Green Refrigeration and Air Conditioning in the Hotel Sector

Achieving CO_2 neutrality and reducing energy costs

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Purpose of this guide

The main objective of this publication is to inform the hotel industry about environmentally, climate and ozone friendly technologies for Refrigeration and Air Conditioning (RAC) devices. Most of the green alternatives presented here are already available in several countries. By "green" technology, it is referred to devices or appliances that have zero impact on the ozone layer, ultra-low or zero Global Warming Potential (GWP below 10) and are also highly energy efficient. This guide aims to provide insights into which technologies are appropriate for which types of applications, taking into account system capabilities, final application, and other relevant considerations. The publication aims to show the way to achieve a large part of the decarbonization of this sector and the benefits of being carbon neutral organizations. It shows the influence of these technologies in the marketing of the organization, the decrease of energy costs and their compliance with respective national and international policies that will mark the future of the RAC sector in the tourism industry.

This publication is based on a previous publication on the RAC sector in the hotel industry in Costa Rica, dated August 2021, by the IKI project "Cool Contributions fighting Climate Change (C4)" and the EU/BMZ Project Sustainable and climate-friendly Phase-out of Ozone Depleting Substances (SPODS)", therefore numerous best practice examples of green RAC equipment from Costa Rica as well as specific country-based values (e.g. electricity costs/mix) are used for this publication.[1]

Proklima, a global program of the Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ (GmbH), has been working since 1996 on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) to provide technical and financial support to developing countries for the implementation of the provisions of the Montreal Protocol on Substances that deplete the Ozone Layer. Since 2008 it has also been working successfully on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) within the framework of its International Climate Initiative (IKI) promoting the dissemination of ozone- and climate-friendly technologies.[2]

1 GIZ2021_Refrigeracion_y_Aire_Acondicionado_verdes_en_sector_hotelero_in_Costa_Rica.pdf (green-cooling-initiative.org)
2 GIZ, n.d: Green Cooling Initiative.

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List of abbreviations

AC	Air Conditioning
BMUV	German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (German acronym BMUV)
BMZ	German Federal Ministry for Economic Cooperation and Development (German acronym BMZ)
BTU/h	British Thermal Unit per hour, used as an alternative to kW (1 kW = 3412.12 BTU/h).
C4	Cool Contributions fighting Climate Change
EU	European Union
CFCs	Chlorofluorocarbons
CO_2	Carbon dioxide
CO_2 eq.	Carbon dioxide equivalent (emissions sizing)
EER	Energy Efficiency Ratio
ESEER	European Seasonal Energy Efficiency Ratio
GCF	Green Climate Fund
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWP	Global Warming Potential
HCs	Hydrocarbons
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HFOs	Hydrofluoroolefin
IKI	International Climate Initiative (German acronym)
kW	Kilowatt (1 kW = 3412.12 BTU/h)
kWh	Kilowatt hour
NDC	Nationally Determined Contribution
NH_3	Ammonia
ODP	Ozone-Depletion Potential
ODS	Ozone Depleting Substances
PFAS	Per- and polyfluoroalkyl substances
RAC	Refrigeration and Air Conditioning
SDGs	Sustainable Development Goals
SEER	Seasonal Energy Efficiency Ratio
SPODS	Sustainable and climate-friendly Phase-out of Ozone-Depleting Substances
TFA	Trifluoroacetic acid

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Important Note

This publication provides examples of climate-friendly products. Although these products are mainly examples from Costa Rica it must be noted that the same or similar products can be found all over the world and in this publication only an excerpt is presented. Reference is also made to experiences and examples of the use of these technologies. Therefore, the case studies can be used as examples also for other countries if the electricity prices are adjusted accordingly. It does not favor any particular product and does not want to support any specific company, or disfavor or harm any product or company. It is emphasized that the examples shown are not unique, which means that there are probably many more products available that have similar specifications and use refrigerants and foaming agents with ultra-low GWP. Some products only use ultra-low-GWP refrigerants but contain Hydrofluorocarbon (HFC) based blowing agents for the insulation material. Therefore, these products are not included, unless there is no alternative, because they cannot be fully labeled as green products. According to our research, if only one company offers a specific green product, we could have used some product photos. Unfortunately, the scope of the publication does not allow a study that considers a larger number of companies and products and thus show a larger number of examples of applications. However, other cases, products, and equipment in the sector with "green" technology are known, just not at the level of detail required for this publication. Consequently, the product lists will only be used as examples of green products, and we strongly recommend anyone looking to purchase a green product to do their own research according to their specific requirements and application.

1 Introduction

In any location in the world, refrigeration equipment, air conditioning and insulation foams are essential to achieve and maintain an adequate level of climate control for various applications, from food storage to the comfort of people in a room. Refrigeration and Air Conditioning (RAC) technologies and insulation foams are responsible for a significant portion of the world's greenhouse gas (GHG) emissions, which are harmful to the climate.[3]

Air conditioning and refrigeration play an important role for most hotels, especially in the warmer regions of the planet. The second largest part of a hotel's energy consumption is due to cooling or climate conditioning devices. For this reason, the carbon footprint of the hotel sector is mainly composed of the direct and indirect emissions emitted by RAC equipment. Aiming for carbon neutrality by switching to better technologies for such equipment is therefore a strategic and necessary step for this sector. Hotel administrators should be wary of the equipment's energy efficiency, refrigerant and blowing agent. For most refrigeration systems there are green applications available.

The green RAC equipment that can help mitigate climate change is characterized by having zero impact on the ozone layer, ultra-low or zero GWP (Global Warming Potential) and a high energy efficiency. It is as well recommended for these technologies to be supplied by renewable sources of energy, reducing the impact of their use as most as possible.

Being a carbon neutral hotel company comes with several benefits. More and more hotels are striving to classify themselves as carbon neutral companies and/or businesses, since in today's market, being green gives a competitive edge to the brand of any company. Also, changing from conventional RAC equipment to green RAC equipment in a company means being truly sustainable and not applying harmful methods such as *greenwashing*.[4]

Today, the sustainability commitments of companies are important to the customer as environmental awareness in society is higher than ever and is expected to continue to increase. Therefore, sustainability and environmental awareness of businesses are going to be an essential criterion in the consumer's decision-making process.

A shift to sustainable green RAC technology generates a reduction in energy costs and, therefore, overall operating cost savings due to the increased efficiency. The inherent advantage of this transition is to have a business in balance with the environment and in tune with international goals towards sustainable development of society.

This publication aims to explain through examples why it is desirable to seek a carbon neutrality status and proposes ways to achieve it through the implementation of green RAC technologies. It seeks to demonstrate the importance of refrigerants and environmentally friendly technologies on a global scale, and to highlight the differences between the environmental and economic impacts of technologies in different types of equipment by comparing the various alternatives on the market. Thus, the publication provides guidance on the acquisition of refrigeration, freezing and air conditioning equipment.

Additionally, this publication focuses on aspects related to the final disposal, recycling or destruction of obsolete equipment, and the importance of dismantling old RAC units in accordance with international standards and their proper disposal.

3 GIZ, 2016: Advancing Nationally Determined Contributions (NDCs) through environmentally compatible refrigeration and air conditioning: Guidance for policymakers, p. 6.

4 Alejos Góngora, Claudia Lucía, 2013: Greenwashing: Being green or looking green.

2 Relevant policies

Several international commitments and agreements to promote the implementation of mitigation and adaptation measures in the face of climate change have been developed and agreed upon. The 2015 Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) is of particular importance because it succeeded in bringing all nations together in a common cause, based on the responsibilities that history, the present and the future demand of them.[5] The agreement aims to address climate change and promote actions and investments aimed at achieving a low-carbon future that is resilient and sustainable in the face of climate change. The implementation of the Paris Agreement is embodied by countries in the form of the Nationally Determined Contributions (NDCs). The NDCs are national plans that take actions towards energy efficiency and introduce guidelines for phasing out climate-damaging refrigerants.

The Paris Agreement is not the first international agreement to reduce society's environmental impact. The 1987 Montreal Protocol is an international initiative to protect the ozone layer, with the ultimate goal of eliminating several groups of substances that contribute to ozone depletion. In that course, the ozone depleting Hydrochlorofluorocarbons (HCFCs) have been phased out. The Montreal Protocol has been ratified by 197 countries, including the world's major economies.[6]

In 2016, the Kigali Amendment was ratified, an agreement by the countries participating in the Montreal Protocol to also phase out hydrofluorocarbons (HFCs) which are not ozone depleting but have a high GWP.[7] Many of the refrigerants currently used in RAC equipment still are HFC-based substances. A few still contain even HCFCs, which are already being actively phased out under the Montreal Protocol. The respective HFC phase-down schedule decided by the Kigali Amendment is adapted to different country categories (lines in different colors). Developing countries generally have less stringent requirements and more time to implement them (see Figure 1).[8]

5 UNFCCC, n.d.: What is the Paris Agreement?
6 International Actions - The Montreal Protocol on Substances that Deplete the Ozone Layer | US EPA
7 United Nations, n.d.: International Day for the Preservation of the Ozone Layer, September 16: Background.
8 DIGECA, n.d.: HFC Baseline and Reduction Schedule.

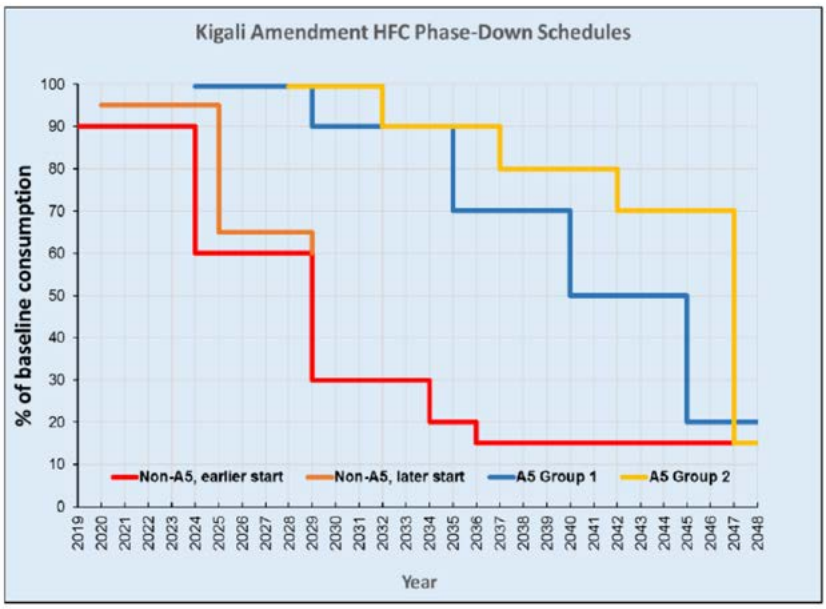


Figure 1: HFC phase-down schedule of the Kigali Amendment.[9]

The Sustainable Development Goals (SDGs), established in 2016 by the United Nations, are universal goals for the adoption of measures to end poverty, protect the planet and ensure peace and prosperity for all people.[10] Since the RAC sector is essential for achieving and maintaining a decent standard of living for people, especially in countries with high ambient temperatures, its use will continue to increase. Economic development of an area or a business sector is directly related to increased air conditioning and cooling of spaces. In addition, the effect of climate change and global warming will make the implementation of these technologies more necessary. In this sense, the RAC sector presents a variety of opportunities for supporting many of the Sustainable Development Goals.[11]

Like companies in other industries responsible for designing, implementing and maintaining air conditioning and refrigeration projects, the hotel industry must comply with these agreements. The earlier the change is made; the more benefits companies will have and the more likely they are to serve as role models.

9 Global Ratification Status of Kigali Amendment to Montreal Protocol Phasing Down HFCs – HFCBANS.COM.
10 THE 17 GOALS | Sustainable Development (un.org).
11 GIZ, 2016: Advancing Nationally Determined Contributions (NDCs) through environmentally compatible refrigeration and air conditioning: Guidance for policymakers, p. 7.

3 Green refrigerants

Carbon dioxide (CO_2), ammonia, water, air and hydrocarbons such as propane, isobutane and propene/propylene are green refrigerants that can be found in nature. These substances have zero ozone depletion potential (ODP) and an ultra-low or zero GWP, unlike the historically used refrigerants, CFCs, HCFCs, and HFCs. In addition, this type of refrigerants does not break down into trifluoroacetic acids (TFA), which are known for their rapid accummulation in water sources, soils, and living beings. HFOs, also a substance type considered to be a new alternative for the synthetic refrigerants, have shown to degrade or break down, completely in some cases (R1234yf), into TFA.

TFA is a chemical substance of type PFAS (Per- and polyfluoroalkyl substances), which are also known as "forever chemicals". The name was coined since they have an extremely long environmental half-life. They have shown to accumulate in humans, and in many living beings, to a degree that has raised alarms regarding its effects on human health.[12]

Natural refrigerants were the first substances to be used in RAC equipment around 1835. Due to their flammability, they were replaced by substances with lower flammability, like CFCs and HCFCs. At this time, it was assumed to be a good solution; however, these substances affected the ozone layer and caused further global warming. Under the Montreal Protocol, the ozone-depleting refrigerants have been largely phased out but many of the climate harmful substances are still in use today. Almost 200 years later, natural refrigerants are being used again because of their ultra-low GWP. They also do not damage the ozone layer, and with today's modern systems, flammability risks can be adequately mitigated.[13]

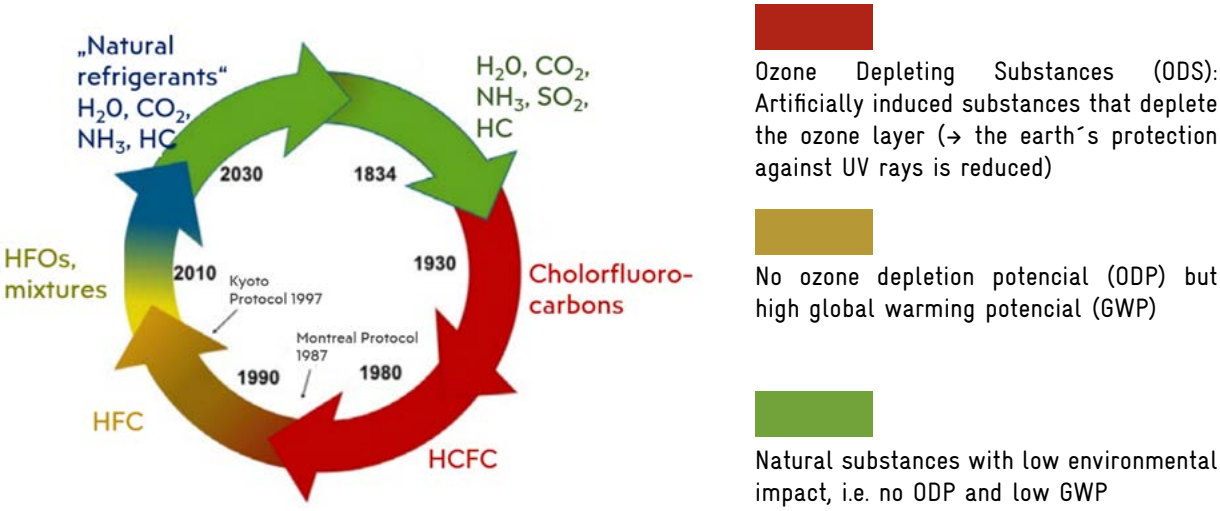


Figure 2: Development of common refrigerants (own illustration based on and translated from.[14])

12 C&EN Global Enterprise, 2019: Guide to PFAS in our environment debuts.
13 GIZ, 2019: A1 Introduction to refrigeration and refrigerants..
14 Ibid.

Green solutions available

There are different options of green RAC equipment available that have high energy efficiency and use environmentally friendly substances. The supply is not very diverse yet but can be expanded depending on demand. The technology and products exist and are already being used in several countries. Green solutions are characterized by their energy efficiency and the use of refrigerants with ultra-low GWP, for example, natural refrigerants based on hydrocarbons. Among these are the R-290 and R-600a. In Table 1 a comparison between these refrigerants and traditional refrigerants such as R-22, R-410A, R-134a, R-404A and R-507A (based on HCFCs and HFCs), which damage the ozone layer and increase global warming, is presented.

Photo 1: Example of high efficiency air conditioning and R-290 refrigerant with ultra-low GWP, © GIZ/Gianfranco Vivi

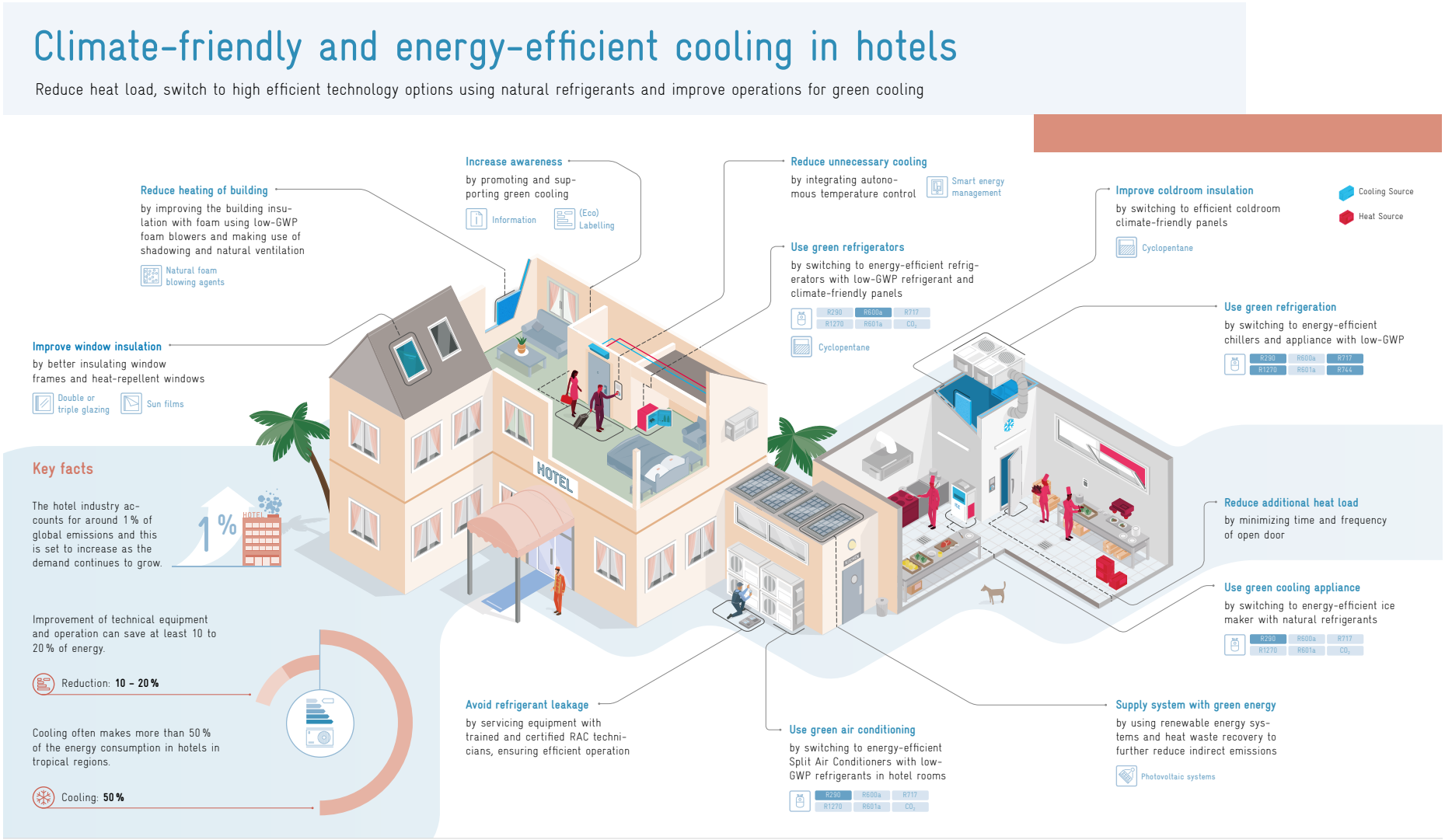
Photo 2: Example of a minibar with R600a, © GIZ/Philipp Denzinger

Table 1: Comparison of Natural and Synthetic Refrigerant Gases

Natural Refrigerants		Synthetic Refrigerants	
	Unique feature, which presents a positive marketing opportunity.		Positive marketing is not possible.
	They produce a negligible amount of emissions, helping to achieve carbon neutrality.		They produce considerable CO_2 emissions and damage the ozone layer in some cases (old equipment with HCFCs).
	PFAS free and no TFA emission to the environment, water, soil, biodiversity.		Many HCFCs, HFCs and HFOs contain PFAS and have a TFA emission to the environment, water, soil and biodiversity.[15]
	Easy methodology for recycling and destruction.		They present complicated recycling and destruction processes.
	Meet international and national sustainability goals.		They will be phased out in accordance with international initiatives.
	Its price will decrease according to international trends.		They will be imported according to a quota system, and their price will increase.
	Most of them are flammable gases; training of the technicians in charge is required.		They are not flammable, and their handling is less risky.
	They have thermodynamic properties that improve energy efficiency (they generally use less refrigerant).		Their thermodynamic properties are usually not better than those of natural refrigerants.

15 Refrigerants: Real GWP and PFAS – ATMOsphere

Below is a graphical summary of the main ideas and solutions regarding air conditioning and sustainable and environmentally friendly cooling in hotels (see figure 3).[16]



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Layout and Design: INFOGRAFIK PRO GmbH – www.infografik.pro

Figure 3: Climate-friendly and energy-efficient cooling in hotels

16 C42018_Non-State_Action_Hotels_web.pdf (green-cooling-initiative.org)

4 Emissions from the RAC sector

The increased use of RAC equipment leads to an increase in GHG emissions for two reasons. Generally, most of the equipment in the RAC sector requires electricity for its operation. The production of this electricity is largely obtained through the combustion of fossil fuels, which causes the emission of a high amount of CO_2. These emissions are called indirect emissions.

The use of a high proportion of renewable energy for the operation of the RAC equipment, can reduce the proportion of indirect emissions enormously. On the other hand, the use of fluorinated gases (HCFCs or HFCs) as refrigerants to transfer heat is still very common and indispensable in most RAC equipment. Therefore, especially the use of these fluorinated gases as refrigerants results in the generation of considerable emissions because they escape during use through leaks or when the equipment is discarded at the end of its useful life. These emissions are called direct emissions and can be sized using the GWP value of each substance, in this case refrigerant.[17]

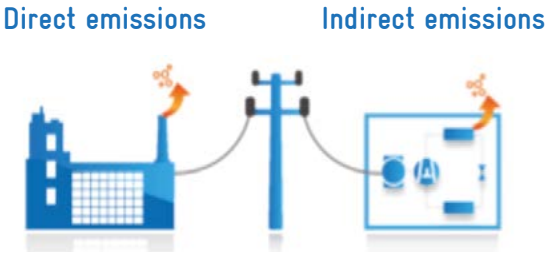

Figure 4: Representation of indirect and direct emissions generation.[18]

On average, indirect emissions from the RAC sector (excluding air conditioning in cars, buses, and trucks) account for about 65 % and direct emissions account for about 35 % of the global RAC inventory, as shown in the figure below.

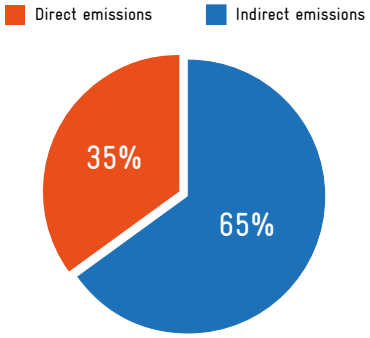

Figure 5: Direct and indirect emissions of the RAC sector globally.

Generally, all emissions from the RAC sector represent around 10 % of a country's total emissions, and due to the expected increased use of technologies in this sector previously discussed, these emissions will progressively increase, representing a larger and larger portion of the country's total emissions.

Indirect emissions	Direct emissions
These are the emissions generated by obtaining electrical energy. They depend on how sustainable and environmentally friendly the energy sources are.	Leaks of refrigerant gases, during service through leaks or when discarding equipment at the end of its useful life.

17 GIZ, 2016: Advancing Nationally Determined Contributions (NDCs) through environmentally compatible refrigeration and air conditioning: Guidance for policymakers, p. 6.
18 GIZ, n.d.: Green Cooling Initiative.

5 Refrigerants and their environmental impact

Refrigerant gases are substances whose environmental impact can be evaluated using two reference values: ODP and GWP.[19] ODP indicates how much a particular substance could damage the ozone layer, as it can release chlorine and bromine, which react with ultraviolet light that depletes the ozone layer. GWP is practically a conversion factor to understand how many kilograms of carbon dioxide equivalent correspond to one kilogram of a specific substance.

Table 2: Climate and environmental impact of various refrigerants (synthetic and natural).[20]

Type	Substance	Type	ODP	GWP 20	GWP 100 years	Contain PFAS[21]	TFA[22]
Synthetic	R-12	CFC	1	12700	12500	No	No
Synthetic	R-22	HCFC	0,055	5690	1960	No	No
Synthetic	R-141b	HCFC	0,110	2710	860	Yes	No
Synthetic	R-32	HFC	0	2690	771	No	No
Synthetic	R-134a	HFC	0	4140	1530	Yes	Up to 20%
Synthetic	R-404A	HFC	0	7208	4728	Yes	Up to 20%
Synthetic	R-407A	HFC	0	4890	2262	Yes	Up to 20%
Synthetic	R-410A	HFC	0	4714	2256	Yes	No
Synthetic	R-507A	HFC	0	7290	4775		Up to 10%
Synthetic	R-245fa	HFC	0	3170	962	Yes	Up to 10%
Synthetic	R-365mfc	HFC	0	2920	914	Yes	Up to 10%
Natural	R-290	HC (propane)	0	0.072	0.02	No	No
Natural	R-744	CO_2	0	1	1	No	No
Natural	R-600a	HC (isobutane)	0	<1[23]	<1[24]	No	No
Natural	R-717	HN_3 (ammonia)	0	0	0	No	No
Natural	C_5H_{10}	HC (cyclopentane)	0	0[25]	11[26]	No	No
Natural	R-601	HC (pentane)	0	<1[27]	<1[28]	No	No
Natural	R-601a	HC (isopentane)	0	<1[29]	<1[30]	No	No

19 IPCC, 2021 6th Assessment Report of the IPCC (Table 7.SM.7)
20 Ibid.
21 ECHA, 2023: Annex to the ANNEX XV RESTRICTION REPORT (europa.eu)
22 Behringer, D. et al. 2021: Persistent degradation products of halogenated refrigerants and blowing agents in the environment, Final report
23 UNEP 2022: Refrigeration, Air conditioning and Heat Pumps Technical Options Committee, 2022 Assessment Report.
24 Ibid.
25 Bakiri, Zahir, 2021: A comparison of a novel formulation of rigid polyurethane foams synthesis by hydrocarbon blowing agents.
26 Ibid.
27 UNEP 2022: Refrigeration, Air conditioning and Heat Pumps Technical Options Committee, 2022 Assessment Report.
28 Ibid.
29 Ibid.
30 Ibid.

Table 2 shows that the impact on the atmosphere is much higher in the case of conventional air conditioning refrigerants compared to refrigerants based on natural gases. While many of the synthetic refrigerants no longer deplete the ozone layer (those based on HFCs), they maintain high GWP values, even higher in some cases when compared against older HCFC-based refrigerants. For this reason, the Montreal Protocol was modified in its Kigali Amendment to phase out the use of HFCs for example, R-410A, in addition to eliminating the use of HCFCs for example, R-22.[31] With respect to natural gases, these have a negligible GWP and none of them deplete the ozone layer.

The gases observed are HCFCs, HFCs and HC, but there are more substances that have been used as refrigerants. Figure 7 shows which ones were or are still in use. As can be seen, CFC-based refrigerants are already banned. Many equipment currently uses HCFC, HFC and HFO-based refrigerants. Changing HCFCs to HFC-based refrigerants and HFOs not only means contributing to global warming, but also choosing lower energy efficiency and therefore high energy costs.

In addition to the ultra-low GWP, natural refrigerants are also highly efficient, which generates significant cost savings.

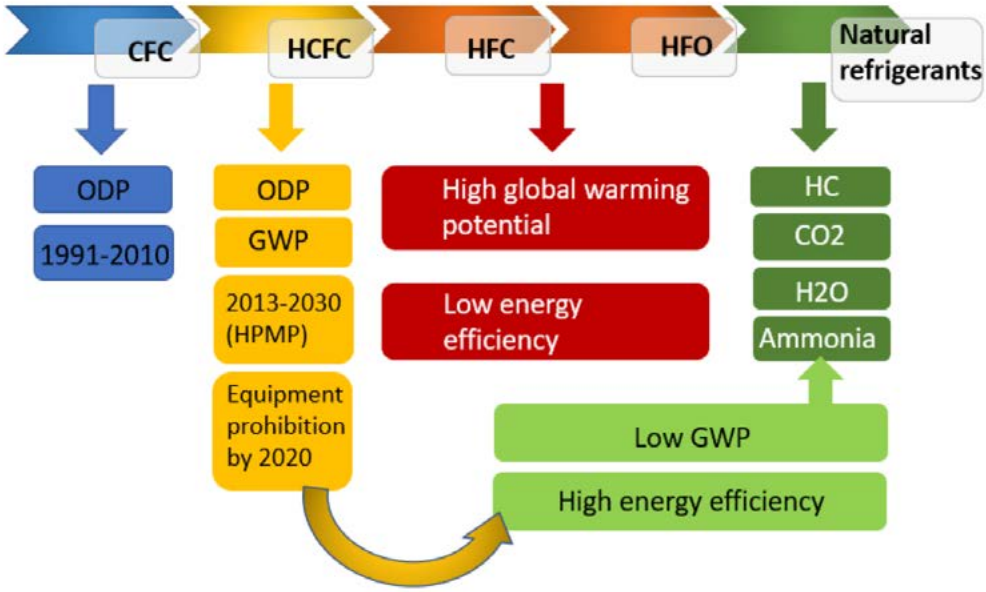

Figure 6: Transition of refrigerants (own illustration based on and translated from).[32]

31 GIZ, 2018: Good Service Practices and Installation of Room Air-conditioners with HCFC-22 and Flammable Refrigerants: Trainers Handbook, p. 9.
32 DIGECA. n. d.: Chemicals Management: Montreal Protocol.

Table 3: Qualitative comparison between different types of refrigerants according to important aspects

Aspects to evaluate	Synthetic refrigerants			Natural refrigerants		
	HCFC	HFC	HFO	NH_3	CO_2	HC
Ozone Depletion						
Global Warming Potential						
Persistent waste						
Exhaustible Resources						
Recycling/Disposal						
Safety aspects (available precautions)						
Energy Efficiency						
Costs						
Possibility of local refrigerant production						

Finally, the advantages of implementing the use of natural refrigerants can be summarized as follows:

- They are substitutes for HCFCs (e.g., R-22) and/or HFCs (e.g., R-134a, R-404A, R-507a, etc.) , for most applications.
- High energy efficiency (even in the high ambient temperatures present in tropical areas).
- They do not have a detrimental impact on the ozone layer.
- Ultra-low or zero GWP.
- They have no remaining residues.
- They do not present the possibility to degrade into TFA, which is a PFAS chemical, unlike the case of HFOs that do present this possibility.
- They can be produced locally.
- Due to their high energy efficiency, systems require less refrigerant charge.
- Lower material costs. Higher quality installations are often performed to avoid leaks, which reduces recharge costs.

Although they are highly flammable and limited to small refrigerant charges, which restricts their application, the equipment is highly efficient. The latter compensates for the lower charges presented by this equipment. In addition, today's mitigation and control systems completely minimize the flammability risk. From an economic point of view, migrating to a new technology involves a relatively large investment; however, this migration will be mandatory in the short term for those institutions where HCFC-based refrigerants (such as R-22) are used.

In the medium term, this will also be mandatory for systems with HFC-based refrigerants. When converting to systems with natural refrigerants, the investment is in most cases higher than when purchasing systems with conventional technology, but the operating and maintenance costs are lower. It is even considered that the value of the investment is recovered in reasonable periods of time, which varies depending on the type of equipment. The price of these HFC-based refrigerants will also increase due to import quota mechanisms that limit their supply in the market.[33] However, if external environmental impacts, leakage, recharge, recovery, and destruction of refrigerants are considered as part of the economic cost analysis, environmentally friendly equipment would be much cheaper.

33 GIZ, 2018b: Implications of natural refrigerants for cooling technologies – Converting from HFCs/HCFCs to natural refrigerants: A guide for refrigeration manufacturers, p. 22.

6 Refrigeration and freezing equipment

Various refrigeration and freezing services are offered in hotels, especially for food products. For this reason, refrigerators and freezers are used to maintain the good condition of these products. Generally, HFC-based refrigerants such as R-134a, R-507 and R-404A, which have a high GWP (1300, 3985 and 3922 respectively) are favored. However, there is an increasing presence of green alternatives such as R-290 and R-600a, which are also highly efficient.[34] These options can be seen from household refrigerators and fridges to freezers and cooling rooms. Climate-friendly solutions are available for all types of refrigeration and freezing equipment, such as commercial refrigerators, ice machines, and display urns such as glass door freezers commonly used for ice cream. This equipment is typically more energy efficient and therefore save operating costs. Their climate and environmental impact are much lower.

These alternatives do not even have a significantly different initial investment cost than conventional options. Prices have declined and are competitive, in some cases indistinguishable between equipment using HFC refrigerants and other HC refrigerants. This is without considering again the added value of green alternatives in helping to reduce environmental impact.

In the following sections of the chapter, comparisons of equipment commonly used in hotels are presented. The differences in environmental impact and financial cost between equipment using synthetic refrigerants and environmentally friendly equipment using natural refrigerants are compared. The specifications of all appliances were obtained through online catalogs and visits to various local stores.

6.1 Commercial refrigerators

Hotels usually have merchandise for sale at different points, and often of franchised products, such as beverages. Commercial refrigerators are those commonly used to store beverages for sale as in supermarkets. In a hotel they can also be used in kitchens, as they have a larger usable volume than a domestic refrigerator. In this equipment the traditional choice of refrigerant is R-134a, while the environmentally friendly alternative is usually R-600a (widely used in domestic refrigerators), but there is also a presence of refrigerant R-290.

In fact, due to the high GWP of R-134a, it has always been seen as an interim solution. R-134a has previously been considered a "climate killer" because of its high impact on the climate.[35] For comparison, the following table shows two appliances widely used in kitchens and supermarkets, such as large two-door refrigerators used for beverages and food.

34 GIZ, 2016: Advancing Nationally Determined Contributions (NDCs) through environmentally compatible refrigeration and air conditioning: Guidance for policymakers, p. 18.
35 GIZ, 2018a: 25 years Greenfreeze: A fridge that changed the world: Learning from a leapfrogging success story to implement the Kigali Amendment, p. 25.

Table 4: Comparison of examples of commercial refrigerators.[36]

Type	Conventional commercial refrigerator 1,000 liters/ 35 cubic feet (ft^3)	Green commercial refrigerator 1,050 liters/37 cubic feet (ft^3)
Brand/model	Imbera/VR35 2PC	Fogel/X-37-PD3-HC
Coolant	R-134a	R-290
GWP	1530	0.02
Refrigerant charge	420 g	105 g
Average accumulated refrigerant[37]	420 g	105 g
Average energy consumption (kWh/year)	2,666	1,415
Lifetime average direct emissions	0.64 tons of CO_2eq	0.000002 tons of CO_2eq
Lifetime average indirect emissions	2.24 tons of CO_2eq	1.19 tons of CO_2eq
Lifetime average total emissions (direct and indirect)	2.88 tons of CO_2eq	1.19 tons of CO_2eq
Average equivalent environmental impact of a vehicle in kilometers traveled	10,367 km	4,276 km
Average lifetime electricity consumption costs*	US$ 6,886	US$ 3,654
Lifetime financial savings	----------	Compared to R-134a: US$ 3,231

* Values converted from Costa Rican colones to US$ using the average currency exchange rate from August 2021 (US$ 1 = ~618 colones)

36 For all assumptions and calculations, please see Annex 1.
37 Useful life of 15 years. Self-contained equipment requiring little refrigerant maintenance. It is assumed that no recharges are needed.

From this comparison, we can highlight the great difference in direct emissions, which are 320,000 times greater in the case of conventional equipment. This is the main motivation for choosing green alternatives. The share of direct emissions is so low for the green alternatives that total emissions are virtually all indirect emissions. In the case of the examples compared, the difference in electricity consumption is also considerable. The conventional equipment generates almost twice as many emissions as the green equipment. It is important to highlight the monetary savings of using the green equipment, a total of US$ 3,231 just in terms of energy consumption. This saving is significant and could finance a renewal of the equipment at the end of its useful life. This saving could be greater since conventional equipment usually requires a refrigerant recharge, a cost that would not be contemplated in the green equipment. This unconsidered recharge would also increase direct emissions, so the comparison made is quite conservative. A hotel that replaces three refrigerators in its kitchen with green refrigerators would generate 5.07 tons of CO_2 eq less at the end of the equipment's useful life.

The following are examples of equipment from some commercial suppliers of green equipment, such as ElectroFrío (FOGEL), Refrigeración OMEGA and TRANSCLIMA.

Photo 3: Examples of commercial refrigerators FOGEL models with R-290, © FOGEL/Electro Frio.

Photo 4: Examples of commercial refrigerators Omega models with R-290, © Omega.

Photo 5: Example of a refrigerated Turbo Air dispenser with R-290 © GIZ/Philipp Denzinger.

Photo 6: Example Heineken/Imbera commercial cooler with R-290, © GIZ/Philipp Denzinger

To further explore the use of environmentally friendly green equipment, the following are examples of good practices implemented by different business groups in Costa Rica.

Best Practice Example: FIFCO

The Costa Rican food and beverages company FIFCO maintains a high percentage of devices with R-290 refrigerants. The equipment is placed throughout Costa Rica and by 2025 it is estimated that 100 percent of the cold equipment will use R-290 refrigerant gas. The equipment comes with LED lighting, which also improves energy efficiency. This equipment varies between 17 types of water dispensers, beer dispensers and 15 types of cold rooms. These units have shown a great reduction in electricity consumption.

Photo 7: Examples of commercial refrigeration applications with R-290 © FIFCO

6.2 Freezers

Most hotels have freezers in their kitchens. Freezers are also found to display various products for sale, such as ice cream or other frozen foods. The economic benefits of environmentally friendly equipment are highlighted, as their energy efficiency is on average 15 to 35 percent better than equipment using HFC refrigerants.[38] In these devices you can find the refrigerant R-134a, but it is not uncommon to find the R-404A and R-507A, which have a GWP greater than 4700 kg CO_2 /kg refrigerant, and therefore a much greater environmental impact. The alternative is usually the refrigerant R-290 or R-600a.

For comparison, two freezers, usually used for frozen products, were selected. These are very useful in any hotel as they can be used both in the kitchens and in spaces designated for the sale of ice cream and other frozen products.

Photo 8: Example of freezers with R-600a at Pricesmart © GIZ/Philipp Denzinger

38 Sheikh, Mujahid; Qureshi, Mohd Abuzar, 2015: Comparative Analysis of Energy Efficiency Ratio & Electric Power Consumption of Domestic Refrigerator using Refrigerant R134a & R600a at Constant Evaporator Temperature.

Table 5: Comparison of examples of horizontal display freezers (usually for ice cream).[39]

Type	Conventional horizontal freezer with glass door	Green horizontal freezer with glass door
Make/model	Fogel/MILAN-9-MAC	Fogel/BLIZZ-12-HC-COB
Volume	255 liters / 9 cubic feet (ft^3)	340 liters / 12 cubic feet (ft^3)
Coolant	R-134a	R-290
GWP	1530	0.02
Refrigerant charge	198 g	71 g
Average accumulated refrigerant[40]	198 g	71 g
Average energy consumption (kWh/year)	1,083	929
Lifetime average direct emissions	0.30 tons of CO_2eq	0.000001 tons of CO_2eq
Lifetime average indirect emissions	0.91 tons of CO_2eq	0.78 tons of CO_2eq
Lifetime average total emissions (direct and indirect)	1.21 tons of CO_2eq	0.78 tons of CO_2eq
Average equivalent environmental impact of a vehicle in kilometers traveled	4,362 km	2,807 km
Average lifetime electricity consumption costs*	US$ 2,799	US$ 2,399
Lifetime monetary savings	----------	Compared to R-134a: US$ 399.8

* Values converted from Costa Rican colones to US$ using the average currency exchange rate from August 2021 (US$ 1 = ~618 colones)

The large difference in direct emissions between equipment with synthetic refrigerant and another using natural refrigerant is again evident. Indirect emissions were not much higher, so the difference in total emissions was only 1.55 times higher in the conventional equipment. Despite the smaller difference in emissions, at least when compared against commercial refrigerators, the monetary savings are significant and could also drive an investment in new equipment at the end of the useful life. It is worth noting that this comparative exercise was carried out with two pieces of equipment of different capacity, i.e., the green freezer has 33 percent more capacity than the conventional freezer. This aspect could mean higher electricity consumption, however, electricity consumption is still lower in the green equipment than in the conventional one.

39 For all assumptions and calculations, please see Annex 1.
40 Average useful life of 15 years. Self-contained equipment requiring little refrigerant maintenance. It is assumed that no recharges are needed.

Best Practice Example: Dos Pinos

A best practice example by the Company "The Dos Pinos" is shown in the following: The Dos Pinos Company indicates that it has started using R-290 equipment since 2016. It has horizontal freezers and vertical cooling chambers. The horizontal freezers have a volume of 5, 7, 9, and 11 ft³ and the cooling chambers a volume of 5, 7, 17, 25, and 35 ft³. This equipment is used to store the various products manufactured by the company at selling locations throughout the country. It is indicated that the electricity consumption of the equipment is up to three times lower than that of alternatives with HFC and HCFC-based refrigerants. This highlights the high energy efficiency of equipment with green refrigerants.

Photo 9: Example of a freezer at Dos Pinos, © GIZ/Philipp Denzinger

6.3 Minibars for hotel rooms

Today's hotel rooms are usually equipped with minibars or refrigerators to offer guests a variety of snacks and beverages conveniently in the room. R-134a predominates in these units, but R-600a and R-290 units can be found in almost equal quantities in the green options. Below is a comparison between two minibar devices with synthetic refrigerant and natural refrigerant.

Photo 10: Example of a minibar with R-600a, © GIZ/Philipp Denzinger

Table 6: Comparison of an example of a minibar with R-134a and another with R-600a.[41]

Type	Minibar with HFC	Green minibar with HC
Make/model	Imbera/ SVC01	Mabe/ RMF0260XMXX3
Coolant	R-134A	R-600a
GWP	1530	<1
Refrigerant charge	65 g	15 g
Average accumulated refrigerant[42]	65 g	15 g
Energy consumption (kWh/year)	470	260
Lifetime average direct emissions	99.5 kg of CO_2eq	0.0003 kg of CO_2eq
Lifetime average indirect emissions	263.2 kg CO_2eq	145.6 kg of CO_2eq
Lifetime average total emissions (direct and indirect)	362.7 kg of CO_2eq	145.6 kg of CO_2eq
Average equivalent environmental impact of a vehicle in kilometers traveled	1,304 km	524 km
Average lifetime electricity consumption costs*	US$ 808.3	US$ 447.7
Lifetime monetary savings	----------	Compared to R-134a: US$ 360.6

* Values converted from Costa Rican colones to US$ using the average currency exchange rate from August 2021 (US$ 1 = ~618 colones)

41 For all assumptions and calculations, please see Annex 1.
42 Useful life of 10 years. Self-contained equipment requiring little refrigerant maintenance. It is assumed that no recharges are needed.

The total lifetime emissions (10 years) of a minibar with R-134a are 362,7 kg CO_2 equivalent, significantly higher than the total emissions of R-600a over the same period. The energy consumption of the green minibar is 44 percent lower than that of a conventional refrigerator. Therefore, a hotel with 50 green minibars instead of conventional ones could save about 105,000 kWh and 10.86 tons of CO_2 equivalent over the lifetime of this equipment. The investment cost of a minibar with R-600a is now the same as that of a minibar with R-134a. The monetary savings could also involve the purchase of new equipment.

6.4 Ice making and storage machines

Ice making and storage machines are other types of equipment commonly used in hotels. They are usually used in kitchens, but it is not uncommon to find such equipment arranged somewhere in room corridors, as are water dispensers.

Photo 11: Example of ice making machine with R-290, © GIZ/Gianfranco Vivi

Photo 12: Example of Industrial ice storage with R-290, © GIZ/Philipp Denzinger.

Below is a comparison chart of two ice machines operating with synthetic and natural refrigerant gas respectively.

Table 7: Comparison of an example of an ice machine with R-404A and R-290.[43]

Type	HFC ice machine	Green ice machine with HC
Make/model (examples)	ETL TT-SK-280P[44]	FETL TT-SK-219S[45]
Capacity	127 kg/24 h.	127 kg/24 h.
Coolant	R-404A	R-290
GWP	4728	0.02
Refrigerant charge	0.290 kg	0.125 kg
Average accumulated refrigerant	0.290 kg	0.125kg
Energy consumption (kWh/year)	No data available. Depending on use and energy efficiency.	On average,15 percent less energy consumption is assumed.
Direct lifetime emissions	1.371 tons of CO_2eq	0.000003 tons of CO_2eq
Indirect lifetime emissions	No data available. Depending on use and energy efficiency.	On average,15 percent less energy consumption is assumed.
Equivalent environmental impact of a vehicle in kilometers traveled	Direct emissions: 4,932 km	Direct emissions: 0.01 km

In this case, the equipment to be compared with traditional refrigerant uses the refrigerant R-404A, which is much more harmful than most other HFC and HCFC gases, at least when considering its GWP (4728 kg CO_2 / kg refrigerant). For this reason, there is such a marked difference in environmental impact. Conventional equipment generates 196,100 times more greenhouse gas emissions than green equipment. Also noteworthy is the reduced refrigerant charge of the green equipment, which is sufficient for its operation due to its high energy efficiency.

43 Two Thousand, n.d.: 127 Kg per day R404a Commercial Ice Cube Making Machine TT-SK-280P
44 Two Thousand, n.d.: 127 kg per day R290 air-cooled ETL large capacity cube ice maker TT-SK-289S
45 Useful life of 15 years. Self-contained equipment requiring little refrigerant maintenance. It is assumed that no recharges are needed.

6.5 Water dispensers

Water dispensers are commonly found in hotels. The most used have been those with HFC refrigerants and energy inefficient.

In Europe, the F-Gas Regulation (No. 517/2014) already banned in 2020 the import and sale of water dispensers containing HFC-based refrigerants such as R-134a.

In these technologies, the green water dispenser alternatives operate with R-600a refrigerant. They are highly energy efficient equipment and are available in the market. This promotes a greater demand and implementation of this equipment in the hotel sector.

Photo 13: Example of a water dispenser, © GIZ/Philipp Denzinger

The following table presents a comparative exercise between examples of conventional and green water dispensers. It shows how a green dispenser with even a slightly larger capacity has better environmental performance and higher energy efficiency.

Table 8: Comparison of an example of a water dispenser with R-134a and R-600a.[47]

Type	HFC water dispenser	Green water dispenser with HC
Make/model (examples)	Waterlogic/ WL270	Waterlogic/ WL3 Firewall[48]
Capacity (tank)	Hot: 1.5 liters Cold: 4 liters	Hot: 2 liters Cold: 4 liters
Coolant	R-134a	R-600a
GWP	1530	<1
Refrigerant charge	0.058 kg	0.030 kg
Average accumulated refrigerant[49]	0.058 kg	0.030 kg
Average energy consumption (kWh/year)[50]	Only cold: 672	Only cold: 580[51]
Lifetime average direct emissions	0.089 tons of CO_2eq	0.00001 tons of CO_2eq
Lifetime average indirect emissions	0.56 tons of CO_2eq	0.49 tons of CO_2eq
Lifetime average total emissions (direct and indirect)	0.65 tons of CO_2eq	0.49 tons of CO_2eq
Equivalent environmental impact of a vehicle in kilometers traveled	2,350 km	1,751 km
Average lifetime electricity consumption costs	US$ 1,736 (cold water only)	US$ 1,498 (cold water only)
Average savings over service life	----------	Compared to R-134a: US$ 237 (cold water only)

As in other cases, the efficiency gains from using a natural refrigerant instead of a synthetic or conventional one, can be seen in the difference of the refrigerant charge. Natural refrigerants require less mass to transfer the same amount of heat. However, since it is a very small equipment, both would emit small number of direct emissions that have a small impact in the indirect emissions. The green option still had approximately 25% less impact to the environment. Also, the average savings over service life can easily motivate the purchase of another unit.

47 For all assumptions and calculations, please see Annex 1.
48 Waterlogic, sf.: Looking after the environment with R600a
49 Useful life of 15 years. Self-contained equipment requiring little refrigerant maintenance. It is assumed that no recharges are needed.
50 These units are usually used to heat and cool water. In this case, we will only observe the consumption when only cooling water.
51 Waterlogic, sf.: Energy Consumption Comparison. It is assumed to be 15% more efficient on average than the HFC model.

6.6 Cold rooms

Cold rooms offer a very appropriate solution when handling large volumes of food. They are also essential if restaurants are looking to offer fresher food that needs to be processed in some way in the same hotel, such as some vegetables and meat cuts. One of the most used refrigerants in large commercial applications is R-404A, others are R-507A and R-134a. R-404A is currently the most widely used refrigerant with the highest GWP (GWP equal to 4728 kg CO_2/kg refrigerant).

Conventional small cold rooms can be found in most hotels with an average of 1 kg R-404A, depending on the size and temperature requirements. This means that, if a cold room refrigeration system with 1 kg of R-404A is replaced, and this leaks into the environment and the corresponding gas recovery is not performed, it is equivalent to the release of 4.7 tons of CO_2. As mentioned in previous cases, there are alternatives available that use in this case the natural refrigerant R-290.

Photo 14: Example of Cold Room,
© Shutterstock.com/Aleksandr Ivasenko

Best Practice Example: Roche

ROCHE Servicios S.A. has an industrial cold room refrigeration system with R-290. From ROCHE Servicios S.A.'s Distribution Center, medicines are shipped to the entire Central American and Caribbean region (more than 23 countries). Its products are biotechnological, which means that they must be kept in temperature-controlled conditions so as not to lose their properties and efficacy (cold chain). There are two cold rooms (160 m^3 and 75 m^3) where all products requiring a cold chain of 2°C to 8°C are stored (the products stored are mainly for cancer treatment). A third room (-18°C to -20°C degrees) is for freezing and is used to store refrigeration elements to maintain the cold chain during the transport of medicines.
In the first instance, the drugs are stored in the cold chamber (2°C to 8°C degrees). To distribute the medicines, the cold chain must be maintained, so coolers with refrigerated and frozen elements are used to transport the medicine to its destination.

The current building began operations in 2015 with the R-290 systems and since that time there have been no changes to the equipment. Five Dorin compressors were implemented between the cold rooms, and all work was assembled by Beirute Industrial Refrigeration. Each compressor works with approximately 5 kg of R-290 refrigerant. ROCHE is a company highly committed to the care of the environment globally in all its subsidiaries, so it aims to adopt non-polluting refrigerants and reduce the impact on the carbon footprint.

Photo 15: Example of cold rooms with R-290 © GIZ/ Gianfranco Vivi

6.7 Monoblocks for cold rooms

Monoblock type units are package type units for small volume cold rooms, with medium to low temperature capacities. This type of equipment is installed on the ceiling or wall of the room to be cooled, leaving the room volume completely free. The predominant refrigerant used in this equipment is R-404A, but there are options that use R-290. For this technology examples of good practices are not presented, but a list of environmentally friendly equipment with natural refrigerants is provided.

Like the market landscape in the other technologies, there is not really a considerable demand, so it does not present a solid supply, but the technology does exist and is present in the Latin American region. Table 9 gives an overview of the monoblock units available (as requested) in Costa Rica. That is, Intarcon equipment is distributed by Dicoma and Omega Refrigeration. Zanotti equipment is in turn distributed by Beirute Industrial.

Table 9: Examples of environmentally friendly monoblock condensing units with ultra-low GWP refrigerants.

Manufacturer	Coolant	Temperature range (°C)	Cooling capacity (kW)	Room volume (m^3)[53]	Energy consumption (kW)
Intarcon[54]	R-290	+10 a 0 +10 a -5 +10 a -5 -15 a -25 -15 a -25 -20 a -35	0,7 -2,1 (+5°C) 0,8 -2,8 (+5°C) 6,5 -51,5 (+5°C) 0,4 -1,1 (-20°C) 0,4 -1,2 (-20°C) 5 -29,7 (-20°C)	7 -43 (+5°C) 6 -28 (+5°C) No information 2 -8 (-20°C) 2 -14 (-20°C) No information	0,4 – 1,31 0,30 – 1,34 2,5 – 17,8 0,26 – 0,96 0,38 – 0,97 3,5 – 20,1
Zanotti (Daikin)[55]	R-290	+10 a -5 +10 a -5 -15 a -25 -15 a -25	1,4 – 2,4 1,4 – 6,3 0,8 0,8 – 2,4	10 – 25 (+5°C) 9,1 – 81 (+5°C) 3,4 -4-4 (-20°C) 2,7 – 22 (-20°C)	0,94 – 1,61 0,94 – 4,66 1,26 1,26
	R-744 (CO_2)[56]	+10 a -5 -16 a -25	1,7 – 12,8 0,8 – 4,8	40 - 200 17 – 72	No information

53 Depends on the ambient temperature.
54 INTARCON, 2020a: Intarblock R-290
INTARCON, 2020b: Intartop R-290
INTARCON, 2020c: Superblock R-290
55 ZANOTTI, n.d.: CO2 Monoblock units
DAIKIN, 2018: 2018 Refrigeration Product Catalog; from Zanotti for units with R-290 that are ceiling-mounted or wall-mounted.
56 R-744 is environmentally friendly, has zero ODP (ozone depletion potential) and a GWP of one. It also has excellent thermodynamic properties and low energy consumption, making it suitable for a variety of applications, such as industrial heat extraction, refrigerated storage, marine, commercial refrigeration and mobile air conditioning.

Table 10 presents characteristics related to the environmental impact of two examples of monoblocks for cold rooms. As shown in the following table, the monoblock working with a green technology contributes 99.9 % less greenhouse gas emissions and GWP compared to a conventional monoblock.

The direct emissions resulting from the R-404A or R-507A refrigerant are about 4.7 tons CO_2 eq. of lifetime. In contrast, the green unit emits less than a kilogram of direct CO_2 equivalent emissions. The green unit is, on average, 15 % more energy efficient than HFC units.

Table 10: Comparison of examples of a monoblock with R-404A/R-507A and R-290.[57]

Type	Conventional monoblock with HFC	Green monoblock
Coolant	R-404A / R-507A	R-290
GWP	4728 / 4775	0.02
Average refrigerant charge	1 kg	0.15 kg
Average accumulated refrigerant[58]	1 kg	0.15 kg
Average energy consumption (kWh/year)	According to size, product, use, etc.	A minimum of 15 percent less is assumed.
Lifetime average direct emissions	4.73 / 4.78 tons of CO_2eq	0.000003 tons of CO_2eq
Lifetime average indirect emissions	No data available. Depending on use, temperature, and energy efficiency.	A minimum of 15 percent less is assumed.
Average total lifetime emissions (direct and indirect)	Depends on the use of the equipment and its corresponding energy efficiency	More than a thousand times less direct emissions.
Average equivalent environmental impact of a vehicle in kilometers traveled	For direct emissions: 17,007 km / 17,176 km	For direct emissions: 0.01 km
Lifetime average monetary savings	----------	Compared to R-404A/R-507A: Assumes a 15 percent reduction in electricity costs.

57 For all assumptions and calculations, please see Annex 1.
58 Average useful life of 15 years. Self-contained equipment requiring little refrigerant maintenance. It is assumed that no recharges are needed.

6.8 Insulating foams

In refrigeration equipment and cold rooms, foaming agents are used to perform the function of thermal insulation, essential to maintain high efficiency and energy savings, and therefore monetary savings. These substances are manufactured with the same or similar bases of refrigerants (HCFC R-141b and HC, CO_2, H_2O) bases. For this reason, they should also be replaced with options that have an ultra-low impact on the environment and the climate.

Currently, HCFC substances are still used, particularly R-141b, which has a GWP of 860 kg CO_2 /kg refrigerant and an ODP of 0,11. As mentioned above, it is expected that refrigerants based on the same chemical composition, such as R-22, will be phased out globally by 2030.[59] However, blowing agents may still contain R-141b or other HFC-type agents. In several countries there are currently no companies that facilitate the destruction of these foams. This results in large amounts of emissions at the end of the useful life of these devices, as there is no choice but to dispose of them without the necessary treatment.

Like other equipment and technology, there are already environmentally friendly alternatives with ultra-low GWP. These options are also based on hydrocarbons (HC) such as pentane, isopentane, cyclopentane and even liquid CO_2. The environmental impact of these agents is ultra-low or none.[60] Many foam producers have already made corresponding changes in their offerings and many others will do so soon. Consequently, it is recommended to obtain refrigeration equipment, from domestic refrigerators to cold rooms, using insulating materials containing ultra-low GWP foaming agents.

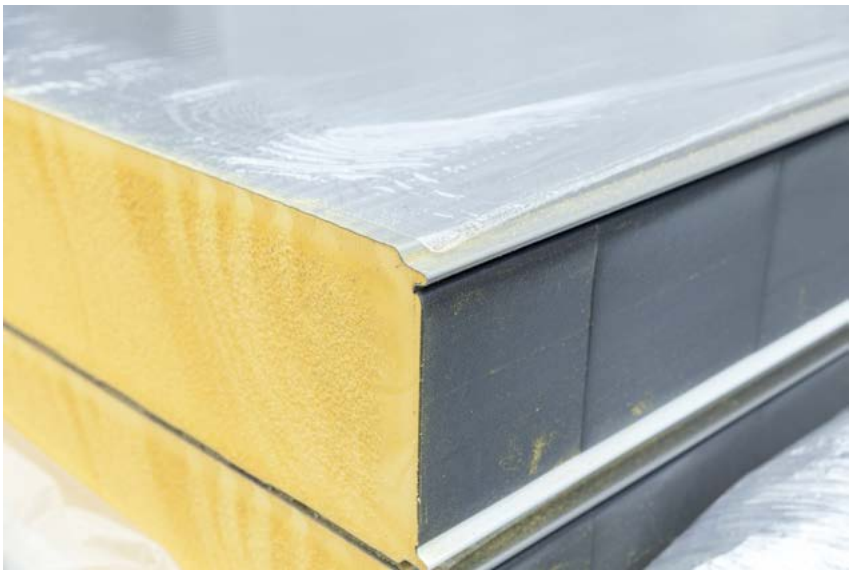

Photo 16: Insulating foam panels,
© DJ Srki/shutterstock.com

59 Multilateral Fund, 2019: HCFC Phase - Out Management Plans and HCFC Production Phase - Out Management Plans.
60 GIZ, 2009: Natural Foam Blowing Agents Sustainable Ozone and Climate - Friendly Alternatives to HCFCs.

7 Air Conditioning (AC)

Air conditioning (AC) plays an essential role in most hotels in the warmer regions of the world. Air conditioning is usually a large consumer of electrical energy in a hotel. Most of the CO_2 emissions of a hotel in this equipment are due to leakage of refrigerants and the consumption of energy that has been produced by burning fossil fuels. When working with natural refrigerants, the emission is reduced by enormous amounts due to the ultra-low GWP and the sharp reduction of leaks. Natural refrigerants are flammable substances, so the equipment is designed to mitigate the risk of leakage, also avoiding possible operating costs for refrigerant recharges. The following chapter will show the different air conditioning equipment that may be present in a hotel, and conventional alternatives will be compared against the green alternatives of high energy efficiency and natural refrigerants.

7.1 AC type Split

So far, this technology has been mainly implemented in India (it is estimated that there are about 2 million equipment installed) and in China, where there is also a large presence of this equipment. Therefore, the market is ready to meet a possible demand from other countries.

Photo 17: Green AC equipment with R-290 (condenser) © GIZ/Gianfranco Vivi.

Currently, R-22 and R-410A refrigerants are commercially available and are the most commonly used refrigerants for room air conditioning. Although these chemicals have no ozone depletion potential (the value of R-22 is practically negligible), their GWP is high.

Photo 18: Split type air conditioner with R-290 © GIZ/Gianfranco Vivi

It is expected that in the near future the implementation of AC units with R-290 refrigerant will increase, in light of recent events. Finally, in Europe, this type of equipment will be launched, and from the Chinese production company Midea. This equipment was the only one to win the strict German "Blue Angel" eco-label.[61] In addition, certain measures have already been prepared and implemented to encourage the entry of more R-290 AC equipment. The European regulation EU F-Gas, from 2020 prohibits the use of HFC refrigerants with GWP values greater than 150 in portable AC equipment (cars and vans).[62]

It is noteworthy that more than 600,000 AC units with R-290 refrigerant have been installed in India since 2009 without any problem, and 370,000 AC units with R-290 in 2020 in China. In addition, under the Multilateral Fund of the Montreal Protocol, AC production lines will switch to R-290 soon. The trend is clear, and it would then be a matter of time before such AC units are available globally. The cooling capacities currently available outside of Costa Rica in AC Split equipment with R-290 are 12,000, 18,000 and 24,000 BTU/h.

61 Hydrocarbons21, 2020: Highly Rated Midea R-290 Room AC Expected in Germany This Year.
62 Review of the regulation on fluorinated greenhouse gases (europa.eu)

Best Practice Example: Hotel Ambassador

The Ambassador Hotel is in Paseo Colón, San Jose, Costa Rica. It was founded approximately in 1978 and in the last years, the administration has changed, and changes have been made to the aesthetics and energy efficiency of the building.

Photo 19: Ambassador Hotel © GIZ/Gianfranco Vivi

Some of these changes have been the inclusion of solar panels to supply the entire building and remodeling of the facade and internal structure. At the end of 2018 and beginning of 2019, another important change has been made with the installation of 20 energy efficient and environmentally friendly split type air conditioners (with R-290 refrigerant), as part of a cooperation with DIGECA, MINAE and GIZ Proklima.

Photo 20: Example of green AC at Hotel Ambassador in Costa Rica © GIZ/Gianfranco Vivi

7.2 Centralized AC Split system with duct

The technology for centralized AC Split systems is ready, experienced and within reach. Many hotels use central air handling units. These systems consist of a condensing unit, usually installed outdoors, and an evaporator unit, also known as an air handler, installed in a machine room. Between these two units the refrigeration cycle takes place and then the cold air is sent to other parts of the building through ducts. They typically have a cooling capacity greater than 36,000 to 60,000 BTU/h, which is equivalent to three to five hotel rooms or a medium to large conference room. A conventional centralized AC Systems unit using R-410A (GWP 2256) is charged with about 2 kg of this refrigerant. Estimated direct emissions are around 10.47 tons of CO_2 equivalent at the end of its service life.[64]

Centralized AC systems with duct are also available with an environmentally friendly refrigerant R-290 with variable frequency drive (Inverter technology). For example, the Colombian company Thermotar (Starlight) produces centralized AC systems in Colombia with a capacity of 36,000 and 60,000 BTU/h. The systems are very energy efficient. According to the manufacturer, they are up to 35 percent more efficient than conventional systems.[65]

Photo 21: Example of a ducted centralized AC unit with R-290, © Thermotar

As can be seen in Table 11, the environmental impact of a centralized AC system with R-290 duct is on average 10 to 12 tons of CO_2 eq. less than conventional systems. It is also proposed, as an approximate calculation, that the indirect emissions of conventional equipment would be at least 1.18 tons of CO_2 equivalent greater than those of equipment with R-290. This means that a conventional ducted centralized AC system with R-410A emits about 10 tons more CO_2 equivalent during its lifetime.

These systems can be connected to ducted or cassette type multi split systems. For multi split systems the evaporator would be needed. The cassette is implemented in the ceiling of any room. Normally, the air from the ducts is also usually discharged through grilles. Both need to have the ducts provided. This complementary equipment is easier to acquire in the domestic market.

64 Average: Assuming 2% leakage at installation, 10% leakage per year and 90% leakage at end of life (average 15 years). See Annex 1.
65 Thermotar, n.d.: Star Light Catalog, NATURAL COOLING CONDENSER UNIT CV290 and Thermotar, n.d.: Central Split Air Conditioning System for R290

Table 11: Estimated environmental impact in examples of centralized ducted type AC equipment.[66]

Type	Conventional with HCFCs	Conventional with HFCs	Green capacitor with HC
Photos (examples)	Photo 22[67]	Photo 23[68]	Photo 24[69]
Examples: Brand/model	Average model with HCFCs	Average model with HFCs	Thermotar/ CV290-060[70] con HC
BTU/h	60,000	60,000	60,000
Coolant	R-22	R-410A	R-290
GWP	1960	2256	0.02
ODP	0.055	0	0
Average refrigerant charge	2.2 kg	2.0 kg	1.0 kg
Average accumulated coolant	5.1 kg	4.64 kg	1.0 kg
Average energy efficiency	35% less efficient compared to a unit with R-290[74]	15% less efficient compared to a unit with R-290[75]	
Average energy consumption[76]	12,641 kWh/year	10,769 kWh/year	9,364 kWh/año[77]
Lifetime average direct emissions	10 tons of CO_2eq	10.465 tons of CO_2eq	0.00002 tons of CO_2eq
Lifetime average indirect emissions	10.62 tons of CO_2eq	9.04 tons of CO_2eq	7.86 tons of CO_2eq
Average total (direct and indirect) lifetime emissions	20.62 tons of CO_2eq	19.51 tons of CO_2eq	7.86 tons of CO_2eq
Average equivalent environmental impact of a vehicle in kilometers traveled	74,181 km	70,194 km	28,294 km
Average lifetime electricity consumption costs in US $	US$ 32,652	US$ 27,816	US$ 24,187
Lifetime average savings in US $		Compared to R-22: US$ 4,835 against R-410A: No savings	Compared to R-22: US$ 8,465 Against R-410A: US $ 3,629

* Values converted from Costa Rican colones to US$ using the average currency exchange rate from August 2021 (US$ 1 = ~618 colones)

66 For all assumptions and calculations, please see Annex 1.
67 Photo 22: Example of split type air conditioner with R-410A © GIZ / Philipp Denzinger
68 Photo 23: Example of split type air conditioner with R-410A © GIZ / Philipp Denzinger
69 Photo 24: Example of split type air conditioner with R-290 © Thermotar
70 Thermotar, n.d.: Star Light Catalog, NATURAL COOLING CONDENSER UNIT CV290, and Thermotar, n.d.: Central Split Air Conditioning System for R290.
71 PUND, 2020: Webinar: UNDP-PM Experience in the use of HC in the manufacture of ducted centralized air conditioning systems.
72 MINAE, 2019: Refrigeration and Air Conditioning Greenhouse Gas Inventory for Costa Rica (2012-2016).
73 Average life of 15 years, 2% leakage at equipment installation, 10% leakage per year, 90% leakage at end of life for conventional equipment. Green equipment would not leak. See Annex 1.
74 Thermotar, n.d.: Star Light Catalog, NATURAL COOLING CONDENSER UNIT CV290, and Thermotar, n.d.: Central Split Air Conditioning System for R290.
75 PUND, 2020: Webinar Questions: UNDP-PM Experience in the use of HC in the manufacture of ducted centralized air conditioning systems.
76 Data calculated with an annual use of 1951 hours, estimated time for the geographical area of Costa Rica according to: UNEP, 2019: United for Efficiency, Energy - Efficient and Climate - Friendly Air Conditioners. MODEL REGULATION GUIDELINES
77 4.8 KWh x 1,951 hours 100% (4.8 kWh) = 9,364 KWh per year x 15 years = 140,472 kWh

7.3 AC Package type

Central AC units, also known as package-type AC, are systems that contain all refrigeration circuits (condenser, evaporator, compressor, and expansion valve) in a single cabinet. These are typically used in hotels with high air conditioning requirements. Their cooling capacities can range from 2 or 3 to 15 tons of refrigeration.[78] The refrigerated air that is generated can be circulated through air handlers, or in the same way as a centralized AC system with ducts, with cassette or split equipment.

Currently in these teams predominates the use of refrigerant R-410A, HFC type. The companies that have been mentioned throughout the document, such as Thermotar, are adapting their equipment to operate with R-290 refrigerant gas.

Photo 25. Example of AC package type, © Thermotar

7.4 AA Chiller

Larger hotels often use centralized AC systems called *chillers*. This equipment can transport chilled water, which in turn cools air to be transported by air handlers to the rooms. It can also heat water (with the extracted heat), which can be used for showers and swimming pools.

Therefore, a centralized air *chiller* system acclimatizes many hotel rooms at the same time, thus using energy efficiently. These centralized air conditioning systems use much more refrigerant charge (R-22 or R-410A), and these systems often leak refrigerant. Many hotels still have *chillers* with R-22 that in addition to the climate impact also have an impact on the ozone layer. Many of these R-22 *chillers* need to be replaced soon due to the Montreal Protocol HCFC phase-out plan. But even *chillers* using the refrigerant R-410A will have to change soon due to the Kigali Amendment to the Montreal Protocol (raises disuse and then elimination of HFCs).

As with the other types of equipment, there are climate-friendly alternatives with natural refrigerants (R-290) commercially available. There are a wide variety of manufacturers in Europe and Asia. One example is the company Thermotar[79] in Colombia, which manufactures its own *chillers* that use R-290 refrigerant. There are *chillers* with a capacity of 60,000 to 240,000 BTU/h (5 - 20 tons of refrigeration), which can be described as "small". Thermotar exports their produced *chillers* widely to other countries which means that there is an existing demand.

Photo 26: Example Thermotar AC Chiller with R-290, © Thermotar

78 One ton of refrigeration is equivalent to 12,000 BTU/h or 3.5 kW.
79 Thermotar, n.d.: Chiller R-290 | Water Chiller for R290

An example of existing larger capacity *chillers* are those offered by the company Sabroe, from 45 to 115 tons of refrigeration (1 ton of refrigeration = 12,000 BTU/h). For the case of this equipment, the refrigerant charge takes a much more critical role than in other cases. When working with larger amounts of refrigerant, the difference in direct emissions becomes even more evident. As with the other air conditioning equipment, electricity consumption will depend on the user's habits, which would imply a monitoring strategy to be able to present concrete data which is not within the scope of this document.

Best Practice Example: Roche 2 Chillers with R-290

The Costa Rican pharmaceutical company ROCHE Servicios S.A. has implemented equipment with natural refrigerants. In 2015, two *chillers* (SABlight A-340-1)[80] with R-290 were installed in Refrigeración Beirute Industrial for its new regional office building (about 4,000 m^2 and 150 office spaces). Compared to previous direct emissions, an R-290 chiller emits almost nothing because it does not leak.[81] ROCHE has confirmed that both *chillers* are performing very well and are highly energy efficient. This is because R-290 is typically more energy efficient (also in warmer climate zones) due to the better thermodynamic properties of the refrigerant.

At the moment, *chillers* with R-290 are generally more expensive than conventional *chillers*, given the higher energy efficiency (price increases for equipment with R-290). In addition, conventional *chillers* can be used until they need to be replaced due to system technical issues as they have a very long service life (more than 25 years). Now they do not fall within the scope of any international environmental agreement, such as the Montreal Protocol, only refrigerants. When considering that HFCs such as R-410A will be increasingly expensive due to these restrictions, and the additional costs for the management and destruction of refrigerants, it can be said that the initial investment costs in a *chiller* with R-290 will probably be harmonized over 30 years of life.

Photos 27 and 28: Example of chiller with R-290, in ROCHE Servicios S.A., Heredia., © GIZ/Gianfranco Vivi.

Table 12 shows a comparison between the equipment installed in Roche Servicios SA and conventional equipment operating with refrigerant gas R-410A. It can be seen how the green equipment, having no leaks, accumulates much less refrigerant and therefore has a negligible environmental impact compared to conventional equipment.

80 Sabroe, n.d.: SABlight.
81 Because of the higher flammability of the refrigerant, better pressure controls are installed to monitor possible leaks. This in turn results in virtually zero refrigerant recharge costs.

Table 12: Comparison between an example of a conventional chiller and one with ultra-low GWP.[82]

Type	Conventional Chiller	Green Chiller
Examples: Brand/model	Daikin/EWAQ-E-XS/XL[83]	Sabroe/SABlight A-340-1[84]
Cooling capacity	334 kW	324 kW
Coolant	R-410A	R-290
GWP	2256	0.02
ESEER[85]	4.14	4.70
Refrigerant charge	53 kg	40 kg
Average accumulated refrigerant[86]	115.01 kg	40 kg
Average energy consumption (kWh/year)	There is no data for comparison.	A minimum of 13.5 percent less is assumed.
Lifetime average direct emissions	259.46 tons of CO_2eq	0.0008 tons of CO_2eq
Lifetime average indirect emissions		Assumes 13.5 percent lower average indirect emissions.
Average equivalent environmental impact of a vehicle in kilometers traveled	For direct emissions: 933,319 km	For direct emissions: 2.88 km
Lifetime average monetary savings	----------	A 13.5 % reduction in electricity costs is assumed.

82 For all assumptions and calculations, please see Annex 1.
83 Daikin, 2017: Applied Systems productcatalog, p 32.
84 Sabroe, n.d.: SABlight R-290 Chiller.
85 ESEER: EuropeanSeasonal Energy Efficiency Ratio.
86 An average useful life of 25 years is assumed. In the case of conventional equipment, a leakage rate of 5% per year and 95% at the end of its life cycle (End of Life). In the green equipment there is no significant annual leakage. See Annex 1.

8 Disposal of disused waste

There are large numbers of minibars, refrigerators, freezers, cold and freezing equipment for cold rooms, air conditioners and *chillers* in hotels that no longer function according to WHO requirements, are old or no longer work properly. To minimize damage to the environment, the ozone layer and the climate, it is strongly recommended to dismantle these appliances and installations according to international standards, to recover and collect refrigerants, as well as to destroy insulation materials (insulation foams), which contain CFC R-11 or HCFC R-141b. Depending on the country, there may be specific national laws that must be followed to deal with this type of waste, for example to declare it as special handling waste etc. Apart from refrigerants and insulation materials, electronic waste should at least try to be recycled according to international and the respective national best practices. [87]

It would be ideal if companies offering such technologies offered users alternatives for disposing of equipment that has become obsolete after the switch to new solutions, thus fulfilling the principle of extended producer responsibility. When the equipment needs to be disposed, it is important to consider the refrigerants, refrigerant oils, and insulating materials as it must be avoided at all costs that they get released into the environment.[88]

8.1 Disposal of old refrigerants and disused equipment

Collection points collect discarded equipment so that the disused or burned gases can be disposed of to prevent leakage into the environment and the harmful effects mentioned above. When it comes to refrigeration equipment ready for final disposal, there also exist companies to properly treat this waste, in addition to companies that receive disused equipment.

Photo 29: Obsolete refrigeration equipment, © GIZ

Photo 30: Obsolete refrigerators, © GIZ

87 GIZ, 2017a: Management and Destruction of Existing Ozone Depleting Substances Banks.
88 GIZ, 2017: Guide for manual disassembly of refrigerators and air conditioners
GIZ, 2014: Guide for conversion of domestic refrigerator production: from halogenated refrigerants to hydrocarbon refrigerants.

9. Water heating systems

If a hotel aims to be carbon neutral, a strategic step is to incorporate green water heating technologies. After air conditioning, water boilers or water heaters are probably the second largest consumer of energy in a hotel. However, even if the largest amount of energy in Costa Rica is produced through renewable energies, calculations on indirect emissions in this publication have shown that the remaining 2 percent of energy that is produced through fossil fuels has a significant environmental impact.[89] This translates to any equipment in a hotel that uses electricity from the national electricity grid. Nevertheless, it always depends on the type, the size and the energy efficiency of the water heating system, as well as on the composition of the electricity mix.

On average, an individual water heater consumes about 1,500 kWh per year. Assuming a useful life of 15 years, it results in 22,500 kWh. One way to avoid indirect emissions from the use of electricity is to implement solutions that use renewable energy sources. For example, more and more hotels are installing individual solar thermal hot water systems. Their main objective is to reduce energy costs, but this also greatly mitigates the environmental impact. There are companies that already offer solar thermal hot water systems. Investment costs are usually amortized in a few years and maintenance costs are comparatively low depending on the water quality. They are highly insulated and store hot water for a long time. In addition, they are equipped with an electrical resistance, which can be used to heat the water if there is no sun for two days or more.

The following is a comparison of the electric water heater technology, hot water tank, versus a solar thermal system. The great energy and monetary savings of the solar thermal option are apparent. In this case, only the indirect emissions, due electricity, are considered since there are no refrigerants.

Table 13: Comparison of examples of conventional electric hot water heaters vs. solar thermal hot water systems.[90]

Type	Conventional electric heater	Heater Solar thermal system
Average energy consumption (kWh/year)	1500	500[91]
Average energy consumption (kWh/lifetime)	22,500	7,500
Lifetime average indirect emissions	1,26 toneladas de CO_2eq	0,42 toneladas de CO_2eq
Average equivalent environmental impact of a vehicle in kilometers traveled	4,529 km	1,510 km
Average lifetime electricity consumption costs in US$ *	US$ 3,875	US$ 1,292
Lifetime monetary savings in US$	----------	US$ 2,583

* Values converted from Costa Rican colones to US$ using the average currency exchange rate from August 2021 (US$ 1 = ~618 colones)

89 For the past five years, close to 98% of the electricity in Costa Rica has been sourced from renewable sources.
90 For all assumptions and calculations, please see Annex 1.
91 This figure depends on location, hours of sunshine, days of sunshine and amount of hot water use. In many regions and for average use, this number will probably be much lower, which translates into much greater potential energy and economic savings.

Photo 31: Example of a solar-thermal hot water system, © GIZ, Philipp Denzinger

The Costa Rican company Thermo Solutions offers solar thermal systems which use the existing air conditioning (AC) unit to produce hot water.[92]

The AC refrigerant extracts heat from the room air. This heat is usually expelled through the outdoor condensing unit. In this system, the heat or part of it is transferred to an insulated hot water tank. On average, an air conditioning unit can produce about 150 liters per day of hot water, which is sufficient for a 5-person household or a hotel room. Therefore, if the air conditioner is used for a few hours a day, there is no additional energy demand to heat the hot water. This system can be highly efficient, and even six times more efficient than the classic thermo showers.

Novel research explores the concept of alternative solutions to further decrease the environmental impact. Professor Michael Stanimirov of the Technological University of Panama comments that a system that works in the opposite direction could be generated. In this case, a thermosolar system would be used to generate hot water to such an extent that would drive the operation of the air conditioning system. The remaining or excess water could be used for showers.[93]

In tropical countries, circumstances such as relatively stable annual temperatures, recoverable rainwater, heat in the ground, combined with frugal habits in the use of air conditioning, offer great opportunities for innovation. Alternative, energy-saving, efficient and environmentally friendly hot water heating systems exist in the market and new variants and improvements are constantly being developed. This is another of the many steps towards carbon neutrality.

92 Costa Rica Solar Solutions, n.d.: Green Heat by Thermo Solutions
93 Stanimirov, M., 2020: Clean Energy Air Conditioning Systems Course

10 Conclusion

The demand for air conditioning and space cooling solutions from the hotel sector will undoubtedly increase as a collateral effect of climate change. Air conditioning and refrigeration equipment are already a major source of harmful emissions to the environment, and ironically the more the global temperature rises, the emissions from this sector will increase. Hence, it is very important to consider and implement green alternatives that exist in this sector to reduce the resulting impacts as much as possible. Many of the conventional and harmful technologies are in a process of elimination or disuse in accordance with global climate agreements. This implies, that the procurement of inputs such as refrigerants will become more and more expensive, making early technology transition an advisable step.

This publication identifies and compares the different green technology alternatives that exist, and fundamentally highlights the difference between environmental and economic impacts of each type of equipment. In refrigeration equipment, it shows how green technologies are already present in the market, and that, despite the initial investment costs, the equipment is profitable at the end of its life due to its high efficiency. Green alternatives for air conditioning equipment are not easily available in some countries. However, a supply for such equipment is present. The dilemma comes down to who takes the first step, the supply, or the demand.

Several efforts have been made to make these green technologies relevant in the market. Split air conditioners have been installed and have been highlighted by good performance and low energy consumption. Also, in the GIZ partner countries many instructors and technicians have been trained in the handling of hydrocarbon-based refrigerant gases, specifically R-290 and R-600a.

As discussed, alternative efficient air conditioning and refrigeration systems are existing and market-ready. They are a cost-effective alternative and in Europe, Asia and other regions, these alternative systems are already widely used. However, it is the consumer who must demand this type of equipment. Besides the environmental benefits there are other advantages, such as the costs and a good image that can be sold to customers. Refrigerants must be recovered and recycled, and insulation materials containing HCFC blowing agents must be properly destroyed.

If a hotel's objective is to have a neutral carbon footprint, it needs to start purchasing alternative systems of this type. It is recommended to contact your suppliers or GIZ Proklima if you need more information about potential green technology providers. Any planned investment is an investment in the future of the planet. So why not voluntarily invest in alternative systems now?

This publication recommends hotel managers, owners, and proprietors:

- Use refrigerants with ultra-low GWP (less than 10), such as natural hydrocarbon-based refrigerants.
- That the equipment contains ultra-low GWP (less than 12) foaming agent isolators, preferably produced from natural refrigerants.
- Use equipment with a high energy efficiency index (SEER greater than 19), or low kWh/day consumption. The equipment should use Inverter technology in the compressor.
- Minimize damage to the environment, the ozone layer and the climate, equipment and facilities in hotels that have reached the end of their life cycle must be dismantled in accordance with national and international standards.

Thank you for making the planet a greener place!

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Annexes

Annex 1. Regarding the environmental calculations in the comparative tables (Tables: 4, 5, 6, 7, 9, 10, 11, 12)

Type	The type of equipment (commercial refrigeration, AC mini split or other), whether it is conventional or green technology, and a distinguishing feature (volume in feet^3 in the case of refrigeration or freezing equipment, and BTU/h in the case of AC) is specified. Examples are sought to be presented, there is no attempt to promote any of the items. There are other companies that sell this equipment. There is no intent to favor or disfavor any store. Data not referenced to a catalog were obtained through physical visits to different points of sale of each type of equipment.
Brand/model	Brand and model of the equipment to be analyzed.
Refrigerant	Refrigerant substance used by the equipment. Usually, HFC or HC based.
GWP	Global Warming Potential (GWP) of the refrigerant used. This index is basically a conversion factor of a kilogram of the substance to kilograms of CO_2 equivalent, a unit designed to assess the environmental impact of different substances.
ODP	The ozone depletion potential (ODP) of the refrigerant used. This index refers to the amount of stratospheric ozone destruction caused by a substance. In this document, present only in HCFC type refrigerant gases. HFC and HC gases have zero ODP.
Refrigerant charge	Amount in mass (grams or kilograms), which uses the equipment. Usually, natural refrigerants have a higher energy efficiency, equipment with natural refrigerants usually have a lower load than a traditional refrigerant equipment for the same application, cooling capacity or volume.
Average accumulated refrigerant	The amount of refrigerant used at the end of the equipment's useful life. This amount considers the possible refrigerant recharges that may be required by an equipment. In AC this is routinely done for leaks (conventional technology) and in refrigeration equipment a single full refrigerant recharge may be needed. In the case of hermetic refrigeration equipment, it is assumed that there is no leakage during service life. However, even some of this equipment leaks during its service life. For AC split and condensing equipment, an average leakage rate of 2% was assumed at installation, and an average annual leakage rate of 10% and 95% at end of life, based on a detailed leakage study for Costa Rica.[94] An annual leakage rate of 5% was assumed for the chillers and 95% at the end of the useful life.

94 GIZ, 2020: Study of leaks in split air conditioning equipment in Costa Rica.

Average energy consumption (kWh/year)	DOES NOT APPLY IN ALL CASES. Value obtained from the technical specifications of equipment whose use is not strongly influenced by user habits, such as refrigeration equipment that is always plugged in. In AC equipment, whose energy demand depends on the user's habits, this data is not determined for the scope of this document.
Lifetime average direct emissions	The amount of refrigerant accumulated in kg CO_2 eq. is converted by multiplying this figure by the GWP. This represents the cumulative environmental impact of dismantling the equipment at the end of its useful life. This is an approximate calculation.
Lifetime average indirect emissions	It is obtained by multiplying the energy consumption (kWh/year) by the number of years of the useful life of the equipment, and all this multiplied by the emission factor of the electrical grid (kg CO_2 eq/kWh). At the end we obtain a figure with unit kg CO_2 eq. The power grid emission factor is a measure of how friendly are the energy sources of the power grid from which the equipment takes the electrical energy. Since this publication is based on a former publication about natural refrigerants in the Costa Rican hotel sector, the power grid emission factor of Costa Rica is used for the calculations. The calculations in this guide use a value of 0.056 kg CO_2 eq/kWh, which is an average for the years 2014-2019. This is an approximate calculation.[95]
Lifetime average total emissions (direct and indirect)	The sum of direct and indirect emissions in kg CO_2 eq. This is an approximate calculation.
Average equivalent environmental impact of a vehicle in kilometers traveled	For a compact vehicle (sedan), whose engine runs on gasoline, approximately 278 kg CO_2 eq are emitted per 1,000 kilometers of travel.[96]
Average lifetime cost of electricity consumption	DOES NOT APPLY IN ALL CASES. Approximate calculation by multiplying the energy consumption (kWh/year) by the useful life of the equipment. The data is then multiplied by the electricity tariff. For the purpose of this document, the monthly rate T-CO: Commercial and Services of 106.42 colones per kWh for consumption less than or equal to 3,000 kWh was used. This data is published by ICE in Scope No. 65 Gazette No. 60 of March 26, 2021.[97] If the energy consumption data (kWh/year) is not available, this data is not presented.
Lifetime average monetary savings	NOT APPLICABLE IN ALL CASES. Estimated by multiplying the difference in **average lifetime electricity consumption costs** between conventional equipment and green equipment. This difference is multiplied by the years of useful life and then multiplied by the electricity rate. If you do not have the data of **energy consumption (kWh/year),** it can be considered that, roughly speaking, the difference in energy efficiency between equipment operating with HFC refrigerant and another operating with HC refrigerant, is about 15%. This difference in energy efficiency is reflected in 15%[98] lower operating costs for electricity consumption in equipment with HC refrigerants.

95 IMN, 2020: Greenhouse gas emission factors.
96 EPA, 2021: Greenhouse Gas Equivalencies Calculator.
97 Grupo ICE, 2021: Tarifas Actuales.
98 Sheikh, Mujahid; Qureshi, Mohd Abuzar, 2015: Comparative Analysis of Energy Efficiency Ratio & Electric Power Consumption of Domestic Refrigerator using Refrigerant R134a & R600a at Constant Evaporator Temperature.

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