embraco

Nidec

Position Paper

Light Commercial Refrigeration

Refrigerants Outlook for Europe

2022

Content

Introduction

With the Kigali Amendment to the Montreal Protocol, the global community made another important step towards preserving our planet for future generations by reducing the CO2 emissions due to human activities. The global phase-down of HFCs in the refrigeration sector represents an important contribution to international climate change mitigation efforts. For many years, Embraco has been actively investing in this direction by developing and promoting hermetic compressors for use with low-atmospheric impact refrigerants on all continents. In addition to isobutane (R600a) in household appliances, significant progress has been made in integrating propane (R290) into light commercial plug-in systems as a natural alternative to R404A, as well as in the use of carbon dioxide in the supermarket sector. EU F-gas regulations impose a ban on high global warming potential (GWP) refrigerants in several categories of commercial applications over the years to gradually reduce direct impact due to HFC refrigerants. Several alternative synthetic refrigerants have been developed by the chemical industry and more are coming. Embraco has performed extensive tests to assess the capacity of these alternatives to replace high- GWP refrigerants presently in use. The biggest difficulty was found in trying to replace R404A. This paper will summarize current testing for R404A and R134a short and long term replacements, with a focus on reliability and performances as well as the evolution of related safety legislation.

Embraco Policy Statement

- Embraco will encourage the use of low GWP refrigerants to support global efforts to mitigate climate change.
- Embraco will continue to provide solutions to improve the energy efficiency of refrigeration equipment with low-GWP refrigerants.
- Embraco will support proactive use of natural refrigerants without compromising appliance safety.
- Embraco will continue to develop products for both natural and synthetic low-GWP refrigerants that exceed present and future energy efficiency standards in order to assure the competitiveness of our products and expectations of our end users.
- Embraco will continue to work with international legislative bodies on the safe use of low-GWP refrigerant options.

EU F-Gas Regulation

The European Union's F-gas regulations (517/2014) limit the use of refrigerants with high GWP values. The EU deadlines for use of refrigerant substances for different refrigeration segments are:

From January 1st, 2020

- Hermetically sealed systems that contains HFCs with GWP of 2500 or more (e.g. R404A, R507A) were banned in refrigerators and freezers used for storage, display or distribution of products in retail and food service (commercial use).
- Stationary refrigeration equipment that contains, or that relies upon for its functioning, HFCs with GWP of 2500 or more (except equipment intended for application designed to cool products to temperatures below -50°C) were banned.

From January 1st, 2022

- Hermetically sealed systems that contains HFCs with GWP of 150 or more (e.g. R134a R407F, R407C, R410A, R448A, R449A, R452A) are banned in refrigerators and freezers used for storage, display or distribution of products in retail and food service (commercial use).
- Use of refrigerants above 150 GWP but below 2500 GWP is still allowed for many applications categories (stationary refrigeration equipment) not covered by definition of refrigerators and freezer for commercial use. Their use is anyway subjected to the quota system provisions of F-Gas regulation.
- Use of refrigerants above 2500 GWP is only allowed for applications designed to cool product below -50 deg C
- Questions on the interpretation of this regulation can be addressed directly thru the European Commission (DG Clima) website or to major industry associations (e.g. ASERCOM, EPEE, AREA), and/or by contacting the national authority in charge of EU F-gas regulations.

Existing Systems Maintenance

From January 1, 2020 the use of F-gases with GWP of 2500 or more in refrigeration equipment with gas charge size exceeding 40 CO2 equiv (e.g., more than 10,2 kg of R404A) was banned. This does not include reclaimed or recycled refrigerants, which will be allowed until January 1, 2030.
For systems impacted by these service and maintenance bans there are two options: retrofit with gases with GWP lower than 2500 or replace them with new equipment that uses a lower GWP refrigerant.

EU F-Gas Regulation Update

EU F-gas regulation (517/2014) is presently under revision process to align it with raising ambitions of EU Green Deal. This update will include revision of the remaining HFC phase-down steps and plan of future HFC phase-down steps beyond reduction required by the Montreal Protocol. Proposal presented by DG Clima in 2021, will also include additional prohibitions in products and equipment where HFC are no longer needed. Among others for stationary AC and HP equipment and stationary refrigeration (small hermetic units for commercial and household use). Further prohibitions are expected in servicing and maintenance of refrigeration equipment. DG Clima proposal includes provisions for mandatory certification of technicians to include skills on the use of low-GWP alternatives and detailed rules to empower customs and surveillance authorities in the EU Member States and facilitate their use of the EU. Revised draft proposal is expected to be published in April 2022.

Quota System

EU F-gas regulations (517/2014) limit the sale and distribution of high-GWP gases under a quota allocation system (see Figure 1), leading to a declining supply and a significant increase in HFC prices (see Figure 2). The amounts of HFC gases available for all applications are limited based on GWP value (as of 2018, a reduction of 49% from 2015 usage - 87MM CO2 equiv) and industry has been forced to switch quickly to low-GWP alternatives.

Fig.1 HFC Phase Down Schedule (EU regulation 517/2014)

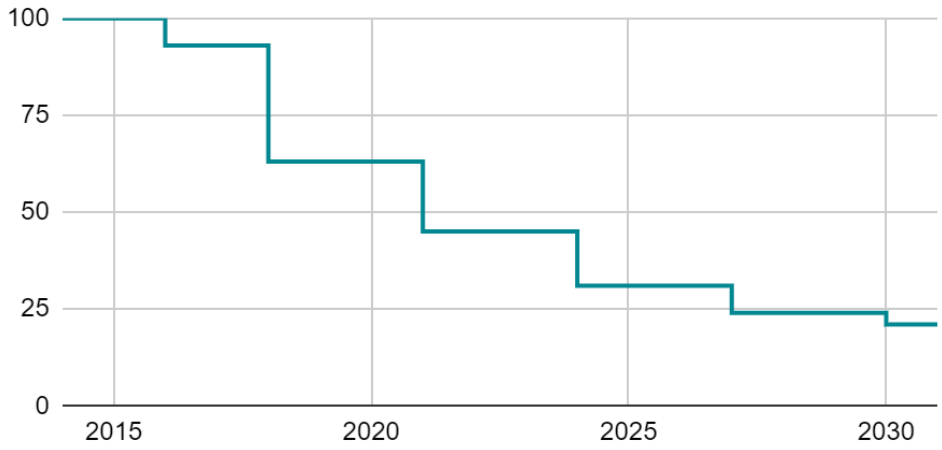
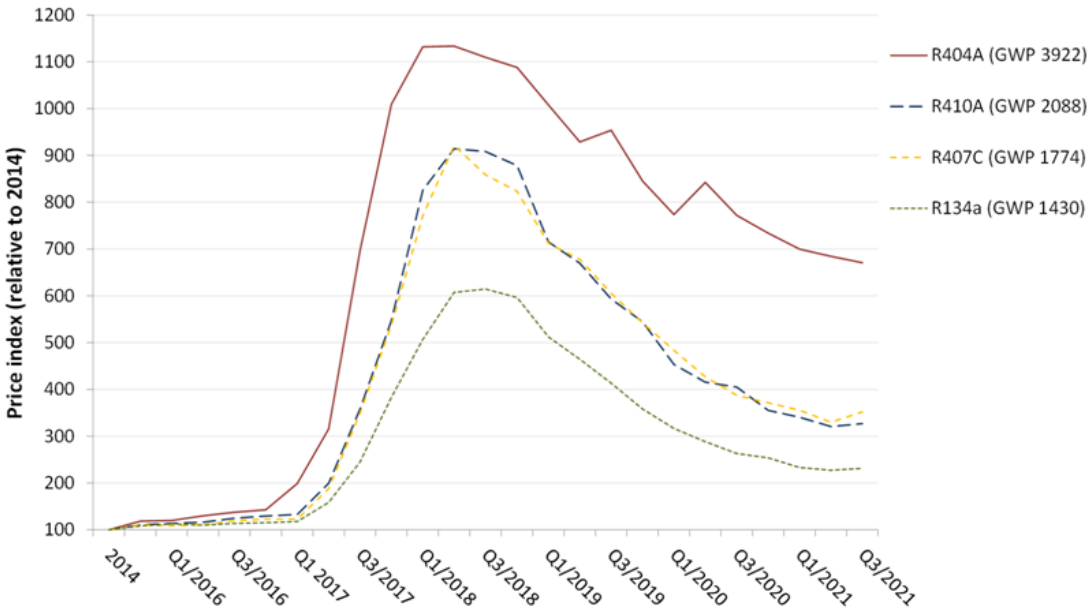


Fig.2 HFC Price Increases in the EU (2014 = 100%)



EU Safety Standards Update

In 2019 IEC standard used for commercial refrigerating appliances (IEC60335-2-89) was updated, raising the charge limit for flammable refrigerants: for propane up to approximately 500 g and up to 1,2 kg for A2L safety class flammable refrigerants per one circuit. This makes the transition of light commercial applications to low-GWP refrigerants much easier than with the previous 150 g limit. This new edition of the standard defines a series of specific additional measures needed to allow higher charge levels without increasing risk as set by the previous edition of the standard. The IEC standard is directly applicable in most of the world countries, but in Europe as in some other countries/regions, it has to be integrated into the local standardization system. CENELEC TC61 is in charge of publishing the EN version of the IEC standard. Proposed draft of EN 600335-2-89 standard was positively voted in 2021 and is expected to be published in 2022. Once published, then the standard must be included into the list of harmonized standards with EU Machine Directive (MD). Anyway, until when EU authorities will adopt recently approved new IEC global standard charge limit, it remains still at 150 g per circuit. In case of larger applications multi-circuit configuration is a feasible option. For systems not in the scope of EN 60335-2-89, the general standard EN 378-1 applies, with charge limits in function of system configuration, access category and room volume.

REACH Directive Update - PFAS

In 2020, 5 countries, Germany, the Netherlands, Norway, Sweden and Denmark agreed to prepare a joint REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) proposal restricting the use of PFAS. PFAS—Per- and Polyfluoroalkyl substances are a complex group of more than 5000 chemicals that have been linked to environmental contamination and negative health effects in humans. Most HFC Refrigerants (A1, A2L) can be affected by PFAS ban. Aim is to restrict all PFAS in non-essential uses. See below the timing of REACH Directive update.

Process Schedule

2021	2022	2023	2024	2025
Stakeholder Inquiry	Submissions of restrictions dossie	Final Recommendations	Final Draft	Entry in force Ban Dates To be Defined

Alternative Refrigerants for Commercial Refrigeration

Embraco offers products for the light commercial refrigeration segment that comply with EU F-gas regulations. This means compressors and condensing units for use with natural and with synthetic refrigerants below 150 GWP. Compressors for transition refrigerants (150<GWP<2500), that were used by the industry to convert their product portfolio into final low-GWP refrigerants by 2022 are still available. We recommend, if possible, going directly to the "future proof" refrigerants considering planned updates of EU F-Gas regulations. Every appliance producer has to make a choice: go natural or use one of the new synthetic blends presently available. Table 1 lists the main criteria that should be taken in consideration when making this decision:

Table 1 - Alternative Refrigerant Options

	High GWP HFCs	HCs	Low GWP HFCs
SAFETY CLASS	A1 Not Flammable	A3 Highly Flammable	A2L Slightly Flammable
ENVIRONMENTAL IMPACT	Very High	Ultra Low	Low
REFRIGERANT COST	Ref	Lower	Very High
COMPRESSOR THERMAL REGIME	Ref	Lower	Higher
INVESTMENTS FOR SAFETY	Ref	Yes	Yes
SYSTEM EFFICIENCY	Ref	Much Higher	Same
CHARGE LIMIT FOR SELF-CONTAINED HERMETICALLY SEALED SYSTEMS (IEC/EN)	No	IEC 13*LFL EN 150g	IEC 1,2kg EN 150 g

Hydrocarbons

PROPANE (R290)

Embraco offers a full product line of HC compressors as a future proof solution to meet EU F-gases regulation (up to 38 cc). Propane (R290) is already widely used on several commercial and air conditioning applications. Most of the existing light commercial applications can be designed for use of HC refrigerants with significant benefits in terms of system efficiency, cost, reliability and acoustic emissions. This is the reason why hydrocarbon compressors are already representing almost 70% of Embraco Nidec sales to European OEMs.

OTHER HYDROCARBONS: ISOBUTANE (R600a)

R600a - isobutane - represents a valid alternative solution for small appliances. It offers benefits in terms of efficiency but has significant limitations in terms of cooling capacity. Due to its low specific cooling capacity, it requires bigger compressor displacement compared to other refrigerants and consequently, a larger and heavier compressor frame. Isobutane's evaporating temperature range is also limited. The Embraco catalogue features a full range of products for both LBP and HBP applications, including small chest freezers, bottle coolers and wine coolers.

OTHER HYDROCARBONS: PROPYLENE (R1270)

Propylene has very similar properties to propane. Although slightly less efficient, it has the advantage of a higher specific cooling capacity. Therefore, propylene use must be limited to very specific situations. Its use can be approved in ad-hoc solutions for specific situations under the supervision of Embraco technical support.

Next Generation HFCs

R404A ALTERNATIVES

A series of new mixtures with GWP below than 150 are already available on the European market. All these candidates are mildly flammable and belong to the A2L classification with temperature glide up to 12 K. Tables 5 and 6 list some long-term alternatives to R404A. Embraco is offering compressor models approved for both R454C and R455A for MBP applications. Their use is still limited mainly to remote applications until the revision of the product safety standards, because with present limit of 150 grams of charge it's almost impossible today to design any type of refrigeration system falling under the scope of the -89 product standard using A2L class refrigerants. It is important to consider that refrigerants with significant glide have to be treated differently than in the past. A dew point pressure approach for cooling capacity and efficiency cannot be used to define actual system operating conditions; a mid-point approach, instead, should be used for more accurate estimation of product performances. Guidelines on how to define mid-point temperature are stated in standard EN 13215:2016+A1:2020 in Annex B, where linear and thermodynamic interpolations are described.

Table 2 - Alternative Blends Physical Data

	R404A	R455A	R454C
TYPE	HFC blend	HFC blend	HFC blend
SAFETY CLASS	A1	A2L	A2L
BOILING TEMP @ 1atm	-47°C	-52°C	-46°C
CRITICAL TEMP	72°C	83°C	82°C
GLIDE @1 bar (ABS)	0,8K	12,4K	8,2K

Table 3 - Embraco Evaluation Summary

	R 404A	R455A	R454C
GWP	3920	148	148
APPLICATION FIELD	L/MBP	L/MBP*	L/MBP*
CAPACITY	Ref	Lower	Lower
EFFICIENCY	Ref	Better	Better
RELIABILITY	Ref	Lower	Lower
LUBRICANT	POE	POE	POE
MOTOR TEMP	Ref	Higher	Higher
DISCHARGE TEMP	Ref	Higher	Higher

*With limited LBP envelope

R134a ALTERNATIVES

R1234yf is a valid alternative to replace R134a, and Embraco offers compressor models for this refrigerant in its catalogue, but nowadays its use is limited to very specific applications. R1234ze is not considered as a valid alternative to R134a for light commercial systems because of its low specific cooling capacity. Its use would require a completely new product line that, at this stage, does not seem to not be a solution for this market segment.

Table 4 - Alternative Blends Physical Data

	R 134a	R1234yf	R1234ze (E)
TYPE	HFC	HFC	HFC
SAFETY CLASS	A1	A2L	A2L
BOILING TEMP @ 1atm	-26°C	-30°C	-19°C
CRITICAL TEMP	101°C	95°C	110°C
GLIDE @1 bar (ABS)	0K	0K	0K

Table 5 - Embraco Evaluation Summary

	R 134a	R1234yf	R1234ze (E)
GWP	1430	Below 1	Below 1
APPLICATION FIELD	L/M/HBP	L/M/HBP	HBP
CAPACITY	Ref	Slightly Lower	Much Lower
EFFICIENCY	Ref	Lower	Lower
RELIABILITY	Ref	Same	NA
LUBRICANT	POE	POE	NA
MOTOR TEMP	Ref	Lower	NA
DISCHARGE TEMP	Ref	Lower	NA

NA – not available

HFC Transitional Solutions

R404A REPLACEMENT

To ease the transition to refrigerants that comply with target final GWP limits, the chemical industry offers several alternatives to existing high- GWP HFC refrigerants. The most notable intermediate refrigerant is HFC blends like R448A, R449A and R452A. They are all in safety class A1 (non-toxic, non-flammable) and are characterized by considerably higher temperature glide than R404A. Tables 6 and 7 outline Embraco's evaluation and the main physical proprieties of these blends. Their use from 1st of January 2022 is limited only for appliances falling under the definition of stationary refrigerating equipment of present European F-Gas regulation. Refrigerators and freezers for commercial use have to use refrigerants below 150 GWP.

Table 6 - Alternative Blends Physical Data

	R 404A	R448A	R449A	R452A
TYPE	HFC blend	HFC blend	HFC blend	HFC blend
SAFETY CLASS	A1	A1	A1	A1
BOILING TEMP @ 1atm	-47˚C	-45˚C	-46˚C	-47˚C
CRITICAL TEMP	72˚C	84˚C	82 ˚C	75˚C
GLIDE@ 1 bar (ABS)	0,8K	6,3K	6,1K	3,8K

Table 7 - Embraco Evaluation Summary

	R 404A	R448A	R449A	R452A
GWP	3920	1386	1397	2140
APPLICATION FIELD	L/MBP	L/MBP*	L/MBP*	L/MBP
CAPACITY	Ref	Better	Better	Same
EFFICIENCY	Ref	Better	Better	Same
RELIABILITY	Ref	Lower	Lower	Same
LUBRICANT	POE	POE	POE	POE
MOTOR TEMP	Ref	Higher	Higher	Same
DISCHARGE TEMP	Ref	Higher	Higher	Same

Compressor temperatures tend to increase when using R448A and R449A. Increased temperature can lead to motors overheating and/or overload protectors being tripped.

This leads to a reduction in reliability and life expectancy (see conclusion notes for their eventual use). R452A presents the same or lower thermal profile than R404A. R452A can be considered as an alternative for Embraco's R404A product line (ECN R452A 2016) with the same operating envelope of R404A in LBP and MBP applications. Both R448A and R449A were approved as an alternative refrigerants to R404A for NE/NT/NJ compressor series (ECN R449A 2018, and ECN R448A 2019 and ECN R448A/R449A LBP 2020), but only with a more restricted operating envelope than R404A due to the higher internal compressor thermal level. The restricted envelope for MBP R448A/R449A is presented in Figure 3 and LBP R448A/R449A in Figure 4. If an application is using an Embraco R404A compressor outside of this restricted envelope, please contact Technical Support for further instructions on how to adjust the thermal level of the compressor eg. by reducing return gas temperature. In addition, customers always have the option of converting systems from R404A to R134a during the transition period just by changing compressor models and relative system design adjustment. Significant increase of displacement in R134a replacement compressor must be considered.

Fig.3 - Restricted R448A/R449A

MBP Envelope (max. return 20°C)

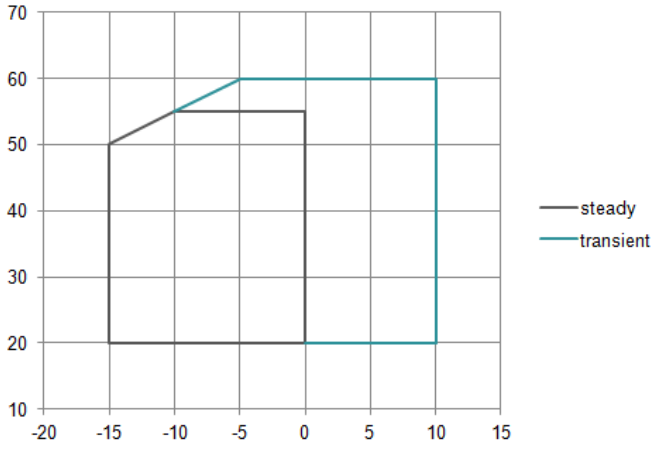
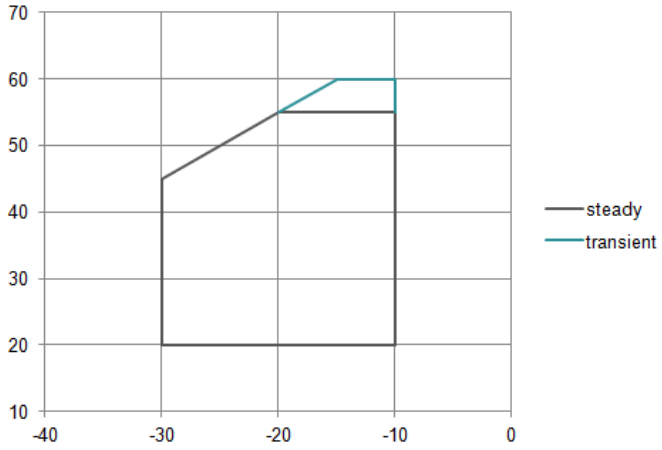


Fig.4 - Restricted R448A/R449A

LBP Envelope (max. superheat 10K)



R134a REPLACEMENT

The only reason to use the below mentioned R134a alternative blends during the transition period is because of their lower GWP allowing greater quantities under quota limitations and possible taxes reduction in some countries. Both R513A and R450A are approved for NB/NE/NT/NJ series (ECN R513A R450A 2017 and ECN CR/2966/en/18/10) as an alternative refrigerant for Embraco R134a models. Use of R450A and R513A, from 1st of January 2022, is limited only for appliances falling under the definition of stationary refrigerating equipment of present European F-Gas regulation. Refrigerators and freezers for commercial use have to use refrigerants below 150 GWP.

Table 8 - Alternative Blends Physical Data

	R134a	R450A	R513A
TYPE	HFC	HFC blend	HFC blend
SAFETY CLASS	A1	A1	A1
BOILING TEMP @ 1atm	-26°C	-24°C	-29°C
CRITICAL TEMP	101°C	106°C	98°C
GLIDE @ 1 bar (ABS)	0K	0,8K	0,8K

Table 9 - Embraco Evaluation Summary

	R134a	R450A	R513A
GWP	1430	605	631
APPLICATION FIELD	L/M/HBP	L/M/HBP	L/M/HBP
CAPACITY	Ref	Lower	Same
EFFICIENCY	Ref	Same	Same
RELIABILITY	Ref	Same	Same
LUBRICANT	POE	POE	POE
MOTOR TEMP	Ref	Same	Same
DISCHARGE TEMP	Ref	Same	Same

Warning

Warning Statement about Use of Flammable Refrigerants (A2L, A3) with Embraco Compressors approved for A1 Safety Class Refrigerants (R134a, R404A, etc.).

Embraco is currently producing hermetic compressors for use with A3 and A2L refrigerants to replace high-GWP HFCs. However, it is important to note that:

1. Embraco compressors designed and approved for non-flammable refrigerants (A1 class), cannot be used with any type of flammable refrigerants, including both A3 and A2L class refrigerants.
2. All Embraco products mentioned in the Declaration of Conformity are compliant with all relevant EU directives.
3. For refrigeration systems falling under the scope of the harmonized standard EN 60335-2-89, EU regulations allow the use of flammable refrigerants up to 150 g refrigerant charge for each single refrigeration circuit until the new IEC limit is adopted.
4. Given the above-mentioned charge limitations and considering that all flammable refrigerants require the same design, manufacturing and maintenance precautions, we strongly recommend the use of HC solutions wherever technically possible.
5. Embraco offers a full portfolio of compressor models for R290, the refrigerant considered the best option for both systems with a 150 g charge limit as well as those with the new IEC charge limit once the harmonized EU standards are approved.
6. Embraco declines any responsibility for compressors used without approved refrigerants (as listed above) and warns that potential reliability issues, such as motor overheating and electrical component malfunction, could occur following the use of unauthorized refrigerants.

Conclusions

Hydrocarbons (isobutane-R600a and propane-R290) represent the best long term (future proof) solution for both low and medium pressure light commercial self-contained applications. Incoming EU legislation will remove some of the existing roadblocks related to charge limits.

From 1st of January 2022, use of transitional blends (R448A, R449A, R452A, etc) is limited only to appliances falling under the definition of stationary refrigerating equipment of present European F-Gas regulation. Self-contained refrigerators and freezers for commercial use have to be charged with refrigerants below 150 GWP.

Transitional HFCs refrigerants can be still used only on appliances falling under the definition of stationary equipment by F-Gas rules. Among them, R452A can be used with specific Embraco R404A models as well as R448A and R449A within a restricted operating envelope. Refrigerants as R513A and R450A can be used as alternative to R134a in specific Embraco R134a series When using the blends mentioned above outside of Embraco approved system conditions, in order to maintain an Embraco warranty, the final application needs to be validated by the Embraco Technical Support Team on a case-by-case basis.

Table 10 – Summary Table Of Alternative Refrigerants

CURRENT REFRIGERANT	TEMPORARY SOLUTION		FUTURE PROOF SOLUTION	
	LBP	MBP	LBP	MBP
R404A / R507	R452A	R452A	R290	R290
	R134a	R134a	R455A	R455A
	R407C	R407C	R454C	R454C
	R448A*	R448A*	R1270	R1270
	R449A*	R449A*	R744	R744
	R407A	R407A		
	R407F	R407F		
R134a	R134a	R134a	R1234yf	R1234yf
	R513A**	R513A**	R600a	R600a
	R450A**	R450A**	R290	R290

* NE/NT/NJ restricted envelope

** Only NE/NT/NJ products

- Embraco Approved Refrigerant
- Please contact Technical Support

General Trends

Table 11: Light Commercial Segment from Embraco's Perspective