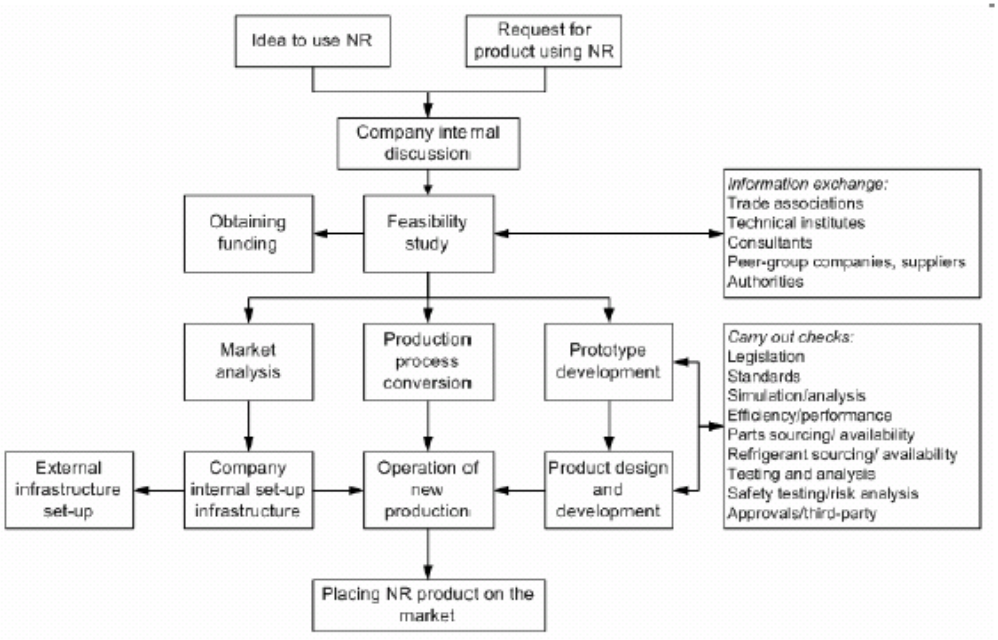

Figure 1: Typical process for an enterprise to introduce a system using a new alternative refrigerant

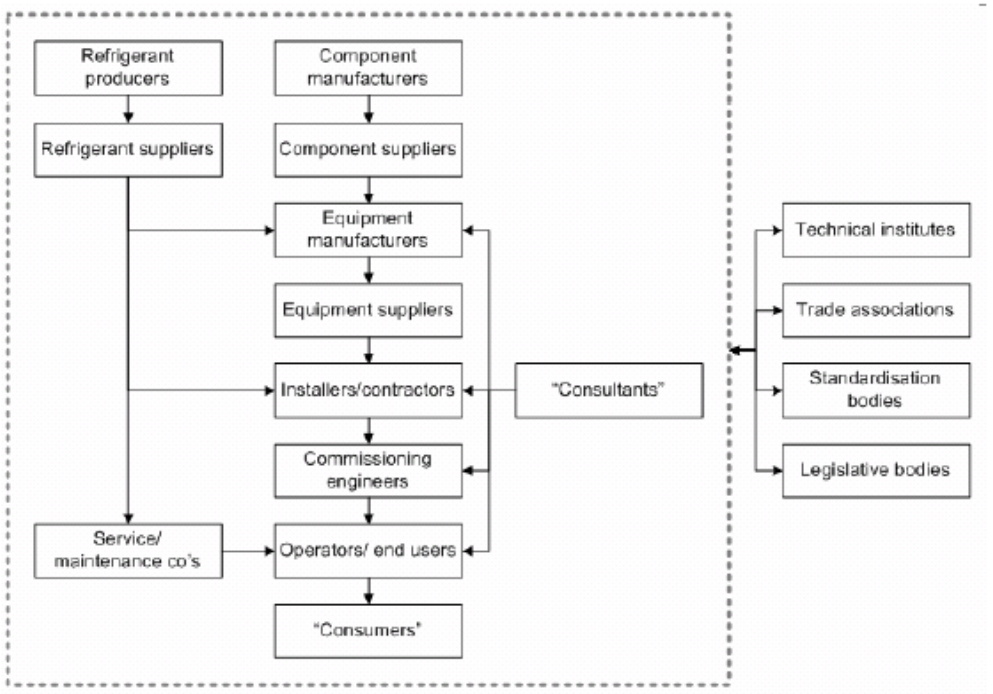

Figure 2: Stakeholders involved in industry

INSTRUCTIONS

Please respond to the following questions, for each of the categories of barriers, providing as much information as possible. Please note that you only need fill in the boxes under the categories that may be relevant to you, and if you can think of more than one barrier for a given category, then please do include within one or more additional answer boxes. Also consider whether each barrier is refrigerant-specific or apply to all alternatives. Lastly, whilst filling in the question boxes, it is important to differentiate between the cause of the barrier and the barrier itself.

In order to assist, an example question box is provided below.

Example question box (Supply and availability; materials, equipment, components, fluids)

Briefly describe what the barrier is	No availability of HC refrigerant in certain countries
What do you believe the causes/origins of this barrier are?	Not enough demand for the refrigerant
What do you believe the causes/origins of this barrier are?	Refrigerant suppliers do not see enough profit potential
Applicable to which refrigerant?	R290, R1270, HC mixtures
Which stakeholder(s) does it directly impact upon?	Equipment/system manufacturers, installers, service technicians
Can you do anything about it?	Yes
If so, what action(s) would it be?	Persuade companies to request the refrigerants from suppliers
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	Difficult
If you cannot do anything about it, which stakeholder(s) could?	Large system/appliance manufactures
Is there a way of by-passing the barrier, an alternative approach?	No
Any other remarks?	

When complete please return this form to the UNEP representative.

Alternatively if you are filling this out electronically please send the completed form by email to Daniel Colbourne d.colbourne@re-phridge.co.uk and copy to Etienne Gonin Etienne.Gonin@unep.org

PLEASE RETURN THE ANSWERED QUESTIONNAIRE BY MONDAY 10TH MAY 2010

PLEASE RETURN BY MONDAY 10TH MAY *26th April 2010*

QUESTIONS

Your job [please ☑]

Service/maintenance technicians		Installer/contractor/commissioning engineers	
Component manufacturer		Operator/end-user/consumer	
Component supplier		Consultant	
Refrigerant producer/supplier		National authority/government	
Equipment manufacturer		Technical institute/university	
Equipment supplier		Trade association	
Other… [please state]			

Describe your job/activities in more detail

Your name	
Email address	
Telephone number	
Country	

1. Technical (refrigeration engineering)

Describe what the specific barrier is; do not give a general statement	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

2. Technical (safety engineering)

Please also note that the toxicity / flammability risk for ammonia and HCs is well known. When completing this section please indicate the specific barriers to adoption, and not refer to these physical characteristics which are common knowledge and as such are not barriers since equipment operating with them are well established throughout the world in many sectors. Please focus on the specific barriers to adoption in your sector, and national situation when answering.

Describe what the specific barrier is; do not give a general statement	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

3. Supply and availability (materials, equipment, components, fluids)

Describe what the specific barrier is; do not give a general statement	
What do you believe the causes/origins of this barrier are?	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

4. Commercial (investment, profit, financial incentives)

Describe what the specific barrier is; do not give a general statement	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

5. Market (customer, consumer, competing products)

Describe what the specific barrier is; do not give a general statement	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

6. Information resources (know-how, guidance, technical data)

Describe what the specific barrier is; do not give a general statement	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

7. Regulatory and quasi-regulatory (legislation, standards)

Describe what the specific barrier is; do not give a general statement	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

8. Psychological and sociological aspects

Describe what the specific barrier is; do not give a general statement	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

9. Additional barriers

Describe what the specific barrier is; do not give a general statement	
Briefly describe what the barrier is	
What do you believe the causes/origins of this barrier are?	
Applicable to which refrigerant?	
Which stakeholder(s) does it directly impact upon?	
Can you do anything about it?	
If so, what action(s) would it be?	
Would it be easy or difficult for you to do this? (easy, viable, difficult, impossible, etc)	
If you cannot do anything about it, which stakeholder(s) could?	
Is there a way of by-passing the barrier, an alternative approach?	
Any other remarks?	

APPENDIX 2: INTERNET SURVEY FORM

Exit this survey

1. BARRIERS TO THE COMMERCIAL USE OF LOW-GWP ALTERNATIVES TO HCFC REFRIGERANTS

As part of the "jump-start" project click here UNEP has initiated a study to look at barriers to the up-take of low global warming potential (GWP) refrigerants, particularly R22, in A5 countries. It is intended to aid the acceleration of HCFC phase-out in Article 5 countries. The objective of this work is to identify the various barriers to the introduction and use of low-GWP refrigerants, initially by means of a survey. Further to this, the intention is to determine ways and means of overcoming such barriers. We would like to ask you for your views about what you consider to be barriers in this regard. When considering what the barriers may be, one may ask the question: "If I wanted to have a low-GWP system tomorrow, what is stopping me?", and in terms of overcoming the barrier: "If I am determined to use a low-GWP refrigerant, what do I need to do?" The questions below are intended gather the details of the barriers you identify.

1. Personal information (Note that your opinions will be kept confidential.)

Country

Your name (optional)

Email (optional)

Telephone (optional)

2. What is your role?

If other, please specify

3. What is the general category of the barrier you are thinking of?

- Technical (refrigeration engineering)
- Technical (safety engineering)
- Supply and availability (materials, equipment, components, fluids)
- Commercial (investment, profit, financial incentives)
- Market (customer, consumer, competing products)
- Information resources (know-how, guidance, technical data)
- Regulatory and quasi-regulatory (legislation, standards)
- Psychological and sociological aspects (rumour and influence of peer groups, personal desire to see or to not see barriers, etc)
- Other

If other, please specify

4. Please describe what the specific barrier is.

NOTE: The toxicity/risk of explosion for ammonia and flammability of HC and HC-mixtures, is well known. When completing this section please indicate the specific barriers to adoption, rather than referring to these physical properties which are to be taken as common knowledge and in themselves are not barriers since equipment operating with these chemicals are well established in many sectors in many parts of the world. Please focus on the specific barriers to adoption in your sector, and national situation when answering.

5. Applicable to which refrigerant?

- R-717 (ammonia)
- Hydrocarbons (e.g. R290/propane, R600a/isobutane, etc.)
- R-744 (CO_2)
- Unsaturated HFCs (e.g. R1234yf)

6. What do you believe the causes/origins of this barrier are?

7. Which stakeholder(s) does this barrier directly impact upon?

8. Can you do anything about overcoming this barrier?

Yes (Go to next questions, and skip Question No.11) No (Go to Question No.11)

9. If so, what action(s) would it be?

10. How easy would it be for you to do this?

	easy	feasible	difficult	impossible
Rating				

11. If you cannot do anything about it, which stakeholder(s) could?

12. Is there a way of by-passing the barrier, an alternative approach?

13. Any other remarks?

14. Would you like to describe another barrier to the introduction of low GWP refrigerants?

Yes No (Exit the survey)

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.

The Office of the Director, located in Paris, coordinates activities through:

- The International Environmental Technology Centre - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- Sustainable Consumption and Production (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- Chemicals (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- 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.

For more information, see www.unep.fr

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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