
Possible Bans for New RAC Equipment

A review of the technical and economic impact of potential bans on the use of HFCs for new equipment in RAC market sectors

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Management Summary

- 1) This document contains a review of the potential for bans for HFCs used in new RAC systems.
- 2) In Section 1 and 2 we describe the complexity of the RAC market and the danger of applying bans in the wrong circumstances. It is easy to get a ban definition wrong and either include “difficult” systems or exclude systems that could have been targeted.
- 3) In Sections 3 to 10 we provide an assessment of all relevant market sectors and sub-sectors. The results of the assessments are summarised in Table 0.1. Note: this document is specifically about bans in new equipment. Issues related to the proposed service ban are not included.
- 4) The proposed high GWP service ban provides a very useful “de facto” ban on R404A and R507 in new systems. This ban will be immediate and create an early move away from these refrigerants. Key sectors affected are supermarket packs and all industrial systems. Assuming a 50 tonnes CO₂ threshold for the service ban (to avoid excessive cost for small systems), two sectors would benefit from an explicit ban on R404A in new equipment: (a) commercial condensing units (from 2015 or 2016) and transport refrigeration (from around 2020).
- 5) Large systems create the best possibilities for further bans with GWP below 150, especially commercial pack systems, large industrial systems and large air-conditioning chillers. Ammonia, CO₂ or pure HFOs are likely to be applicable for the majority of systems in these sectors. Three key issues would need to be addressed: (a) the threshold for “large”, (b) the exact definition of the relevant sectors (to avoid “surprises” and (c) the possibility of an exemption mechanism for difficult situations (e.g. extreme low temperature industrial plants or safety related).
- 6) The use of mildly flammable refrigerants in small air-conditioning (especially split systems) looks a very interesting possibility. R32 and HFO / HFC blends could provide efficient and cost effective equipment for small split system air-conditioning. Exemptions for safety issues would be required (e.g. to cater for unsafe locations such as basements or national fire regulations).
- 7) It is important to recognise the relative size of each sector in terms of HFC demand, as shown in Table 0.1 for 2010. 3 of the 19 sectors in the table represent 63% of HFC demand. One of these (MACs) is already covered by a ban. The largest sector (commercial packs) is well suited to a ban (and there is significant voluntary action). The second largest sector (split system air-conditioning) may be suited to a ban at GWP <700, although a number of safety issues need to be addressed and commercial development is at an early stage.
- 8) Possible bans with “green lights” in Table 0.1 can be introduced as “phase down sign posts”. They will help support the phase down without adding any significant extra costs. However, some of these bans may be difficult to draft with unambiguous but simple wording.

Table 0.1: Summary of Ban Opportunities for New Equipment

	RAC Market	% 2010 HFC Demand	Approximate GWP Threshold for New Product Ban				Comments
			150	700	1400	2500	
Refrigeration	Domestic refrigeration	0.2%	●				Already banned from 2015
	Commercial Small Hermetic	0.2%	●				Already banned from 2020. Needs new definition
	Commercial Condensing Units	4%	●	●	●	●	Use of mildly flammable refrigerants possible. Early R404A ban recommended
	Commercial Multipack	33%	●	●		●	CO ₂ looking a good option on large packs. Smaller packs may need GWP 700
	Transport Refrigeration	1%	●	●		●	CO ₂ being piloted. R404A ban from 2020
	Industrial Small / Medium DX	8%	●	●	●	●	Many variants. De facto R404A ban
	Industrial Large DX	3%	●			●	Ammonia and CO ₂ . May need exemptions
	Industrial chillers	1%	●	●			Large chillers < 150; small chillers < 700
	Industrial flooded	0.1%	●			●	Ammonia and CO ₂ . May need exemptions
Air-Conditioning and Heat Pumps	Small portable units	1%	●				Already banned from 2020
	Split systems	20%	●	●			Almost green! Good possibilities for mildly flammable refrigerants at small end of size range, but still much development needed. May need safety exemptions
	Packaged systems	0.4%	●	●			Good possibilities for mildly flammable refrigerants if safety Regulations allow high charge. Needs further development,
	VRF systems	2%	●	●			
	Small and medium chillers	6%	●	●			Good possibilities for mildly flammable refrigerants. May need safety exemptions
	Large chillers	2%	●				
	Domestic hydronic heat pumps	1%	●	●			Mildly flammable refrigerants may be suitable if efficiencies good enough
	Other heat pumps	1%	●	●			
	MAC: cars and vans	10%	●				Already banned via MAC Directive
MAC: large vehicles	7%	●	●			Many variants and safety issues	

Key to Traffic Lights	
●	Ban suitable (but may need small number of exemptions in some sectors)
●	Ban may be suitable for part of sector, but more commercial development needed
●	Ban not suitable at this time

Introduction

This document provides a discussion of the potential for banning the use of HFCs in new equipment in certain parts of the RAC market. Note: this document is specifically about bans in new equipment. Issues related to the proposed service ban are not included.

In Sections 4 to 10 we present an assessment of alternative refrigerants in each RAC market sector and sub-sector. For each market we discuss the possibility and desirability of HFC bans for new equipment and identify any “special cases” where a ban will prove especially challenging or counter-productive in environmental terms.

Before discussing the possibility of bans we provide some background information to explain why the broad ranging bans being requested by certain stakeholders are very optimistic and do not fully take into account the wide variation of conditions across the EU.

Market Complexity

A key aspect of understanding the potential for HFC bans in RAC applications is to recognise the complexity of the market. Bans that can be shown to be practical and costs effective in certain parts of the market may be impossible in other apparently similar markets. Some of the key variables that are usually ignored in “overly simplistic” ban proposals include:

- a) **Geographic location**, especially in relation to ambient temperature and available skill base. For example, the use of CO₂ in supermarkets in Northern EU has been shown to be effective, but it is not easy to transfer this technology to hotter and less technically developed parts of the EU.
- b) **Size and location of equipment in the small air-conditioning market**. Certain applications of small split system air-conditioning might be able to use highly flammable or mildly flammable refrigerants. However, with small changes in either the location of the cooling unit (e.g. ceiling versus floor level) or in the size of the room being cooled it is possible for a specific model to change from being safe to unsafe (in terms of the requirements in safety codes).
- c) **Cost effectiveness for different sizes of system**. Oko Recherche 2011 suggested that ammonia was available for all industrial applications. In their analysis a “small” industrial system contained 630 kg of refrigerant. In reality a lot of industrial plants are 10 to 20 times smaller than this – ammonia is not easy or cost effective to use at such small sizes.
- d) **Cooling temperature level**. The temperature at which cooling is required can vary considerably within a single market sub-sector. For example food retail systems are required to operate at medium temperature (MT, for chilled products around 4°C) or at low temperature (LT, for frozen products around -20°C). The options for low GWP alternative refrigerants vary considerably depending on temperature level.
- e) **Commercial and Reputational Issues**. Equipment manufacturers carry liability for the safety of their products in use. In addition to this legal responsibility, they value their reputation highly. They are understandably cautious about introducing products which, although safe in certain applications, might be unsafe in other quite similar applications. They have insufficient control of the installation and maintenance activities to be certain that their products will be safe through the whole product lifecycle. This makes them reluctant to move to certain alternatives.
- f) **Energy efficiency**. Some bans could push up energy use in parts of the defined market. This could lead to an overall increase in GHG emissions.

- g) **Over-optimistic assumptions on very low GWP gases.** Some potential bans rely on the effective use of new HFO refrigerants in a range of applications. But these gases have not yet been proven for these applications. It is assumed that new blends will be suitable, but this is, at present, an assumption and not a fact. The current problems with HFO 1234yf and the MAC Directive illustrate the difficulty of forcing technology to meet a timetable set by a ban.
- h) **Confusion between market sectors.** Some of the commonly used market sector definitions are not very precise and it is not always clear what type of equipment is targeted in a ban proposal. Also, some similar types of equipment are used in different sectors and ban applicability is affected by the end user circumstances as well as the type of equipment. This is particularly a concern for chillers which are mainly used for building air-conditioning, but are often used in industrial applications.

GWP Threshold

Another important consideration is what level of GWP threshold should be applied to a ban. As shown in Table 1.1, there are 4 main groups of refrigerant in terms of GWP. The very low GWP refrigerants all have a GWP below 10, but all have safety / practicality issues that limit their cost effective application in many parts of the market. There are no refrigerants in the GWP range 10 to 150 that are in current use or that have been announced as potential future refrigerants. A ban with a GWP threshold of 150 is effectively the same as a ban with a threshold of 10. This type of ban is much more restrictive than a ban that allows the use of low / moderate GWP refrigerants in the 200 to 1,000 GWP range.

Table 1.1: Refrigerant GWP Grouping

GWP Group	GWP Range	Examples	Comments
Very low	0 to 10	Ammonia, CO ₂ , HCs, HFOs	All have safety related issues including flammability, toxicity and / or pressure level.
Low / moderate	200 to 1,400	Available: R32, R245fa Future: HFO Blends	R32 and "blend 300" are flammable. Some blends in the 500 to 1,400 range may be non-flammable
Medium	1,430 to 2,107	R134a, R407A, R407C, R407F, R410A	All non-flammable.
High	3,900	R404A, R507	R404A is dominant HFC in EU currently

Examples of Unsuitable Ban Definitions

Ban in Leaked Proposal

The leaked Commission proposal (October 2012) contained the following ban:

HFCs Other refrigeration and freezing systems for commercial use 1/1/2020 for all HFCs

There are at least 3 major problems with this type of wording:

- a) Most importantly, the proposal includes a very wide range of systems and does not account for variations within this wide scope. For example, system size varies from very small (<5 kg) to very large (>500 kg) and systems are required to operate at MT and LT conditions. A ban

with a narrow scope (e.g. large MT supermarket systems) is more realistic and much easier to analyse in terms of cost effectiveness.

- b) The ban applies to “all HFCs”. This is very restrictive and would not allow any blends with a tiny percentage of HFCs. It is better to include a GWP threshold (although as noted above, a threshold of 150 is a de facto threshold of 10 with the refrigerants currently available).
- c) Wording such as “for commercial use” is very vague and does not properly define the market. It is believed that the intention of this ban was to focus on food retail refrigeration, but there are many other systems that could be considered “commercial” e.g. leisure facilities (such as ice rinks), small public cold stores and food service systems.

“Simplistic” ban for all split system air-conditioning equipment

A hypothetical ban is one in which a general HFC ban is applied to all new split system air-conditioning equipment, using a GWP threshold of 150. Whilst such a ban would appear to drive significant GHG emission reductions in a large market sector, the nature of the ban could lead to problems in at least 2 areas:

- a) Safety: a GWP threshold of 150 forces use of a very low GWP refrigerant, which would either be highly flammable (HCs), mildly flammable (HFOs) or very high pressure (CO₂). In some applications the safety issues can be addressed (e.g. HC in very small systems) but not in all.
- b) Energy efficiency: a move away from R410A to a very low GWP alternative will usually result in higher energy consumption, negating some or all of the GHG emission reductions.

A ban with a much more narrow scope and a higher GWP threshold could prove much more beneficial to the environment.

Ban definitions that miss part of the relevant market

The proposed ban for non-domestic hermetic equipment uses the following wording:

“Refrigerators and freezers for the storage, display or distribution of products in retail and food service (“commercial use”) - hermetically sealed systems”

The precise wording of a ban such as this needs careful consideration to ensure that it covers all intended applications. Factory built small hermetic systems are used for a range of applications that are outside the above definition. For example small ice making machines and in-line drink coolers in pubs and vending machines probably fall outside the definition. Specialist freezers used for storing drugs are another example. Ideally the ban wording needs to remain simple but encompass the widest possible range of suitable applications (e.g. *“all other¹ hermetically sealed systems containing less than 1 kg of refrigerant”*).

The 3 examples in this section are intended to illustrate how important it is to (a) use precise wording that defines all applications intended and (b) use bans of relatively narrow scope to avoid unforeseen problems.

¹ The word “other” is used as the previous line in Annex III refers to an earlier ban on domestic refrigerators and freezers.

RAC Market Sectors

Our discussion of the potential for bans in this document is split into the 7 main sectors used in Oko Recherche 2011 and in our work for EPEE. These are:

1. Domestic refrigeration
2. Commercial refrigeration, including food retail and food service (hotels, restaurants, pubs etc.)
3. Transport refrigeration
4. Industrial refrigeration
5. Stationary air-conditioning and heat pumps
6. Chillers & hydronic heat pumps
7. Mobile air-conditioning

In the following 7 sections of this document we also discuss the variations across the key market sub-sectors that could be used to provide narrow scope bans where these are most appropriate.

It is useful to understand the importance of each market sector in terms of the demand for HFCs. Table 3.1 shows the demand for HFCs in 2010. Demand includes refrigerant required for new equipment (including pre-charged imports) and refrigerant required for servicing and retrofills of existing systems. Key points of interest from this table include:

- Commercial refrigeration accounts for over one third of total demand – of which multipack central systems represent the bulk of demand.
- Stationary air-conditioning and heat pumps represent nearly a quarter of demand in 2010 – this demand is growing rapidly. Split systems, which contain between 1 and 10 kg of refrigerant, represent about 85% of the demand in this market sector.

Table 3.1: HFC Demand in 2010

Sector	kT CO2	% of HFCs	Key Subsectors
Domestic refrigeration	400	0.2%	
Commercial refrigeration	68,400	36.4%	Multipacks 32%
Transport refrigeration	2,700	1.4%	
Industrial refrigeration	23,000	12.2%	DX Systems 11%
Stationary AC and HPs	43,800	23.3%	Split systems 18%
Chillers and hydronic HPs	18,800	10.0%	
Mobile air-conditioning	30,800	16.4%	Cars / vans 11%
Total RAC Applications	187,700	100%	

Source: SKM Refrigerants Model

Domestic Refrigeration (0.2% of 2010 HFC Demand)

The domestic market consists of three main types of system: refrigerators, freezers and fridge-freezers. These all use the same types of technology i.e. hermetically sealed factory built systems containing between 50 and 250 g of refrigerant.

Current refrigerants: Widespread use of HCs (>90% of all new systems). Some HFC 134a is used, mainly for large refrigerators manufactured in the USA.

Very low GWP Alternatives: HCs are clearly well suited and can be used for almost the whole of this market. If flammability risk is critical, mildly flammable HFO 1234yf is a possible future alternative.

Impact of proposed service ban on new equipment: None in this market sector.

Is a ban suitable for new equipment? Yes. A GWP threshold of <10 is achievable. A ban by 2015 is feasible for all systems that could use HCs. If HFO 1234yf is required a later ban (e.g. 2017) may be required to allow commercial development of such systems.

Are there any “difficult” applications? Not in ordinary domestic situations. Domestic units might be used in non-domestic situations where flammability risk is especially important – these may require HFO 1234yf which would not be available by 2015 (although they can be considered as non-domestic special applications covered by a ban on “other small hermetic systems”).

Are there any applications that could be left out unintentionally? Refrigeration cycles are used in other types of domestic equipment such as heat pump dryers used in tumble dryers and ice cream makers. These are hermetically sealed factory built systems that need to be considered under a ban covering “other small hermetic systems”.

Commercial Refrigeration (36% of 2010 HFC Demand)

This is a complex market with 3 completely different types of application: (a) small hermetic systems, (b) single condensing unit systems and (c) large pack systems. Each of these is discussed separately below.

As discussed in Section 2, the word “commercial” is not very helpful. It is clear that it encompasses food retail and food service systems. These include (a) small cold storage rooms (e.g. in shops and hotels), (b) retail display cases for food and drink products and (c) related applications such as ice makers, beer cellar coolers, in-line drink coolers and vending machine coolers. There are some “grey areas” where commercial applications overlap with industrial e.g. ice rinks and large cold stores. There are also some specialist refrigeration applications that are not really covered by any of the other refrigeration categories and therefore need to be included within “commercial” e.g. specialist systems in hospitals and mortuaries.

5.1 Commercial Small Hermetic Systems (0.2% of 2010 HFC Demand)

Small hermetic systems are used for a range of different commercial applications. They consist of standalone hermetically sealed factory built systems mostly containing between 50 and 250 g of refrigerant (although some larger systems with up to 1 kg of refrigerant are used). Applications include integral display cases (e.g. ice cream freezers, chilled food displays), storage cabinets (essentially these are large domestic refrigerators), ice making machines, in-line drink coolers, vending machine coolers.

Current refrigerants: Widespread use of HFC 134a (>70% of all new systems). Some use of HFC 404A. Growing use of HCs in many applications and some use of CO₂.

Very low GWP Alternatives: HCs are well suited and can be used for a significant part of this market. If flammability risk is critical, mildly flammable HFO 1234yf is a possible future alternative and CO₂ can be used in some applications.

Impact of proposed service ban on new equipment: None in this market sector.

Is a ban suitable for new equipment? Yes. A GWP threshold of <10 is achievable. The timetable for a ban needs to be slower than for domestic systems as (a) the market for low GWP alternatives is much less developed in this sector and (b) there is a much larger number of different applications that all need to undergo design and risk assessments by manufacturers. A ban by 2020 is feasible for most applications, allowing time for development of HC and HFO alternatives. The proposed interim ban for GWP > 2,500 in 2017 will eliminate any use of HFC 404A at an early date – this is a reasonable proposal. The ban should be widened beyond the description given in the Annex III of the Commission proposal to ensure that nearly all small hermetic systems are included in the ban.

Are there any “difficult” applications? Yes. There are 2 issues that may need to be addressed with suitable exemptions. A key issue relates to very low temperature systems e.g. specialist equipment used in medical applications and in research laboratories. If flammability is not an issue certain HCs may be a feasible solution for very low temperatures, but if a non-flammable refrigerant is required a ban may create difficulties. For normal temperature applications, if flammability is particularly crucial, even the mild flammability of HFOs may be considered a problem.

Are there any applications that could be left out unintentionally? There are numerous types of commercial small hermetic system that are not covered by the current Annex III description. It is important to have a “wide scope” HFC ban related to all hermetic systems, otherwise the exclusion of hermetic systems from the pre-charge ban in Article 12 could encourage people to import small hermetic systems where non-hermetic equipment is more efficient.

5.2 Commercial Small Condensing Units (4% of 2010 HFC Demand)

Small condensing units are used for a range of different commercial applications. They are all based on “split system” refrigeration, with an evaporator located where cooling is required, connected to a “condensing unit” that includes a compressor and condenser. This is often located outdoors or in a well ventilated machinery room. Most systems use about 3 to 10 kg of refrigerant (although up to 30 kg is used in some applications). The condensing unit is factory built, but not usually pre-charged. Interconnecting pipework is always fitted during installation. The most common applications include retail display cases, walk-in cold rooms and beer cellar coolers. Some “grey area commercial applications” include milk coolers on farms and mortuary coolers.

Current refrigerants: Widespread use of HFC 404A (>50% of all new systems). Some use of HFC 134a. Growing use of HFC 407A or HFC 407F in place of R404A.

Very low GWP Alternatives: This is an undeveloped market at present. It is unlikely that very low GWP alternatives (i.e. with GWP < 10) will be usable in this sector if energy efficiency and cost are taken into account. Almost all systems are too big for safe use of HCs. Pure HFOs may be appropriate for MT systems, but are expected to be unsuitable for LT systems. There is no published data from HFO trials carried out in this sub-sector. CO₂ is feasible, but a cost effective and energy efficient system has not yet been demonstrated in Northern EU. CO₂ would not be applicable in Southern EU on efficiency grounds (it is not cost effective to consider a CO₂ cascade system for small condensing units). Ammonia would be too expensive for such small systems (due to costs of complying with safety regulations).

Impact of proposed service ban on new equipment: There is a de facto ban on R404A for all new systems above the size threshold for the service ban from 2014 (assuming new Regulation agreed by January 2014). Most R404A systems in this sector are above 5 tonnes CO₂ but most are below 50 tonnes CO₂. Assuming the service ban threshold is raised to 50 tonnes CO₂ (as we have recommended) then there could be continued use of R404A for new systems in this market. There are already reasonable alternatives to R404A for all new systems in all EU geographic regions – hence an explicit ban on new R404A systems, from 2015, would be worth considering.

Is a ban suitable for new equipment? No, particularly if a ban at a GWP threshold of 150 is being considered. A ban above GWP 700 is feasible for parts of the market that can tolerate mildly flammable refrigerants – this may be the case for the small end of the size range in this market. Mildly flammable refrigerants such as L40 or DR7 are currently being developed – these have properties similar to R404A, with GWPs in the 250 to 350 region. Also, R32 (mildly flammable, GWP 675) can be considered. When new safety codes for A2L mildly flammable refrigerants are finalised it may be possible to safely use these refrigerants with charges of up to around 10 kg in a wide range of locations – that could include a significant proportion of this market. However, mild flammability may not be acceptable for some applications of small condensing units and the safety codes have not yet been agreed. National fire regulations in some Member States would prevent the use of mildly flammable refrigerants even in small quantities. Options for non-flammable alternatives have higher GWPs. For LT systems the lowest GWPs for non-flammable refrigerants based on HFO blends are expected to be in the range 1200 to 1400 (N40 and DR33). For MT systems a non-flammable refrigerant with a GWP of 600 to 700 may become available (e.g. N13 and XP10). A ban on R404A (and other refrigerants with GWP above 3500) for new systems could be applied to the whole of this sector from 2015.

Are there any “difficult” applications? Yes. As discussed above, there are no very low GWP refrigerants suitable for the whole EU. CO₂ may be a future possibility for cool climates but is definitely not suited to hot climates. If non-flammable refrigerants are required there are currently no solutions on the horizon for LT systems with a GWP below 1200 or for MT systems below 600. If mildly flammable refrigerants can be tolerated they could be used for a significant part of this market, but it may be difficult to create simple wording for a ban that covers part of a market with so many variables in terms of size and application area.

Are there any applications that could be left out unintentionally? As with small commercial hermetic, this market subsector contains quite a number of applications that do not fit in other market sectors e.g. milk coolers on farms and mortuary coolers. It may be worthwhile to have discussions with stakeholders to identify further “unusual” applications in this sector.

5.3 Commercial Multipack Central Systems (33% of 2010 HFC Demand)

Multipack central systems are used in medium and large sized supermarkets. A “pack” consisting of compressors and various other components is located in a back of store machinery room or outdoors. It is connected to a number of retail display cases and sometimes to walk-in cold rooms. It is also connected to an air cooled condenser system located outside, often on a roof. Large supermarkets often have at least 4 separate packs, 2 for LT loads and 2 for MT loads. Typical pack systems contain between 100 kg and 200 kg of refrigerant.

This market is of particular importance as it represents a significant proportion of current HFC use, due to the use of R404A (with a very high GWP of 3,922) and high rates of leakage.

Current refrigerants: Dominant use of HFC 404A (90% of existing systems). Some use of HFC 134a for MT applications. Growing use of HFC 407A or HFC 407F in place of R404A, both in new systems

and retrofilled into existing systems. Rapid growth in use of CO₂, especially in Northern EU. Some use of HC integrals (hermetically sealed systems) combined with chilled water systems.

Very low GWP Alternatives: There are rapid developments of very low GWP refrigerants in this market subsector. CO₂ is being widely used in new systems by a number of major supermarket companies. CO₂ can be used either as a transcritical system or a subcritical system linked in cascade to an MT system that operates on a more conventional refrigerant (including HCs or HFOs). Transcritical systems are suited to low ambient temperatures (i.e. Northern EU). For efficient use in warm climates the subcritical cascade system must be considered. For large pack systems the extra complexity and cost of a cascade system can be justified to provide a very low GWP option in Southern EU (unlike in the single condensing unit sector where a cascade system would be much too costly). HCs are also being used, either in the form of small integral systems in each display case or for chillers associated with cascade CO₂ systems and integral HC systems. HFO 1234ze could also become an important option for such chillers.

Impact of proposed service ban on new equipment: There is a de facto ban on R404A for all new systems above size threshold for service ban from 2014 (assuming new Regulation agreed by January 2014). All R404A systems in this sector are well above 50 tonnes CO₂ so there should be an immediate stop to the use of R404A in new systems (indeed, the threat of the service ban in the Commission proposal is already beginning to have this effect).

Is a ban suitable for new equipment? Yes, for large sized pack systems. Given the amount of voluntary activity related to CO₂ in supermarkets, it is possible to envisage a ban with a GWP threshold of <10 for all new systems from around 2020. Three key issues that have not been adequately addressed are:

- Energy efficiency – it is vital that CO₂ systems can be at least as efficient as the best HFC options. Early evidence is positive, especially if subcritical designs can be produced at reasonable cost for Southern EU applications.
- Capital cost and component availability – costs are still high compared to HFC systems, although with higher volumes the cost difference should reduce. Components are not yet available in the full range of sizes and types required – again this should improve with volume of sales.
- Reliability and maintenance – CO₂ is a difficult refrigerant to use because operating pressures are high and most maintenance contractors are unfamiliar with the technology. There is some evidence that current new systems leak very badly. Although that is not a significant problem in terms of GHG emissions (as the GWP is 1) it is a major risk in terms of reliability and availability of suitably skilled technicians.

Issues such as those above must be addressed before CO₂ can be cost effectively used across all regions of the EU. It is worth considering whether a higher GWP threshold would allow more flexibility i.e. would allow the use of low / moderate GWP refrigerants in parts of this market not well suited to CO₂. It is reasonable to assume that non-flammable refrigerants are required – the refrigerant quantities in pack systems are too high to allow use of mildly flammable refrigerants. Unfortunately, for LT applications this might require an HFO / HFC blend with a GWP of at least 1200. For MT applications there may be non-flammable HFO / HFC blend with a GWP of around 600.

Are there any “difficult” applications? No. This is a fairly homogeneous market subsector. Southern EU is more difficult in commercial terms (i.e. they cannot so easily afford extra costs and there is very little skill base available). However, given that cascade systems will operate efficiently in Southern EU there is a technical solution available that should be reasonably mature by 2020.

However, it is worth noting that although most supermarket buildings are purpose-built, some town-centre retail outlets are located in legacy buildings. In these cases, the options for locating the refrigeration systems are often very limited, e.g. sometimes the compressor systems are located in the basement. It would be difficult to use flammable refrigerants in these applications.

Are there any applications that could be left out unintentionally? No. This is a well defined and fairly homogeneous market subsector.

Transport Refrigeration (1.4% of 2010 HFC Demand)

This market sector includes:

- Refrigerated vans, lorries and trailers
- Refrigerated containers
- Larger refrigeration systems in ships and in trains

The SKM Refrigerants Model does not provide any details about use of refrigeration in ships or trains. Ship based refrigeration systems are similar to industrial applications and could be considered with them, taking into account the unusual location of equipment that will make use of flammable refrigerants difficult. There are very few train based systems (other than refrigerated containers that are transported by train).

The refrigerated road transport and container sector is an important market, although it only represents 1.4% of EU HFC demand. Most systems contain between 2 and 10 kg of refrigerant. Vans and small lorries have a refrigeration unit that is directly powered by the main vehicle engine. Large lorries, trailers and containers have a separate refrigeration unit that includes a small diesel engine.

Current refrigerants: Dominant use of HFC 404A (90% of existing systems). Some use of HFC 134a for MT applications.

Very low GWP Alternatives: Some manufacturers are carrying out trials with CO₂.

Impact of proposed service ban on new equipment: With current 5 tonnes CO₂ threshold transport systems would be affected by the service ban. However, this is the sector for which retrofit would be most problematic and we have recommended it is excluded from the service ban (either by raising the threshold to 50 tonnes or by restricting the ban to stationary systems). Assuming this exclusion goes ahead there is currently no incentive to move away from R404A apart from the phase down. An explicit R404A ban for new systems from around 2020 may be worth consideration. Note: this is the only sector for which a very early R404A ban (e.g. from 2015) for new systems is not a good option. In stationary refrigeration sectors refrigerants such as R407A and R407F are already available or close to commercialisation in all relevant applications. In transport refrigeration it is believed that there are no R404A alternatives that are close to commercialisation.

Is a ban suitable for new equipment? Not at this time for a low GWP threshold. The results from CO₂ trials will not be available for a few years so it is not appropriate to agree a ban until it can be shown that CO₂ is energy efficient and practical. Mildly flammable refrigerants may be deemed unsuitable in this sector because of strict transport fire regulations (e.g. in case a truck is stuck in a tunnel). If CO₂ is not suitable then this sector might require a non-flammable refrigerant with characteristics similar to R404A. R407A and R407F may be suitable, although early trials by some manufacturers are not conclusive. HFO / HFC blends such as N40 and DR 33 may become suitable – but these have GWPs in the 1200 to 1400 range.

Are there any “difficult” applications? Large lorries and containers need to be able to operate in a wide range of climate conditions and may need to operate at either MT or LT conditions. This makes design of efficient and reliable transport systems challenging.

Are there any applications that could be left out unintentionally? No. This is a well defined and fairly homogeneous market subsector.

Industrial Refrigeration (12.2% of 2010 HFC Demand)

The industrial sector encompasses a complex mixture of systems that are used in very varied circumstances. The industrial market is the least homogeneous of the 7 main RAC market sectors.

A key advantage in this market is that personnel access to refrigeration systems and areas being cooled is almost always restricted. The EN 378 safety regulations allow much higher charges of flammable or toxic refrigerants when personnel access is restricted. However, this advantage is offset by the wide range of different applications that could make a ban definition difficult. Key variables in the industrial sector include:

- a) **Size.** Many systems are quite small (e.g. 10 to 50 kg refrigerant). However, the largest systems can contain over 10,000 kg.
- b) **Temperature level.** The range of operating temperatures is greater in the industrial market than other RAC markets. A significant proportion of the market does operate at “normal” MT and LT temperatures, similar to those required in retail. However, processing of frozen food requires lower temperatures than storage of food, so many industrial freezer plants operate 10 to 20 deg C colder than retail plants. Other sectors such as chemicals often require even lower temperatures, sometimes in the -50 to -100 °C range. Air liquefaction plants and certain specialist scientific applications require cryogenic systems that operate between -150°C and -270 °C.
- c) **Location and flammability risk.** Some plants are used in areas of high risk (e.g. oil platforms, oil refineries etc.) and this may add to the cost of using flammable or toxic refrigerants.

The SKM Refrigerants Model uses 10 different market sub-sectors for the industrial market. In the discussion below we have simplified this into 4 different groups of industrial equipment:

- Small and medium sized DX systems
- Large DX systems
- Industrial chillers
- Large flooded systems

7.1 Industrial Small and Medium Sized DX Systems (8% of 2010 HFC Demand)

This includes systems for process cooling and product storage. It represents the main use of HFCs in the industrial sector. Small systems are in the 10 to 50 kg size range and medium systems are 50 to 200 kg. In general terms these are systems that are too small for the cost effective use of ammonia.

Current refrigerants: Dominant use of HFC 404A. Some use of HFC 134a for MT applications. HCFC 22 is still used in some older systems.

Very low GWP Alternatives: Ammonia is technically feasible, but at such a small system size the cost penalties are usually significant. Very little ammonia is currently used. CO₂ is also feasible and has been used in a few applications. Technology transfer from the CO₂ experience being gained in the supermarket sector could help development of CO₂ in this market. Medium industrial DX systems are similar in size to supermarket pack systems. Pure HFOs may be applicable for some MT

applications, but appropriate HFO / HFC blends are likely to be more efficient and cost effective. HFC 32 might be applicable for some small / medium sized industrial DX systems, but there is little operating experience.

Impact of proposed service ban on new equipment: There is a de facto ban on R404A for all new systems above size threshold for service ban from 2014 (assuming new Regulation agreed by January 2014). All R404A systems in this sector are well above 50 tonnes CO₂ so there should be an immediate stop to the use of R404A in new systems (indeed, the threat of the service ban in the Commission proposal is already beginning to have this effect).

Is a ban suitable for new equipment? Not at this time. The market is too complex for a simple ban definition and there is insufficient experience regarding the use of CO₂ or mildly flammable refrigerants. The de facto R404A ban will create a shift to much lower GWPs. Some encouragement of very low GWP systems such as CO₂ would be beneficial, but a broad ranging ban applied to small industrial systems is not appropriate.

Are there any “difficult” applications? As discussed above, this is a very complex market, with unusual applications in a wide range of different industry sectors. Extreme low temperature systems will create some difficulties for system designers. There are overlaps with “commercial” sectors. For example ice rinks and cold stores use industrial type equipment in a commercial environment.

Are there any applications that could be left out unintentionally? Yes. Due to the complexity of the sector it would be easy to include or exclude systems unintentionally.

7.2 Industrial Large Sized DX Systems (3% of 2010 HFC Demand)

This market subsector comprises larger versions of the type of systems discussed in 7.1 above. Typical refrigerant charge is in the range from 250 to 750 kg.

Current refrigerants: Dominant use of HFC 404A. Some use of HFC 134a for MT applications. Ammonia used in a small proportion of installations. HCFC 22 is still used in some older systems.

Very low GWP Alternatives: Ammonia is technically feasible, and is cost effective for some large systems. CO₂ is also feasible and has been used in a few applications. Technology transfer from the CO₂ experience being gained in the supermarket sector could help development of CO₂ in this market. Large industrial DX systems are larger in size to supermarket pack systems. Pure HFOs may be applicable for some MT applications, but appropriate HFO / HFC blends are likely to be more efficient and cost effective. HFC 32 might be applicable for some large industrial DX systems, but there is little operating experience.

Impact of proposed service ban on new equipment: There is a de facto ban on R404A for all new systems above size threshold for service ban from 2014 (assuming new Regulation agreed by January 2014). All R404A systems in this sector are well above 50 tonnes CO₂ so there should be an immediate stop to the use of R404A in new systems.

Is a ban suitable for new equipment? Perhaps. In large sizes ammonia and CO₂ are both good candidates. The main barrier is the complexity of the market and the need to ensure that difficult applications can be dealt with. The de facto R404A ban will create a shift to much lower GWPs. Some encouragement of very low GWP systems such as CO₂ would be beneficial, but a broad ranging ban applied to small industrial systems is not appropriate.

Are there any “difficult” applications? As discussed above, this is a very complex market, with unusual applications in a wide range of different industry sectors. Extreme low temperature systems will create some difficulties for system designers. There are overlaps with “commercial” sectors. For example ice rinks and cold stores use industrial type equipment in a commercial environment.

Are there any applications that could be left out unintentionally? Yes. Due to the complexity of the sector it would be easy to include or exclude systems unintentionally.

7.3 Industrial Chillers (1% of 2010 HFC Demand)

This market subsector comprises medium and large sized chillers used to produce a chilled secondary refrigerant (typically water or glycol) which is pumped to a range of end use cooling loads. Typical refrigerant charge is in the range from 50 to 500 kg.

Current refrigerants: HFC 134a and ammonia are the most common refrigerants. HFC 410A is used in some small systems. HCFC 22 is still used in some older systems.

Very low GWP Alternatives: Ammonia is a good option for many larger chillers. HFO 1234ze is undergoing trials for both medium and large chiller sizes and looks a promising alternative to HFC 134a. DR 2 is under development and can be used in low pressure centrifugal chillers (it has similar characteristics to CFC 11).

Impact of proposed service ban on new equipment: None in this sector as R404A is not used for chillers..

Is a ban suitable for new equipment? Yes for larger chillers. A GWP threshold of <10 is possible from around 2020. Ammonia or HFO 1234ze are most promising options. Further research may be required to select a suitable threshold for “large” industrial chillers.

For medium and small chillers a very low GWP threshold is more problematic – ammonia will be too expensive and it is not clear how effective HFO 1234ze will be for small chillers. Mildly flammable refrigerants may be acceptable in the majority of industrial chiller applications. Some HFO / HFC blends may become available to suit small industrial chillers e.g. DR 3, a mildly flammable refrigerant with a GWP of around 150 and properties similar to R22. If non-flammable refrigerants are required HFO / HFC blends such as N13 and XP10 may be suitable – with GWPs in the 600 to 700 region.

Are there any “difficult” applications? No, this is a reasonably homogeneous market. The key issues are size and the acceptability of mildly flammable refrigerants. The most difficult applications are small / medium sized chillers that cannot use a mildly flammable refrigerant.

Are there any applications that could be left out unintentionally? No.

7.4 Industrial Large Flooded Systems (0.1% of 2010 HFC Demand)

This market subsector comprises large flooded systems, usually with pumped circulation, used for large processing applications (e.g. blast freezers) and for large cold stores. Typical refrigerant charge is in the range from 1,000 to 5,000 kg. This market only represents a small proportion of HFC usage as most HFCs are not well suited to flooded applications.

Current refrigerants: Ammonia is dominant for both MT and LT systems. Historically R22 was used in many LT and MT installations – some of which is still in use and will need replacement or retrofit by 2015. HFC 134a is used in some MT systems but is not suited to LT. HFC 507 has been used in a few LT systems where safety characteristics of ammonia are unsuited to the location.

Very low GWP Alternatives: Ammonia is already dominant and can probably be used in a wider range of applications at reasonable cost. CO₂ is an interesting possibility and has been piloted in a few installations (e.g. cold stores). HCs are not suitable because of high flammability and it is unlikely that pure HFOs would be used in such large quantities (on cost grounds, and HFOs only conceivable for MT applications).

Impact of proposed service ban on new equipment: The service ban would immediately stop any further investment in R507 systems. R404A is not used in flooded systems because of relatively high temperature glide.

Is a ban suitable for new equipment? Yes. Most applications can use ammonia or CO₂. A GWP threshold of <10 is feasible from relatively early e.g. 2016.

Are there any “difficult” applications? There could be some difficult applications. Key issues are extreme LT systems (ammonia is not suitable below -50°C) and situations where safety issues prevent use of ammonia (e.g. oil platforms). There may need to be an exemption for such situations.

Are there any applications that could be left out unintentionally? No.

Stationary AC and Heat Pumps (23.3% of 2010 HFC Demand)

This is a large and rapidly growing part of the RAC market. It includes various types of small and medium sized air-conditioning systems in which the primary refrigerant is used directly to cool the occupied space (or in a duct in the ventilation system feeding an occupied space). Systems based on chillers and secondary chilled water loops are dealt with separately in Section 8.

Many of the systems in this market sector are “reversible” units, which operate as air-conditioning systems in summer and can be used as air-source heat pumps in winter. In many applications the market for cooling only systems is becoming obsolete – the majority of new systems are reversible.

The SKM Refrigerants Model uses 11 different market sub-sectors for the stationary air-conditioning and heat pump market. In the discussion below we have simplified this into 4 different groups of air-conditioning equipment:

- Small portable units, cooling only
- Small, medium and large split systems
- Packaged systems
- VRF systems

8.1 Small portable units, cooling only (1.1% of 2010 HFC Demand)

This market subsector comprises small hermetically sealed portable air-conditioning systems. Typical HFC systems have a refrigerant charge of 0.5 kg. Most are imported pre-charged in to the EU

Current refrigerants: HFC 410A is dominant for all new systems.

Very low GWP Alternatives: HCs can be safely used in this type of system. The HC charge required is much lower than for HFC systems – hence these systems will typically contain 250 g of refrigerant.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? Yes. The current Annex II proposal is reasonable (no HFCs with GWP >150 from 2020).

Are there any “difficult” applications? No.

Are there any applications that could be left out unintentionally? No.

8.2 Split Systems (20% of 2010 HFC Demand)

This is a very important and growing market sector. Single split systems consist of an outdoor unit, including compressor, air cooled condenser and system controls connected by site assembled

pipework to a single indoor unit. Multi-split systems may have one outdoor unit connected to several separate indoor units. Small systems are all single splits and have a refrigerant charge of 1 to 2 kg. Medium systems are usually single and have a refrigerant charge between 2 and 4 kg. Large systems are often multi-split and have refrigerant charge between 4 and 10 kg. Most split systems are imported pre-charged in to the EU

Current refrigerants: HFC 410A is dominant for all new systems.

Very low GWP Alternatives: There are no very low GWP refrigerants suited to this market. The refrigerant charge required makes HCs unsafe in many applications. Ammonia and CO₂ are unsuited on cost and efficiency grounds. Pure HFOs are not suitable because of the large compressor size required.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? Not with a GWP < 150. However, this market may be suited to a ban with a GWP set at around 700. R32 is already being marketed by one of the major air-conditioning manufacturers. R32 has a GWP of 675 and is mildly flammable. HFO / HFC blends aimed at this market have recently been announced with GWPs in the 500 to 600 region (L41 and DR 5). These probably consist mainly of R32 with a small proportion of an HFO. They are mildly flammable. In the majority of installations of small split systems the draft EN 378 Regulation would allow sufficient mildly flammable refrigerant to be safely used. Hence a ban in this market with a GWP threshold of 700, starting around 2010 is worthy of consideration. It has been claimed that R32 is more energy efficient than R410A, so there could be strong drivers to move to R32 or the proposed HFO / HFC blends that might compete with R32.

Are there any “difficult” applications? Yes, if mildly flammable is a problem. The maximum amount of R32 allowed for floor mounted coolers is about 30% of the amount allowed for ceiling mounted units. In a small room with a big cooling requirement (e.g. a computer server room) the use of mildly flammable split systems may be problematic, especially if the cooler is floor mounted. In some Member States the current national fire regulations will not allow mildly flammable refrigerants in certain locations (e.g. areas with public access such as shops, hotels etc.).

Are there any applications that could be left out unintentionally? No.

8.3 Packaged Systems (0.4% of 2010 HFC Demand)

This type of system includes rooftop mounted systems with a cooling coil fitted in ventilation ductwork to cool air that is being circulated round a mechanically ventilated building. Typical packaged systems have a refrigerant charge in the 15 to 30 kg range.

Current refrigerants: HFC 410A and to a smaller extent R407C are used in new systems.

Very low GWP Alternatives: There are no very low GWP refrigerants suited to this market. The refrigerant charge required makes HCs unsafe in all applications. Ammonia and CO₂ are unsuited on cost and efficiency grounds. Pure HFOs are not suitable because of the large compressor size required.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? Not with a GWP < 150. The typical charge required is above the safety limit for mildly flammable refrigerants using Method C3 in EN 378 (11 kg for R32). However, method C4 may be appropriate in some circumstances – this requires further research. If method C4 is applicable then a ban set at GWP < 700 from around 2020 might be applicable.

Are there any “difficult” applications? Yes, if mildly flammable is a problem.

Are there any applications that could be left out unintentionally? No.

8.4 VRF Systems (2% of 2010 HFC Demand)

This type of system consists of outdoor units connected to a number of indoor units. Typical VRF systems have a refrigerant charge in the 20 to 40 kg range.

Current refrigerants: HFC 410A and to a smaller extent R407C are used in new systems.

Very low GWP Alternatives: There are no very low GWP refrigerants suited to this market. The refrigerant charge required makes HCs unsafe in all applications. Ammonia and CO₂ are unsuited on cost and efficiency grounds. Pure HFOs are not suitable because of the large compressor size required.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? Not with a GWP < 150. The typical charge required is above the safety limit for mildly flammable refrigerants using Method C3 in EN 378 (11 kg for R32). However, method C4 may be appropriate in some circumstances – this requires further research. If method C4 is applicable then a ban set at GWP < 700 from around 2020 might be applicable.

Are there any “difficult” applications? Yes, if mildly flammable is a problem.

Are there any applications that could be left out unintentionally? No.

Chillers and Hydronic Heat Pumps (10% of 2010 HFC Demand)

This sector mainly consists of water chiller systems that are used to provide chilled water to for large building cooling systems. It also includes domestic heat pumps that provide heat to hydronic (hot water) heating systems and larger hydronic heat pumps

The SKM Refrigerants Model uses 10 different market sub-sectors for the stationary air-conditioning and heat pump market. In the discussion below we have simplified this into 4 different groups of air-conditioning equipment:

- Small and medium chillers
- Large and very large chillers
- Domestic heat pumps
- Larger heat pumps and reversible chiller/heat pumps

9.1 Small and medium chillers, cooling only (6% of 2010 HFC Demand)

This market subsector comprises air cooled and water cooled chillers with refrigerant charge in the range 20 to 200 kg.

Current refrigerants: HFC 410A is used in most smaller systems. HFC 134a used for larger equipment.

Very low GWP Alternatives: The options for low GWP refrigerants depend on the location of the chiller. If it is in a separate machinery room that can be fitted with suitable safety systems, the HCs can be considered for small chillers. HFO 1234ze is currently being trialled and may be suitable for medium sized chillers.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? Yes, in some circumstances. Mildly flammable refrigerants might be safe to use for a wide range of chiller locations. For medium sized systems a low GWP threshold may be possible, if pure HFOs are proved to be suitable. For small chillers R32 is likely to be an efficient alternative to R410A and certain mildly flammable HFO / HFC blends may also be cost effective and efficient, for example DR3, DR5 or L41. A GWP threshold of 700 would allow use of these refrigerants.

Are there any “difficult” applications? Yes, where the chiller location makes it difficult to use a mildly flammable refrigerant (e.g. in a basement).

Are there any applications that could be left out unintentionally? No.

9.2 Large and very large chillers, cooling only (1.5% of 2010 HFC Demand)

This market subsector comprises air cooled and water cooled chillers with refrigerant charge in the range 200 to 1,000 kg.

Current refrigerants: HFC 134a is used for all very large chillers (centrifugal) and most large chillers (screw).

Very low GWP Alternatives: HFO 1234ze is currently being trialled and may be suitable for most large sized chillers. DR 2 (GWP 10) has been announced as a possible low pressure replacement for R11. Ammonia is technically feasible but not usually cost effective compared to HFC chillers in the building air-conditioning market.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? Yes, if HFO trials are successful. If HFOs can be shown to be efficient and cost effective in large and very large chillers then a ban with a GWP threshold <20 may be possible by around 2020.

Are there any “difficult” applications? Yes, where the chiller location makes it difficult to use a mildly flammable refrigerant (e.g. in a basement).

Are there any applications that could be left out unintentionally? No.

9.3 Domestic Hydronic Heat Pumps (1.5% of 2010 HFC Demand)

This market subsector comprises small air source heat pumps providing hot water for domestic space heating. Most systems are factory built standalone units that are located in an outdoor enclosure. Typical refrigerant charge is 3 to 5 kg.

Current refrigerants: HFC 410A.

Very low GWP Alternatives: There are no very low GWP refrigerants suited to this market. The refrigerant charge required makes HCs unsafe in all applications. Ammonia and CO₂ are unsuited on cost and efficiency grounds. Pure HFOs are not suitable because of the large compressor size.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? No, not at very low GWP. Mildly flammable refrigerants could be used for most systems, especially in outdoor locations. R32 is likely to be an efficient alternative to R410A and certain mildly flammable HFO / HFC blends may also be cost effective and efficient, for example DR3, DR5 or L41. A GWP threshold of 700 would allow use of these refrigerants.

Are there any “difficult” applications? No, unless mildly flammable is unacceptable.

Are there any applications that could be left out unintentionally? No.

9.3 Other Hydronic Heat Pumps and Reversible Chillers (1.1% of 2010 HFC Demand)

This market subsector comprises heating only air to water heat pumps and reversible systems (air to water heat pump or air cooled water chiller). Typical refrigerant charge is the range 20 to 200 kg.

Current refrigerants: HFC 410A and HFC 134a.

Very low GWP Alternatives: There are no very low GWP refrigerants suited to this market. The refrigerant charge required makes HCs unsafe in all applications. Ammonia and CO₂ are usually unsuited on cost and efficiency grounds (although ammonia is possible at very large sizes). Pure HFOs are not suitable because of the large compressor size.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? No, not at very low GWP. Mildly flammable refrigerants may be suitable in a significant proportion of locations. R32 is likely to be an efficient alternative to R410A and certain mildly flammable HFO / HFC blends may also be cost effective and efficient, for example DR3, DR5 or L41. A GWP threshold of 700 would allow use of these refrigerants.

Are there any "difficult" applications? Yes, where the heat pump location makes it difficult to use a mildly flammable refrigerant.

Are there any applications that could be left out unintentionally? No.

Mobile Air-conditioning (16.4% of 2010 HFC Demand)

This market sector includes cars and light vans (that are covered by the MAC Directive and a range of larger vehicle air-conditioning systems including buses, trains and large industrial vehicles (e.g. cranes, tractors etc.).

10.1 Cars and Light Vans (10% of 2010 HFC Demand)

This important market subsector includes all car and light van air-conditioning systems. Typical refrigerant charge is the range 0.4 to 0.8 kg.

Current refrigerants: HFC 134a.

Very low GWP Alternatives: HFO 1234yf has been developed specifically to meet the requirements of car and van MAC systems. It is mildly flammable and had been shown to be safe for these applications, although recent problems created by Daimler have cast some doubt on this. CO₂ pilot trials in the period 2007 to 2009 showed that CO₂ is a viable alternative, although development of CO₂ systems was halted when HFO 1234yf was chosen by the majority of the car industry.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? Yes. This is already required via the MAC Directive.

Are there any "difficult" applications? No, unless the safety concerns raised by Daimler cannot be sorted out.

Are there any applications that could be left out unintentionally? No.

10.2 Large Vehicle MACs (7% of 2010 HFC Demand)

This market subsector includes MACs used in large vehicles, especially buses and trains. Typical refrigerant charge is the range 10 to 20 kg.

Current refrigerants: HFC 134a and HFC 410A.

Very low GWP Alternatives: HFO 1234yf may be applicable, but more development is required to confirm this. CO₂ systems are also being considered. Ammonia and HCs are not suitable for safety reasons.

Impact of proposed service ban on new equipment: None.

Is a ban suitable for new equipment? No, not until further development work has been done.

Are there any “difficult” applications? Yes, safety Regulations may require a non-flammable refrigerant for many types of vehicle. If CO₂ can be used in an efficient and cost effective system this would be a good non-flammable option, but this has not yet been demonstrated. If a non-flammable HFO / HFC blend is required this is likely to have a GWP of at least 600.

Are there any applications that could be left out unintentionally? Yes, there are many different vehicle types that require air-conditioning. Some may operate in unusual circumstances that means that a “mainstream” option is not suitable (e.g. a vehicle used in a mine).