Non-state action towards climate-friendly and energy-efficient cooling

Assessing the potential of major end-user industries

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

Imprint

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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Bonn and Eschborn, Germany

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Programme/project description:
Cool Contributions fighting Climate Change (C4)/ Proklima

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Acknowledgement for Review and Input:
Philipp Munzinger, Denise, Andres, Daniela Boos,
Leon Becker, Alireza Saadatfar, Maraida Licerio,
Maike Kauffmann, Nicole Müller (GIZ GmbH)
Sashika Kaluwahewa (Jetwing Hotels)
Olaf Schulze (METRO Group)
Dietram Oppelt (HEAT GmbH)

Acknowledgement:
We thank the Federal Ministry for the Environment,
Nature Conservation and Nuclear Safety (BMU)
for their comments that greatly improved this publication.

Design/layout:
INFOGRAFIK PRO GmbH – www.infografik.pro

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GIZ is responsible for the content of this publication.

Printed on 100% recycled paper, certified to FSC standards.
Eschborn, 2018

Abstract

This paper seeks to inform policy makers and other stakeholders in Cool Contributions fighting Climate Change (C4) partner countries about the potentials offered through both top-down and bottom-up approaches to promote effective mitigation action in key RAC subsectors. It looks in particular at certain **end-users** of cooling technologies as important potential **non-state** actors whose technology choices can have significant impact on current and future RAC sector emissions. A focus is placed on three relevant end-users of RAC equipment: supermarkets, cold stores and hotels. Through in-depth sector studies, the paper provides a better understanding of the mitigation potential, ownership structures, technology options and decision-making processes prevalent in these end-user industries. The analysis also looks at existing non-state activity in the specific subsectors and provides a basis for enhanced mobilisation and coordination of non-state action in C4 partner countries (Costa Rica, Grenada, Iran, Philippines, Vietnam), supporting long-term transformation in the RAC sector towards sustainable, low-carbon development. Key results of the study include the recognition that to date, only few non-state actor driven initiatives exist that specifically target the RAC sector. Yet, taking timely action on HFCs is likely to bring multiple benefits for end-users of cooling technologies. It is thus important to address the barriers and challenges that non-state actors face when engaging in mitigation action in the RAC sector, for example through the formation and support of alliances. At the same time, it must be kept in mind that non-state action is not a “silver-bullet” to the climate challenge, but needs to be accompanied by effective, mandatory regulation from the side of the government.

Table of contents

List of Tables

List of Figures

Table of Abbreviations

1	3PLs	Third-Party Logistic Providers
A	AC	Air Conditioning
	AGRA	Alliance for Green Revolution in Africa
B	BAU	Business-As-Usual
	BEEC	Building Energy Efficiency Code
	BMUB	German Federal ministry for the Environment, Nature Conservation, Building and Nuclear Safety
C	C4	Cool Contributions fighting Climate Change
	CCAC	Climate and Clean Air Coalition
	CCAP	Cold Chain Association of the Philippines
	CCH	Costa Rica Hotel Association
	CE	European Conformity
	CGF	Consumer Goods Forum
	CHTA	Caribbean Hotel and Tourism Association
	CO_2	Carbon dioxide
	COP	Conference of the Parties
E	EC	European Community
	EE	Energy Efficiency
	EU	European Union
F	F-gas	Fluorinated Greenhouse Gases
G	GCCA	Global Cold Chain Alliance
	GFAN	Green Freight Asia Network
	GHG	Greenhouse Gases
	GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
	GSTC	Global Sustainable Tourism Council
	GWP	Global Warming Potential
H	H_2O	Water
	HACCP	Hazard Analysis and Critical Control Point
	HCFC	Hydrochlorofluorocarbon
	HCMI	Hotel Carbon Measurement Initiative
	HEAT	Habitat, Energy Application & Technotlogy
	HFC	Hydrofluorocarbon
	HRAP	Hotel and Restaurant Association of the Philippines
	HVACR	Heating, Ventilation, Air Conditioning and Refrigeration
I	IACSC	International Association for Cold Storage Construction
	IARW	International Association of Refrigerated Warehouses
	ICE-E	Improving Cold Storage Equipment in Europe
	ICR	International Congress of Refrigeration
	IFS	International Featured Standards
	IHA	Iran Hotel Association
	IHEI	International Hotels Environmental Initiative
	IKI	International Climate Initiative of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
	IPEEC	International Partnership for Energy Efficiency Cooperation
	ITA	International Trade Administration
	ITP	International Tourism Partnership
	IWLA	International Warehouse Logistics Association

L	LED	Light-emitting Diode
	LEED	Leadership in Energy and Environmental Design
	LPI	Logistics Performance Index
M	MEET-BIS	Mainstreaming Energy Efficiency through Business Innovation Support
	MENA	Middle East & North Africa
	MEPS	Minimum Energy Performance Standards
	MIT	Mitigation
	MP	Montreal Protocol
	MVE	Monitoring, Verification and Enforcement
N	NAZCA	Non-state Actor Zone for Climate Action
	NDC	Nationally Determined Contribution
	NEECP	National Energy Efficiency and Conservation Program
	NGO	Non-governmental Organization
P	PEEP	Philippine Energy Efficiency Project
	PHOAI	Philippine Hotel Owners Association
R	RAC	Refrigeration, Air conditioning
S	SE4All	Sustainable Energy for All
	SLoCat	Sustainable, Low Carbon Transport
	SME	Small and Medium-sized Enterprise
	STEP	Sustainable Tourism Eco-Certification Program
T	TEWI	Total Equivalent Warming Impact
U	UK	United Kingdom
	UNEP	United Nations Environmental Programme
	UNESCO	United Nations Educational, Scientific and Cultural Organization
	UNFCCC	United Nations Framework Convention on Climate Change
	UNICEF	United Nations International Children's Emergency Fund
	US	United States
V	VNEEP	Vietnam Energy Efficiency and Conservation Program
W	WBCSD	World Business Council for Sustainable Development
	WFLO	World Food Logistics Organization
	WTTC	World Travel & Tourism Council

1. Introduction

The Cool Contributions fighting Climate Change (C4) project aims to contribute to an accelerated implementation of an international regulation of F-gases, a strengthened and clustered cooperation between various F-gas initiatives, and the advancement and exemplary implementation of Nationally Determined Contributions (NDCs) in the Refrigeration and Air Conditioning (RAC) sector of the partner countries.[1] Such a transformational change in the sector requires climate-friendly solutions that avoid the use of F-gases and push for increased energy efficiency. Mitigation activities in the sector hence target direct greenhouse gas (GHG) emissions from the refrigerants themselves as well as indirect emissions associated with energy use of refrigeration equipment.

From a top-down perspective, the recently adopted Kigali Amendment to the Montreal Protocol establishes a framework that ensures progressively more stringent controls on the use of hydrofluorocarbons (HFCs) to further reduce HFC emissions. The Kigali Amendment can work alongside the Paris Agreement to obtain the level of emission reductions needed to achieve the internationally agreed 'well below 2°C' global warming limit. In this context, it is crucial to understand the relationship between the Kigali Amendment and the NDCs presented by countries in the context of the Paris Agreement. Since several countries mention HFCs in their NDCs, a better understanding needs to be developed where action on HFCs, e.g. through NDC implementation, will be truly additional and where the ambition level in the sector can be increased.

Taking a bottom-up perspective, non-state action has proven to have an impact on global emission reductions that can go beyond countries' political commitments communicated in their NDCs.[2] Also in the RAC sector, non-state action can help realise additional mitigation potentials towards global climate goals. This paper looks at relevant end-user industries as one of the key non-state actor groups in this sector that can drive behavioural change and more ambitious emission reductions on the demand side. For policymakers, it is important to understand how these actors can be mobilised.

A number of industries are particularly relevant end-users of cooling technologies, including, for example, tourism, retail, fast food, data centers and food processing industries. Their technology choice, which is often highly influenced by ownership structures (i.e. concentrated/ family-owned vs. dispersed ownership), has a significant influence on current and future GHG emissions. As such, end-user industries are instrumental in increasing the dissemination of climate-friendly technologies, shifting away from the use of F-gases in refrigeration and air conditioning and improving energy efficiency. A better understanding of the mitigation potential, ownership structures and related technology choices as well as decision-making processes in relevant end-user industries can help policymakers to mobilise non-state action in the design and implementation of national mitigation strategies in the RAC sector.

This paper seeks to inform policy makers, in particular those in C4 partner countries, about potentials offered through both top-down and bottom-up approaches to promote action on HFCs and energy efficiency in key RAC subsectors. A focus is placed on how in particular non-state action can contribute to closing the emissions gap.[3] It casts light on the actual contribution of the Kigali amendment towards the international climate target (Chapter 2), provides an overview of current non-state action in the sector (Chapter 3) and a more detailed analysis of mitigation potentials, feasibility and scalability of non-state action in key demand sectors (Chapter 4). With this understanding, the paper drafts recommendations to encourage participation from the end-user industries, for example in the form of non-state initiatives or alliances within and across sectors, and/ or in the form of collaborative initiatives that involve public sector institutions (Chapter 5). Specific recommendations are made on how to drive non-state action and form alliances in the five C4 partner countries (Chapter 6). At the end, key messages of each chapter are summarised in a conclusion (Chapter 7).

1 C4 partner countries are Costa Rica, Cuba, Grenada, Iran, Philippines, and Vietnam. Activities in Cuba, however, are still pending an official agreement and have not started yet.

2 See Graichen et al. 2016. Climate initiatives, national contributions and the Paris Agreement, available at: https://newclimateinstitute.files.wordpress.com/2016/05/discussion-paper-sbsta-final.pdf, last access July 2018.

3 According to the latest UNEP Gap Report (2017), the Paris Agreement has indeed incentivised action at scale by the public and private sectors. Nevertheless, countries' NDCs – which present the cornerstones of the Paris Agreement – cover only approximately one third of the emissions reductions needed to be on a least-cost pathway towards the 2°C goal (UNEP, 2017).

2. The role of non-state action to advance the climate and ozone agenda

Tarties to the Montreal Protocol (MP) agreed in Kigali in October 2016 to globally phase down HFCs. The Kigali Amendment envisages a stepwise reduction of the consumption and production of HFCs between 2019 and 2045, based on baselines, freeze dates and individual HFC phase-down schedules for different country groups. This agreement on a global HFC phase-down has been broadly acknowledged as providing momentum for the Paris agenda and as a good demonstration of action that can be used to close the emissions gap.

Complementarity of the ozone and climate agendas

Even though the Kigali Amendment to the Montreal Protocol and the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) are separate treaty regimes, HFC management under the Kigali Amendment shows substantial overlap with actions taken under the UNFCCC. Since the ozone and the climate regime include similar mandates to "protect the atmosphere from anthropogenic emissions that affect adversely human health and the environment" (UNEP Ozone Secretariat, 2016), they offer a fundament for synergies and mutually supportive action.

While the UNFCCC establishes a framework for emission reductions of all GHGs not controlled by the MP, including HFCs, actions under the UNFCCC focus on GHG emission reductions in general and do not set specific targets for HFCs. The Kigali Amendment, on the other hand, puts in place control measures for the production and consumption of HFCs but does not explicitly address GHG emission reductions from HFCs and other energy use related emissions. Against this background, it is currently being discussed to which extent controls of HFC production and consumption under the Kigali Amendment can enhance efforts to reduce HFC emissions under the UNFCCC and play a bigger role in achieving the global climate target.

Role of HFCs in NDCs

In order to make use of potential synergies, mitigation actions in HFC related sectors under the Kigali Amendment should be aligned with mitigation actions under the Paris Agreement as set forth in countries' NDCs.

The Paris Agreement does not indicate which specific GHGs should be included in the NDCs, giving countries the flexibility to address or not address HFCs as long as total emission reductions contribute to the overall goal of limiting global warming to well below 2°C. In the first submission round, most countries addressed all major national GHG emissions, with 83 out of 197 Parties explicitly mentioning HFCs in their NDCs. However, hardly any country has included specific mitigation measures for HFC related emission reductions in its NDC. In addition to HFC emissions, consideration must be given to energy efficiency efforts associated with the use of cooling appliances and equipment. Energy savings from cooling appliances present significant potential in terms of GHG emissions reductions. However, the picture is similar to the HFC situation: while many NDCs reference energy efficiency (e.g. in the power sector or for electrical appliances), most lack specific targets and clear policies that recognise the potential of energy savings to help countries realise their climate targets. It should be noted that detailed implementation plans do not necessarily have to be included in a country's NDC but might rather be part of (sector) level implementation strategies which map out the process to achieve overall national targets.

Estimated additional impact of the Kigali Amendment

There is limited research on the actual impact of the Kigali Amendment on global warming. Early studies suggest that HFC emissions could, in the absence of any additional regulation, result in 0.35-0.5°C of warming by 2100 (Xu et al., 2013). This range has been used to estimate the potential impact of the Kigali Amendment, which would accordingly result in a 0.5°C global warming benefit.

The estimated warming benefits of the Kigali Amendment are based on scenarios that model HFC emissions in the absence of any further climate policies. Hence, these scenarios do not take into account action planned in countries' NDCs. Given that most countries cover all major GHG emissions in their NDCs, including HFCs, there is reason to believe that mitigation action under the Paris Agreement already includes action on HFCs to a certain extent. This is especially the case where NDCs are defined as economy-wide emission reductions of all GHGs. Consequently, the Kigali Amendment can be assumed to be only partially additional to projected emission reductions under the Paris Agreement. Nevertheless, the Kigali Amendment provides a valuable framework for GHG emission reductions that can work alongside the Paris Agreement, by locking in effective action on HFCs and support countries with the implementation of their NDCs.

Relevance of non-state action in the RAC sector

To date, neither top-down measures under the Montreal Protocol nor under the UNFCCC have yielded the required results in terms of limiting global warming. Together, the countries' RAC sector specific contributions as part of their NDC pledges and the estimated emission reductions related to countries' HCFC phase out, HFC phase down or energy efficiency plans are still insufficient to deliver a fair sectoral share to limit global warming to well below 2°C (EESI, 2009; Grunbaum, 2015). It is generally agreed that there is considerable scope to strengthen efforts to reduce HFC emissions and improve energy efficiency by including ambitious actions in countries' NDCs. Bottom-up activities initiated and executed by relevant end-user industries – 'non-state actors' – that go beyond current regulatory and policy requirements set by national governments, are central for tapping this potential. Non-state action can be led by single actors, such as companies or investors, or include several actors within and across sectors, in a non-state collaborative initiative or alliance[4]. Such initiatives or alliances can include other stakeholders, for example non-governmental organisations, but also international organisations like UN Environment, UNICEF and others that often assume a coordinating role even though they might not be considered as 'non-state actors' in the strict sense (ICAT, 2017).

Recent analysis on climate change action has shown that those bottom-up activities can play an important role towards reducing global emissions and ultimately reinforce national policy action (Graichen et al., 2016). It is important in this context to differentiate between additional bottom-up initiatives led by non-state actors and broader non-state action under existing policies. Indeed, the vast majority of climate mitigation activities on the ground are effectively 'non-state': regulated and mandated by governments but implemented by non-governmental entities. The focus of this paper, however, is placed on additional emission reductions that go beyond current regulatory and policy requirements and that have been triggered by non-state initiatives in relevant end-user industries (see Table 1).

While non-state initiatives are already well established in some sectors, few bottom-up initiatives specifically target the RAC sector. Especially end-users of cooling technologies, as a specific group of non-state actors, are likely to have an impact on GHG emissions and emission reductions through technology choices that take – or do not take – the use of HFCs in refrigeration and air conditioning as well as energy efficiency into account. Successful initiatives led by companies that use advanced cooling technologies may challenge governments, financial institutions and other stakeholders to develop and deploy energy-efficient and climate-friendly technology solutions at the required scale. By forming alliances with other actors, strong synergies may emerge that advance and enhance progress on both the technical and the policy side, facilitating and accelerating transformational processes throughout the sector. It is therefore useful to take a closer look at a number of relevant end-user industries, their mitigation potential as well as decision-making processes. On this basis, recommendations for the mobilisation of these actors can be derived and more ambitious mitigation action in the RAC sector achieved, ultimately helping countries to meet and go beyond their climate targets.

4 In this paper, alliance is understood as a formal or informal agreement between a group of actors to cooperate for a specific purpose. Alliances can include only state- or non-state actors or both. In the context of this paper, we understand alliance as a form of non-state initiative, comprising several non-state actors or even a number of initiatives.

3. Mapping of non-state action in the cooling sector

Non-state action in the RAC sector can be understood as additional efforts or commitments for emission reductions by companies that go beyond existing policy regulations mandated by a government. Non-state initiatives can be led by manufacturers of RAC equipment or refrigerants, end-users in the cooling sector and/or a mixture of both. Such actions can form non-state initiatives that may focus on reduction of HFCs or increasing energy efficiency, or both. Participation from public stakeholders such as civil society, organizations, and governments can also be observed in such non-state initiatives.

The mapping in this chapter focuses on non-state action by end-user industries in the RAC sector, defined as the final users of RAC equipment and refrigerants. End-user industries have been chosen due to their critical influence on industry standards and supply chains from the demand side perspective. Changes in their demand structure can accelerate the uptake of climate-friendly technologies in the market and exert pressure on governments to improve regulatory conditions.

There are only a few bottom-up initiatives specifically targeting the cooling sector by defining explicit targets for HFCs or energy efficiency[5]. Analysis from the major and publicly available international databases on non-state action, such as the UNFCCC-hosted 'Non-state actor zone for climate action' (NAZCA) or the UN Environment-hosted Climate Initiatives Platform, shows that non-state action in the cooling sector covers the entire value chain spanning producers of chemical refrigerants, manufacturers of refrigerant appliances and end-user industries (Table 1).

Table 1 shows that all initiatives have a specific target for the reduction and/or phase-out of HFCs. Their actual contribution towards HFC abatement, however, is less clear.

Graichen et al. (2016) estimate that Refrigerants, Naturally! has contributed to the avoidance of 33 million metric tonnes of CO_2eq and could potentially avoid 60 Mt CO_2eq if the initiative's target is met. The same study also stated that the contribution from the Climate and Clean Air Coalition (CCAC) could reach 450 Mt CO_2eq in 2030. Potential contributions from the other initiatives have not been determined so far and no information is available on their contribution to date.

5 Several non-state actors and/ or initiatives included here for their cooling sector relevance might also have other climate targets, e.g. CO_2 related ones. However, the focus of this paper is placed on HFC and energy efficiency related targets which are central to effectively address cooling sector emissions.

6 This includes several sub-initiatives, such as the Global Refrigerant Management Initiative and the Global Food Chain Council, which have a focus on non-state action. For more information please visit: http://www.ccacoalition.org/en/initiatives/hfc.

7 http://www.ccacoalition.org/en/resources/hfc-initiative-factsheet, last access July 2018.

Initiative	Stakeholders involved	Target(s)	Mitigation impact and/ or potential	Source
Alliance for Responsible Atmospheric Policy	100 businesses; an industry coalition representing more than 95% of U.S. HFC production and a significant majority of user industries.	Support of policies and actions with the goal to reduce global HFC emissions by 80% by 2050.	N.a.	alliancepolicy.org
Climate and Clean Air Coalition (CCAC)[6] – HFC initiative	Governments, intergovernmental organisations, NGOs, businesses; led by UN Environment.	Implementation of policies that deliver substantial reductions of short-lived climate pollutants by 2030; including a 30-50% reduction of HFCs by 2025 in the refrigerant servicing sector.	Up to 450 Mt CO_2eq in 2030 (Graichen et al., 2016).	ccacoalition.org/en/initiatives/hfc
Consumer Goods Forum	15 manufacturing and retail companies.	Phase-out of HFCs and increase in energy efficiency.[7]	N.a	theconsumergoodsforum.com/sustainability-strategic-focus/climate-change/refrigeration
eurammon	Companies and institutions in the field of refrigeration and natural refrigerants.	Boost the awareness and acceptance of natural refrigerants, promote their use in the interest of a healthy environment, continue developing a sustainable approach to refrigeration.	N.a.	eurammon.com
European Partnership for Energy & the Environment (EPEE)	40 member companies, national and international associations.	Promote a better understanding of the heating, ventilation, air conditioning and refrigeration (HVACR) sector in the EU and contribute to the development of effective European policies in order to achieve a long-term sustainability agenda.	N.a.	epeeglobal.org
Refrigerants, Naturally!	Coca Cola, Unilever, PepsiCo, Red Bull; supported by Greenpeace and UN Environment.	Promote implementation of climate-friendly, natural refrigerants through encouraging best practices and the development of a regulatory framework that facilitates investment. Initial goal: 10 million HFC-free refrigeration units installed by 2020.	By October 2016, installation of 5.5 million unites using natural refrigerants worldwide, preventing the emission of 33 million metric tons (Mt) of CO_2e. Full mitigation potential: 60 Mt CO_2e per annum (UN Global Compact, UNFCCC and UNEP, 2016).	refrigerantsnaturally.com

Table 1: Mapping collaborative non-state initiatives with a focus on HFCs

Company	Relevant RAC end-user sector(s)	Target(s)	Mitigation impact	Source
Aeon	Supermarket	Decrease leakage from refrigerant substances, use natural refrigerants.	Estimated energy saving effect: about 20 % compared to HFC refrigerants; Estimated GHG emissions reduction: 813 t CO_2eq; of that: indirect GHG reduction: 60 t CO_2eq; direct GHG reduction: 753 t CO_2eq (2015 compared to 2011).	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2016-CGF-Refrigeration-Aeon-Case-Study.pdf
Ahold Delhaize[10]	Supermarket	Ahold: Decrease leakage from refrigerant substances. Delhaize: Reduce leakage, increase use of natural refrigerants. 20 % emission reduction by 2020 compared to 2008, i.e.149 kg CO_2eq/m² (equivalent emissions from refrigerants per m² sales area). Increasing the share of ozone friendly refrigerants from currently 73 % to 85 % in 2020	Ahold: In 2014, leakage of refrigerant substances decreased by 34 % compared to 2010 to a total of 5.5 % of total installed base. Delhaize: 25 % reduction of refrigerant emissions per m² sales area from 2013 to 2014 (in Luxemburg and Belgium; 15 % in the United States (US)).	Ahold: theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Ahold-Case-Study.pdf Delhaize: theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Delhaize-Case-Study.pdf aholddelhaize.com/media/6440/supplementary-report-on-sustainable-retailing-performance-2016.pdf
Carrefour	Supermarket	Reduce emissions by 40 % by 2025 compared to 2015.	No tangible results reported (BUT good reporting on how to make transition happen).	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Carrefour-Case-Study.pdf
Heineken	Food processing	Replace HFCs by hydrocarbon refrigerants; replace standard lighting by LED illumination; introduce an energy management system; install energy-efficient fans.	In 2015, energy savings of 45 % compared to 2010.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Heineken-Case-Study.pdf
ICA	Supermarket	Use of natural refrigerants is a standard.	Almost 10 % of the 1,300 ICA stores in Sweden are using 100 % natural refrigerants. The total equivalent warming impact (TEWI) reduction exceeds 40 % on all new ICA store profiles since 2009. For refrigeration systems, the reduction is 50-60 %.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-ICA-Case-Study.pdf
Marks & Spencer	Supermarket	Reduce GHG emissions from UK and Ireland store refrigeration by 80 % by 2020. Replace HFCs by 2030.	Since 2007, GHG emissions from refrigeration equipment in UK and Ireland stores were reduced by 73 %; energy efficiency in stores was improved by 35 % per square foot.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Marks-and-Spencer-Case-Study.pdf
METRO	Supermarket	Reduce emissions from refrigerant leakage by 29 % by 2020.	Leakage rate from METRO Cash & Carry fell from 14.6 % in 2014 to 11.0 % in 2015 in worldwide refills, including accidents.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Metro-Case-Study.pdf

Table 2: Mapping single end-user non-state action with a focus on HFCs[8,9]

Company	Relevant RAC end-user sector(s)	Target(s)	Mitigation impact	Source
Nestle	Food processing	Phase-out of the use of high-GWP refrigerants such as HFCs) and replacement with safe and natural refrigerants.	Replacement of synthetic refrigerants with natural alternatives in more than 92 % of industrial refrigeration systems. For commercial applications, in 2014, all new ice cream chest freezers in Europe used natural refrigerants. New ice cream chest freezers (70 % of Nestlé's total) consume 50 % less energy.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Nestle-Case-Study.pdf
PepsiCo	Food processing	All future point-of-sale equipment (coolers, vending machines and fountain dispensers) purchased in the US will be HFC-free by 2020. PepsiCo also joined a private-sector initiative led by the Obama administration to reduce cumulative global consumption of HFCs by the equivalent of 700 million Mt CO_2e by 2025.	In 2014, improved efficiency of vending machines by 53 % and by 67 % for coolers compared to 2004. Additionally, from 2013 to 2014, decreased supply chain GHG emissions by 205,000 metric tonnes CO_2eq.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-PepsiCo-Case-Study.pdf
SABMiller[11]	Food processing	Reduce CO_2 emissions across value chain by 25 % by 2020, based on a 2010 baseline; no purchase of any HFC fridges beyond 2020, where technologically and financially feasible.	In Europe, up to 85 % of new fridges purchased in 2015 have been HFC free; in Latin and Central America, nearly 19 % of new fridge purchases were HFC free, in Africa about 8 %.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-SABMiller-Case-Study.pdf
Sobeys	Supermarket	Phase out HFC refrigerants and use natural refrigerant alternatives in new buildings by 2015.	Reduced GHG emissions by 800,000 kg CO_2eq less per store per year. In addition, reduction of energy costs, maintenance and installation costs. Comparing to a traditional HFC system, the use of a natural refrigerant system enables: GHG emissions: -62 %; installation cost reductions: up to -15 %; electric energy use: up to -15 % heating gas savings: up to 20 %.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Sobeys-Case-Study.pdf
The Coca-Cola Company	Food processing	Phase out the use of HFC refrigerants in cold drink equipment across global value chain.	Placed a total amount of 1.7 million units of HFC-free equipment globally. Total HFC-free installations will prevent the emission of approximately 9 million Mt CO_2eq over 10 years.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-The-Coca-Cola-Company-Case-Study.pdf
Unilever	Food processing	Minimize the contribution of freezers to climate change.	Since 2004, replacement of point-of-sale ice cream freezer cabinets with climate-friendly hydrocarbon refrigerants, which are 10 % more energy-efficient. EE gains of the freezers bought in 2013 avoided around 40,000 tons of CO_2 emissions compared to 2008 models.	theconsumergoodsforum.com/files/resources/sustainability/refrigeration-case-studies/2015-CGF-Refrigeration-Unilever-Case-Study.pdf

8 Information for table 2 is extracted from the Consumer Goods Forum, available at: http://www.theconsumergoodsforum.com/sustainability-strategic-focus/climate-change/refrigeration/case-studies, last access July 2018.

9 Information for table 2 is extracted from the Consumer Goods Forum, available at: http://www.theconsumergoodsforum.com/sustainability-strategic-focus/climate-change/refrigeration/case-studies.

10 Ahold and Delhaize merged in July 2016. However, latest information from the Consumer Goods Forum on HFC related action of the two companies dates from 2015. Information on the individual companies is therefore included here.

11 Please note that SAB Miller has merged with AB Inbev in late 2016 and thus no longer exists as an independent company.

Information on individual non-state action led by single companies in the end-user industries is only available for larger supermarkets, companies engaged in food processing and/ or operating large stores for beverages (Table 2). One of the most important supra-regional databases in this context is the one operated by the Consumer Goods Forum. Respective information for other relevant sectors, for example hotels, is not available in this database, even though such initiatives might exist in some countries.

It is important to note that while individual company initiatives tend to be more specific and their targets more ambitious, all identified individual actions are already part of wider initiatives. Therefore, while the mapping includes individual non-state actions, the further analysis will concentrate on non-state collaborative initiatives.

In addition to the examples of collaborative and single-actor initiatives with a focus on HFCs, several cooperative initiatives exist which do not focus on HFCs per se but are closely related and could eventually be extended to cover also the cooling sector. The most promising opportunities exist for initiatives that are broadly linked to increasing energy efficiency (Table 3). Many of those initiatives bring

Initiative	Sector(s)	Stakeholders involved	Target(s)	Source
Global Buildings Performance Network	Buildings, Energy Efficiency	Extensive partnerships with international organisations, governments, industry, research institutes and NGOs.	Contribute to the building sector achieving its full energy savings and CO_2 mitigation potential of more than 2.1 Gt by 2030.	http://www.gbpn.org/
Green Freight Asia Network (GFAN)	Transport (freight)	25 manufacturers and logistic companies.	Advance sustainable freight in Asia. Enhance collaboration to share best practice and jointly scale up green freight efforts. Ensure active participation of the private sector in the development of national green freight policies. Develop consistent methods for measuring and reporting fuel use and GHG emissions from road freight and establish a database with verified data.	http://greenfreightasia.org
Haga Initiative	Food processing, cold stores, manufacturers	15 companies	Reduce 40 % of carbon emissions from the business sector by 2020 and show that ambitious climate strategies lead to business advantages and improve profitability.	http://hagainitiativet.se/en/
Hotel Owners for Tomorrow	Tourism, hotels	Hotel owners, Hotel Companies, Industry Bodies, and Media & Hotel Development	5 actions, e.g. including sustainability considerations from the beginning of investment decisions and evaluating one renewable energy project and one efficiency project per year.	http://www.hotelsfortomorrow.org/
International Partnership for Energy Efficiency Cooperation (IPEEC)	Energy efficiency related sectors	Governments with active participation from businesses and financial institutions; co-leads G20 working group on energy efficiency.	Accelerate the adoption of energy efficiency policies and practices.	https://ipeec.org/
Logistics Carbon Reduction Scheme	Transport (road)	125 companies	8 % reduction in emissions intensity by 2015, based on 2010 levels.	http://www.fta.co.uk/policy_and_compliance/environment/logistics_carbon_reduction_scheme.html

Table 3: Mapping collaborative non-state initiatives with a potential to include HFCs

together not only a group of companies, but also governments, multilateral organisations and NGOs among others.

In general, non-state collaborative initiatives offer the advantage that they can bring together a critical mass of companies behind a common goal and can thus attract more attention than individual commitments. At the same time, when multiple actors work together, they can reinforce each other, and the mitigation impact can be higher than when working in isolation. Both individual and collaborative non-state initiatives are particularly relevant where regulatory and policy frameworks are not sufficiently stringent and are lagging behind actual potentials for action in the sector. A good example for the effectiveness of non-state action is the US, where in June 2017 the federal government under President Trump announced to formally withdraw the US from the Paris Agreement and to stop the implementation of the country's NDC. However, recent analysis shows that commitments by sub-national and non-state actors would already take the US around halfway towards achieving the higher end of its NDC by 2025 (NewClimate Institute and The Climate Group, 2017).

Initiative	Sector(s)	Stakeholders involved	Target(s)	Source
Low Carbon Technology Partnerships initiative	Renewables, transport, agriculture, forestry, buildings, cement, chemicals	160 companies and 70 partners, led by the World Business Council for Sustainable Development (WBCSD).	Scale up deployment of business solutions to a level and speed that are consistent with limiting global warming to below 2 degrees.	http://lctpi.wbcsd.org/
One million tons of cold storage initiative	Agriculture	Alliance for Green Revolution in Africa (AGRA), UPL India and governments.	Mobilise USD 2 billion in the next decade to create integrated value chains; reach 15 million farmers over the next decade, impacting 100 million people across Sub-Saharan Africa.	http://agrinatura-eu.eu/2016/05/one-million-tons-of-cold-storage-initiative-launched/
Partnership on Sustainable, Low Carbon Transport (SLoCat)	Transport	Multi-stakeholder partnership of over 90 organizations (UN, multilateral and bilateral development organizations, NGOs and foundations, academia and the business sector).	Mobilise global support to promote sustainable, low carbon transport and thereby reduce the growth of GHG emissions generated by land transport in developing countries. Comprises various sub-initiatives.	http://www.slocat.net/
SAVE FOOD	Food, waste, packaging	300 members, including global enterprises, organizations and research institutes.	Drive innovations, promote interdisciplinary dialogue and spark off debates in order to generate solutions across the entire value chain "from field to fork".	https://www.save-food.org/
Science-based targets initiative	All	315 Companies	Company targets in line with a 2°C goal.	http://sciencebasedtargets.org/
Sustainable energy for All (SE4All): Global Energy Efficiency Accelerator Platform	Energy Efficiency related	Governments, UN, businesses and civil society.	Support of three interlinked objectives: 1) provide universal access to modern energy services; 2) double the global rate of improvement in energy efficiency; 3) double the share of renewable energy in the global energy mix.	http://www.se4all.org/energyefficiencyplatform
We Mean Business coalition	All	Large group of companies and investors.	A number of sub initiatives, including e.g. adoption of a science-based target; commitment to improve energy productivity.	https://www.wemeanbusinesscoalition.org/
World Global Building Council	Buildings, Energy Efficiency	Network of 74 global Green Building Councils and their 27,000 members, primarily companies.	Reduce the building and construction sector's CO_2 emissions by 84 Gt. Ensure all buildings are net zero emissions.	http://www.worldgbc.org/

4. Analysis of Focus Sectors

4.1 Identification of Focus Sectors

To identify end-user groups relevant for reducing GHG emissions from cooling appliances, this paper first creates a picture of the various RAC subsectors and the size of their cooling-related emissions. In a second step, a longlist of end-user groups identifies the most 'promising' subsectors in terms of reduction potential. The third step then entails a rough qualitative analysis of the longlisted end-user groups to identify three demand sectors to be analysed in more detail in the following chapter.

The estimated highest share of emissions in the RAC sector in 2015 are in the subsectors of unitary air conditioning and mobile air conditioning, followed by commercial refrigeration, industrial refrigeration, domestic refrigeration and chillers. Transport refrigeration is listed separately with a small overall contribution to total emissions (Figure 1).

For each of the subsectors, specific applications and systems are used. For example, centralised systems, condensing units, and stand-alone equipment are used in the commercial refrigeration subsector. Figure 1 also illustrates the particular contributions to the estimated total emissions by applications and systems. Therefore, it provides a more differentiated picture and further insight as to where relevant

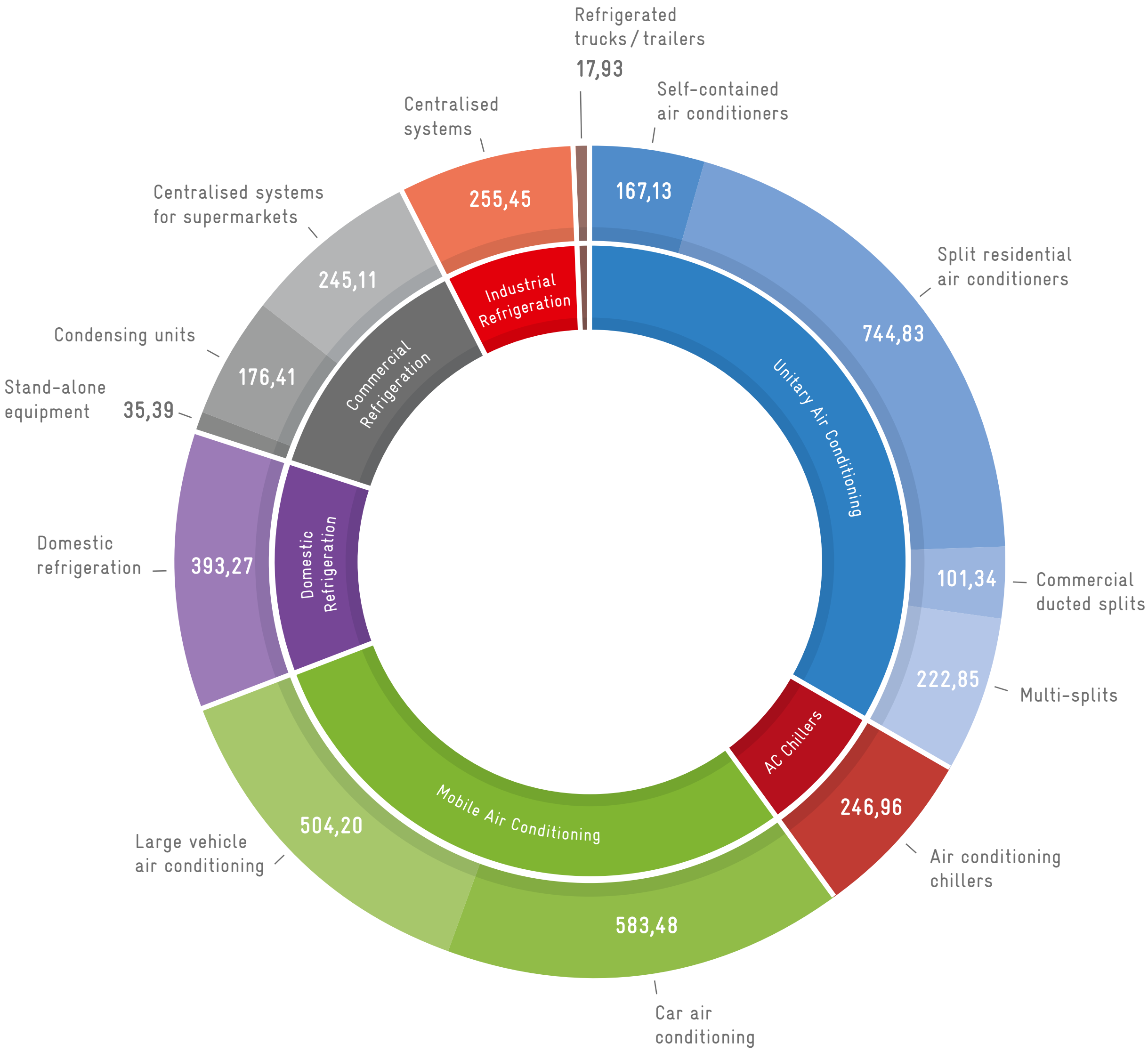


Figure 1: Estimated total emissions by system in 2015 in Mt CO_2eq (Data: Green Cooling Initiative)

end-user groups might be located. The analysis then proceeded to look for specific end-user groups with a relatively large share of systems and corresponding emissions.

The following table provides an overview of typical end-user groups in the various subsectors and applications for which the emissions were quantified above.

Subsector	Application	Typical end-user groups		
Unitary air conditioning	Self-contained air conditioners	• Private households	• Individual stores (food retail and others)	
	Split air conditioners	• Private households • office buildings (including with dedicated server rooms)	• small cornershops • doctors, rural health centers • hospitals	• hotels • banks • universities • (airports)
	Ducted splits	• Small businesses (including with dedicated server rooms)		
	Multi-splits	• Stores (food retail and others)	• businesses (including with dedicated server rooms)	• private households
Chillers	Air conditioning chillers	• Hotels • airports • universities	• businesses operating large office buildings (including with dedicated server rooms)	• shopping centers • data centers • hospitals • textile industry
Mobile air conditioning	Car air conditioning	• Private individuals • car rental and taxi companies	• companies with large car fleets	• (all via the car manufacturers)
	Large vehicle air conditioning	• Public and private bus companies	• companies operating fleets of trucks/delivery vehicles	
Domestic refrigeration	Refrigerators, freezers, refrigerator/ freezer	• Private households • small shops	• offices (kitchens) • hotels	
Commercial refrigeration	Stand-alone equipment	• Convenience stores • supermarkets	• cold-drink and ice-cream manufacturers • gas stations	• bars and restaurants (including fast food) • rural health centers
	Condensing units	• Cold stores • Small businesses (selling drinks, food, flowers, growing flowers) • gas stations	• bakeries, butchers (stores and manufacturing) • hotels • restaurants (including fast food)	• hospitals • discounter stores • cafeterias/kitchens (e.g. in office buildings)
	Centralised systems for supermarkets	• Supermarkets	• hypermarkets	
Industrial refrigeration	Centralised systems	• Cold stores • pharmaceutical production	• food processing facilities (dairies, breweries, meat, fish processing)	
Transport refrigeration	Refrigerated trucks/trailers	• Logistics companies (refrigerated road transport)	• supermarket chains (operating their own truck fleet; or delivery vehicles)	
	Refrigerated containers	• Logistics companies (refrigerated cargo on ships)	• food producers • supermarkets	
	Refrigeration for ships or vessels	• cruise ships	• fishery	• ferries

Table 4: Typical end-user groups for RAC applications

This paper on non-state action specifically aims to address business interests for advanced climate action. For this reason, the paper focuses on the applications and systems operated by businesses and commercial end-users rather than the public sector or households. Domestic refrigeration, car air conditioning as well as unitary air conditioning in private homes were not further considered. Other end-user groups where larger numbers are organized in chains seem more relevant and reachable for efforts to mobilise private sector action collectively (e.g. through alliances). Using this approach, the following "longlist" of end-user groups was identified:

1. **Data centres:** Opposed to server rooms, data centres are separate buildings dedicated to the operation of computer servers, network and storage hardware. Data centres incorporate cooling, back-up power, fire suppression and security systems. They range from small modular data centres to individual, company owned facilities, to large industrial scale operations.

2. **Server rooms:** A server room is a separate room for the operation of computer servers as may be needed within office buildings. Those rooms are part of a building and have a dedicated air-conditioning or ventilation system.

3. **Cold stores:** Cold stores cover commercial establishments in the logistics industry that store food and other perishable products in one or more controlled temperature zones (frozen food at up to -20°C, chilled food at 0 to 4°C, flowers typically at 5 to 7°C) for preservation. They range in size from small (<10.000 m^3) to medium (10.000 to 40.000 m^3) to large and very large cold stores (>40.000 m^3). The cold stores considered here are separate warehouses located along the cold chain in between the production and the delivery to the retailer or end-user. Walk-in cold storage rooms that are part of supermarkets, hotels, or food production facilities are not considered.

4. **Food retail stores:** Food retail stores can be grouped into minimarkets (or convenience stores), supermarkets, and hypermarkets with corresponding floor sizes of approximately less than 200 m^2, 200 to 2000 m^2, and above 2000 m^2. Stores of all three categories offer a variety of food products, parts of which must be stored chilled or frozen, and additional ranges of household products. This study focuses larger supermarket chains.

5. **Fast food restaurants:** Fast food restaurants serve mass-produced, 'fast' food and have minimal table service. Foods are pre-processed and stored for easy servings. Although all restaurants with quick services could be called fast food restaurants, only fast food chains with many restaurants operating under the same name and offering standardised menus, such as McDonalds, Starbucks, Subway, to name a few, are considered here. A focus is placed on the refrigeration equipment of a restaurant, not the entire supply chain.

6. **Hotels:** Hotels primarily provide lodging for tourists or other travellers. They may also provide restaurant services and other services to their guests. They range from individual, family-run businesses to multinational chains. The sector is part of the hospitality or wider tourism industry. Hotels are usually classified from 1 to 5 (or above) stars. Hotels with 3 stars and above are in focus here. They typically have central air conditioning and ventilation systems, room refrigerators and kitchen refrigeration equipment. Smaller hotels in warmer climates primarily have room air conditioning systems.

7. **Refrigerated cargo on ships:** A reefer ship is a refrigerated cargo ship used to transport perishable commodities which require temperature- and humidity-controlled transportation (frozen or chilled), such as fruit, meat, fish, vegetables, dairy products, flowers and others. In a fully refrigerated ship, or reefer, all cargo spaces are refrigerated; otherwise it is called a partial reefer. The refrigerated holds are generally those closest to the machinery spaces.

8. **Refrigerated road transport:** Vans, trailers, heavy and small trucks with a capacity of refrigerated space typically between 3.5 to 7.5 tonnes used to transport products such as plants, flowers, foods and pharmaceutical products. Currently around 12 million of these vehicles are in use worldwide.

9. **Food processing:** A variety of food processing involves refrigeration technologies in various production stages as well as during the storage or transport of products. Controlled temperature zones are essential to ensure food safety and durability. Included are dairies, breweries, fish and meat processing as well as production of ready-to-eat and frozen food products. Considered are food processing plants including their storage space but excluding transport.

For this study, three end-user sectors were selected based on the relevance that can be expected for most countries: Cold stores, food retail stores (with a focus on larger supermarket chains) and hotels. Specifically, these sectors were selected based on the analysis of the following factors:

- GHG mitigation potential in each sub-sector;
- Ease of implementation of mitigation options;
- Scalability of mitigation options;
- Relevance of the mitigation potential in each C4 partner country.

The mitigation options in the three selected focus sectors are

- The cold store market is rapidly growing in developing countries (Burnson, 2016); As alternative solutions, CO_2 and ammonia as cascade systems, or also pure ammonia chillers are possible; there is also a high energy saving potential through automated control systems (Dohlen, 2010).

- Hotels could use absorption and hydrocarbon chillers, hydrocarbon room ACs, and refrigerators as alternative cooling systems; improvements are also possible by lowering the cooling demand through building optimisation such improved building architecture with better natural shadowing and air ventilation or system optimisations allowing the automatic adjustment of the cooling supply to the respective cooling demand of the building. In the case study of the Jetwing hotels group in Sri Lanka, the potential of reduced GHG through improved energy efficiency and building design are highlighted (Wright, 2014); the green image is quite important for hotels with numerous certification opportunities and labels.

- Supermarkets have various green cooling options: hydrocarbon standalone (plug-in) equipment, display units, hydrocarbon chillers or centralised systems using CO_2 (EIA, 2016); there is also a large energy saving potential; the green image is already very important for supermarkets in developed countries and related initiatives could be expanded to developing countries.

In the detailed analysis in chapters 4.2 to 4.4, the three groups are described in terms of their size, organisation, existing initiatives and typical set-up with regard to RAC equipment. They are also examined more closely considering the potential to mobilise non-state action. Specific information from expert interviews, where available, is included. Regarding the mitigation potential, an exemplary quantitative analysis is also provided. Each sector analysis is developed along the following structure:

- Sector description
  - Structure and size
  - Initiatives and policies
  - Common system types and refrigerants

- Mitigation potential
  - Alternatives and efficiency improvements
  - Emissions and mitigation scenarios

- Ease of implementation
  - Technology trends – availability and financial implications
  - Barriers and solutions

- Scalability and relevance in C4 partner countries
  - Sector in C4 countries
  - Relevant networks

Overview 1: Climate-friendly and energy-efficient cooling in supermarkets

Reduce heat load, switch to high efficient technology options using natural refrigerants and improve operations for green cooling

Minimize heat gain

by improving thermal insulation in refrigeration equipment with climate-friendly panels and foam

Cyclopentane

Minimize heat gain

by ensuring enclosing and efficient insulation of appliances

Double or triple glazing

Cabinet doors

Reduce heat load of building

by optimizing building design and improving building envelope insulation with low-GWP foam

Natural foam blowing agents

Reduce additional heat load

by minimizing time of open door

Automatically closing supermarket doors

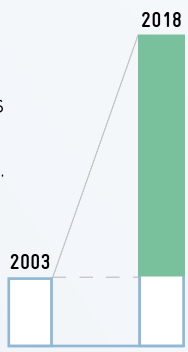
Key facts

Cooling systems typically account for about 40-60 % of the total energy consumption in a supermarket.

Energy Consumption: **40 – 60 %**

Retail sales in developing countries have increased more than 350 % in the last 15 years and now represent more than half of total global retail sales.

Retail Sales: **+350 %**



Cooling Source

Heat Source

Raise green cooling awareness

and enable monitoring by using proper labelling for RAC products and equipment

Information

(Eco) Labelling

Use green cooling appliance

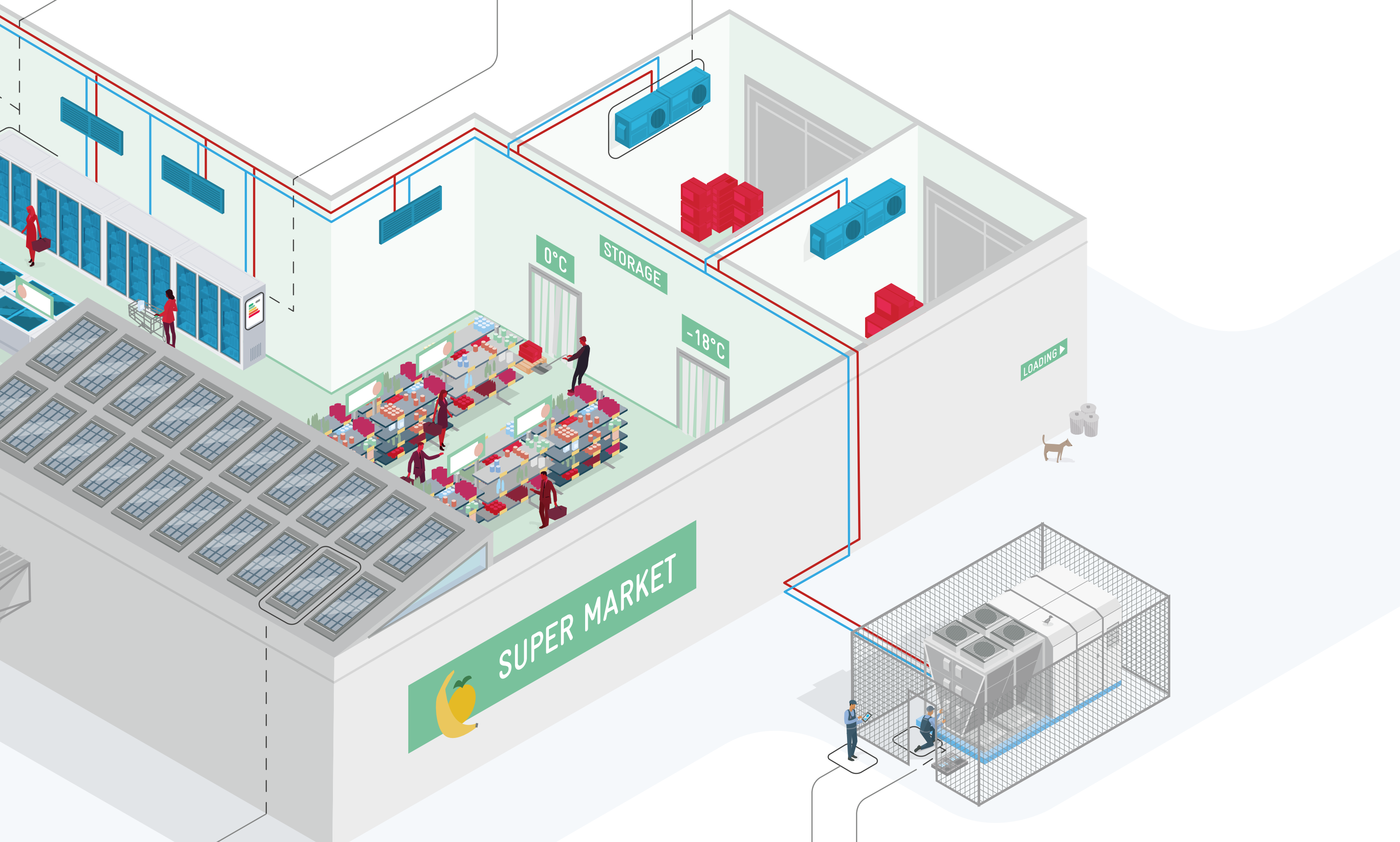
by installing energy-efficient refrigerated stand-alone furniture with low-GWP refrigerants

R290	R600a	R717
R1270	R601a	CO2

Use green refrigeration appliances

by adopting an energy-efficient and low-GWP cooling system

R744	CO_2	CO_2	Cascade systems
R290	R1270	R717	



Supply system with green energy

by using renewable energy systems and heat waste recovery to further reduce indirect emissions

Photovoltaic systems

Avoid refrigerant leakage

by servicing equipment by trained and certified RAC technicians, ensuring efficient operation

Ensure professional handling

of appliances by training and certification of contractors, operators, and servicing staff in dealing with new technologies

4.2 Focus Sector: Supermarkets

4.2.1. Brief Sector Description

Food retail stores are typically structured into small, medium sized and very large outlets. This structure can be found in many countries globally, both in developed and developing countries. In most cases, RAC appliances found in these stores have distinguished configurations:

- Small stores (< 200 m²), minimarkets, normally only have stand-alone RAC appliances;
- Mid-sized stores (200 to 2000 m²), supermarkets, have stand-alone appliances, condensing units or smaller-sized central systems;
- Large stores (> 2000 m²), hypermarkets, have centralized systems in addition to stand-alone appliances and condensing units.

Among these store types, this paper focuses on supermarkets, being the category with the most significant number of stores and mitigation impact regarding use of refrigerants and energy consumption across the number of stores.

Structure and sizes of supermarket chains

Typical sizes of larger supermarket chains range from owning several dozens to more than a thousand stores. The strongest global players (see Table 5) own several hundred stores distributed across continents and the globe, but also predominantly national or regional players with more than a thousand stores exist, e.g. South African Pick N' Pay. Some global players penetrate regional and local markets with subsidiary companies. Supermarkets are typically operated through larger chains. In more developed countries these chains then also own, operate or control the selection of the RAC appliances. In less developed countries, stand-alone appliances are often directly owned by and operated through product brands like Coca-Cola or Unilever.

Typical decision makers concerning the use of RAC equipment of supermarket chains are technical directors, technology & innovation/sustainability managers or sales managers. Depending on the internal structures, they may have to forward technical proposals to their managing director or board of directors for final decisions.

Initiatives and policies

Climate-friendly RAC appliances in supermarkets can be addressed through initiatives and policies to reduce both direct emissions by shifting to natural refrigerants and indirect emissions by increasing energy efficiency.

The EU F-Gas Regulation is a main driver in Europe for the supermarket sector's transformation to green cooling technologies. A ban of HFCs with a GWP above 150 will be enforced from year 2022 for "multipack centralised[12] refrigeration systems for commercial use with a rated capacity of 40 kW…[13]" and above (Table 6, Regulation (EU) No 517/2014). Significant systems used in large supermarkets are considered in this paper. Other HFC bans stipulated by Regulation (EU) No 517/2014 with relevance to the commercial refrigeration sector are also listed in Table 6.

The EU F-Gas Regulation also requires proper labeling of RAC products and equipment. Otherwise their placement on the market is not permitted. To obtain the recognized CE mark for their products, manufacturers must submit an EC declaration which includes the specification of applied standards and regulations. In this context, Directive 2009/125/EC established Ecodesign requirements for the energy efficiency of products and equipment.

Some countries, e.g. Spain, have taken further measures, such as negative incentives for the use of fluorinated gases in order to encourage supermarket chains to convert their stores to non-fluorinated refrigerants. Outside of Europe, other industrial countries have also started to accelerate the transition to low-GWP, non-HFC refrigerants. An example is Japan with its Japanese Fluorocarbon Regulations. The Japanese retailer Aeon's has been promoting the switch to CO_2 systems since 2011 (EIA, 2016).

Name	Origin	Number of countries, main target markets	Revenue (in billion US$)	Number of stores
Walmart Stores, Inc	U.S.	27 countries incl. Argentina, Brazil, Canada, Chile, China, Mexico, UK, US	486	> 11,000
Tesco PLC	U.K.	12 countries across Europe, Asia and North America	101	> 7,000
Carrefour	France	33 countries, mainly Europe, also Argentina, Brazil, China, Arabian countries	99	> 10,000
METRO	Germany	31 countries, mainly Europe and Asia	86	> 2,000
Aeon Ltd.	Japan	12 countries, mainly Asia	63	> 12,000

Table 5: World's largest food retailers by revenue (Food Retail World, 2012; UFCW, 2012; Listovative, 2015)

Equipment		Date of prohibition
Refrigerators and freezers for commercial use (hermetically sealed equipment)	that contain HFCs with GWP of 2,500 or more	1 January 2020
	that contain HFCs with GWP of 150 or more	1 January 2022
Stationary refrigeration equipment, that contains, or whose functioning relies upon, HFCs with GWP of 2500 or more except equipment intended for application designed to cool products to temperatures below -50°C		1 January 2020
Multipack centralised refrigeration systems for commercial use with a rated capacity of 40 kW or more that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1500 may be used		1 January 2022

Table 6: HFC bans under EU F-gas Regulation with relevance to commercial rerigeration (Source: EU Regulation No. 517/2014.)

In contrast to being forced through legislation, many large food retail chains have adopted early voluntary action to shift to climate-friendly and energy-efficient appliances as part of their sustainability programs as well as to benefit from the favorable properties of natural refrigerants and achieve energy savings. Such initiatives are most prominently supported through the Consumer Goods Forum (CGF) and the non-governmental organization (NGO) Refrigerants, Naturally!. In developed countries, consumer goods companies are already being critically monitored by consumers and environmental NGOs regarding their climate and environmental footprint. Publically listed companies are urged to transparently report and lower their carbon footprint. Many companies are realising that acceptance of their products increases if they proactively pursue sound climate and environmental behavior. The transition to climate-friendly and energy-efficient commercial refrigeration can be highly rewarding with relatively low costs.

Common system types and refrigerants

As outlined at the beginning of this chapter, different RAC appliances are installed in food stores related to their size. With regard to the refrigerant handling, centralized systems and condensing units are charged on site, whereas self-contained or stand-alone units are often pre-charged by the manufacturer. The centralized systems used in supermarkets centrally connect all refrigerated furniture in a store through the circulation of a refrigerant (direct expansion systems), chilled water or another heat transfer medium in a secondary circuit (indirect systems). Various units used to cool food and beverages range from dedicated compartments, cabinets, freezers, to display refrigerators, bottle coolers etc. Each unit operates with a set temperature which may range from +12°C to below -20°C. The most common conventional, fluorinated refrigerants in use are R-134a, R-404A and R-22. The HCFC phase-out under the Montreal Protocol along with the HFC phase-down as envisioned by the Kigali Amendment, and the Paris Agreement all drive the global need to move to climate-friendly and energy-efficient refrigeration appliances.

4.2.2. Mitigation Potential

Alternatives and efficiency improvements

The use of alternative systems aims at lowering both direct (or refrigerant related) and indirect (or energy consumption related) greenhouse gas emissions.

Through the mandatory phase out or phase down of HCFCs and in some countries and regions already also for HFCs, the transition to alternative, low-GWP systems has already become obligatory.

As for larger stores (i.e. cooling demand approximately ≥ 40 kW), the primarily used non-fluorinated alternative is CO_2, especially in the food retail sector. In warmer climate zones, CO_2 transcritical[14] technology has experienced a boost in use during the last three years. After its technological advances, CO_2 transcritical technology has become the standard for medium to large supermarkets today in moderate climate zones. Recent energy efficiency improvements include parallel compression, boosters, ejectors, sub-coolers and adiabatic cooling. Such advances also mark a breakthrough for the application of multi-ejector CO_2 technology in warmer climate zones (Hafner, 2016; Öko-Recherche, 2016; shecco, 2016). The multi-ejector technologies allow for an improved heat exchange which results in better energy efficiency performance compared to conventional HFC-404A systems even in hot climates. Other variations are cascade systems where CO_2 serves as a heat transfer medium and either hydrocarbons or ammonia as refrigerants, e.g. by CO_2/HC290, CO_2/HC1270

12 'multipack centralised refrigeration systems' means systems with two or more compressors operated in parallel, which are connected to one or more common condensers and to several cooling devices such as display cases, cabinets, freezers or to chilled store rooms (Regulation (EU) No 517/2014).

13 "…except in primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1,500 may be used".

14 Transcritical is a thermodynamic state where the fluid is no longer a liquid or a gas; transcritical CO_2 passes through this state.

or CO_2/ammonia. These components also serve to extend the operating range to higher ambient temperatures with the higher critical temperatures of hydrocarbons or ammonia with possibly improved energy efficiencies. Ammonia, which is mainly known from its use in large-scale industrial applications, has also proven useful at commercial scale by forming the cascade to the primary CO_2 circuit providing energy savings. Due to its toxic properties, its use is subject to strict safety regulations. Thermal storage and the utilization of waste heat for the heating of other parts of the building are further general considerations for energy efficiency improvement measures. The complexity of technology increases with the integration of additional components, making elaborate solutions less favorable for smaller chains where the multiplying effect is low (Öko-Recherche, 2016; shecco, 2016).

The supermarket chains Albert Heijn, Makro (both based in Netherlands), Aldi Nord/Süd, Kaufland, METRO (German), Auchan, Carrefour (French), Aeon, Lawson (Japanese), Coop, Migros (Swiss), Pick N Pay, Woolworths Holdings Ltd (South African), Tesco, The Co-operative, Waitrose (UK), and Walmart (US) have been identified as the leaders of adopting CO_2 technology in recent years with international outreach (EIA, 2014, 2016a, 2017). Tesco and Auchan have implemented various CO_2 cascade systems while Carrefour and many others have focused on transcritical CO_2 systems. On the other hand, Save On (Japanese), Tesco and others have also adopted hydrocarbon technology by using HC-290 as refrigerant (EIA, 2014, 2016, 2017; shecco, 2016).

Recently, a shift to lower GWP systems has taken place regarding the focus of HFC-free technological innovation, more to smaller stores and their special needs in warmer climate zones. Therein, CO_2 condensing units or larger hydrocarbon stand-alone refrigeration systems play an important role. Smaller stores also adopted hydrocarbon solutions, for example as plug-in units using HC-290 as refrigerant (EIA, 2016).

Another important aspect for lowering refrigerant related emissions is the minimization of leakage. Developing countries typically have high leakage rates leading to inefficient operation of RAC systems as well as high direct emissions where high-GWP refrigerants are used. Regarding the ambition to lower indirect emissions and to improve energy efficiency, the installation of doors on refrigeration compartments and display refrigerators is also important. Many key players still have not installed doors on their units given their concerns of sales impacts. Both issues have been tackled in past years on different levels but are still far from being implemented as a worldwide standard (EIA, 2014; shecco, 2016).

Emissions and mitigation scenarios

For a simple modelling of emissions and mitigation scenarios, an average set of conventional RAC equipment was assumed for an exemplary supermarket, such as could be found in warmer climates, e.g. in the Philippines. The direct and indirect emissions were calculated based on an estimated set of parameters, such as cooling capacity, runtime per year, COP, lifetime and refrigerant charge, for each equipment type (see Table 7).

For the mitigation scenario, a reduction of direct emissions using alternative green technologies, i.e. a change of refrigerants to natural refrigerants, and a reduction of indirect emissions through 20 % improvement of the energy efficiency (COP) were considered. This improvement, for instance, could be achieved by better thermal insulation or by installing doors on the refrigerator compartments.

The assumption for the exemplary supermarket in the medium size range from 200 to 2,000 m² using conventional technology is that the market operates the following cooling equipment to cool food and drinks:

Indirect emissions: Considering the cooling capacity, average COP, and runtime of the equipment, the market would consume 215,360 kWh/a. Considering the Philippines grid emission factor (Brander et al., 2011), this amounts to indirect emissions of 113 t CO_2 per supermarket per year.

Direct emissions: Considering the type of refrigerant, charge, estimated emission factors (1 % at manufacturing, 100 % at disposal, 20 % at servicing), direct emissions amount to about 9 t CO_2eq per supermarket per year.

Equipment type	further specification	COP	number of units	cooling capacity (kW) per unit	refrigerant	GWP	charge (kg)	runtime per year (h)
condensing unit	7m³	1.7	1	10.2	R-134a	1,430	4.0	5,580
condensing unit	8m³	1.7	1	11.5	R-134a	1,430	4.6	5,580
condensing unit	ca. 27m³	1.7	1	39.5	R-134a	1,430	10	5,580
stand-alone upright	1.8m³	3.5	1	2.5	R-134a	1,430	1.2	4,380
stand alone upright	3.6m³	3.5	1	5.1	R-134a	1,430	2.4	4,380
stand alone chest	300l	3.5	10	0.4	R-134a	1,430	0.16	4,380

Table 7: Assumed parameters for an exemplary supermarket

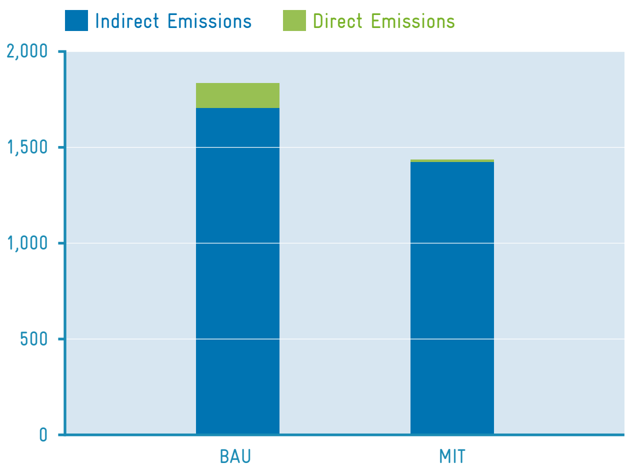


Figure 2: Mitigation potential of an exemplary supermarket (considering equipment lifetime)

Mitigation potential: If the same exemplary supermarket used R-290 as a refrigerant and increased energy efficiency by 20 %, the overall emissions would be reduced from 122 t CO_2eq per year to 94 t CO_2eq per year, or from 1,835 to 1,416 t CO_2eq considering a lifetime of 15 years as shown in Figure 2:

For the selected country cases, Vietnam, the Philippines, Costa Rica, Grenada and Iran, the country-specific grid emission factors (Brander et al., 2011) were taken into consideration. The emissions of the exemplary market were then multiplied by the number of supermarkets. The BAU- and MIT-scenarios were creating with the following assumptions:

- the total number of supermarkets increases by 10 % every 5 years;
- all new cold stores are equipped with the energy-efficient systems using low-GWP natural refrigerants;
- old equipment is replaced with new technologies in 20 % of the old supermarkets (existing in 2015) every 5 years (reaching 100 % in 2035 and all cold stores having the green cooling technology from 2035).

Table 8 provides an overview of the country-specific number of supermarkets, the estimated current total emissions of the supermarket RAC sector and its share of the country's total emissions as well as the BAU emissions and the estimated mitigation potential for the C4 countries in 2050.[15]

4.2.3. Ease of Implementation

Technology trends – availability and financial implications

Large supermarket chains usually develop their own technical solutions which are then replicated within their estate. Given the widespread corporate structure, newly developed technologies also find their way from holding companies to regional and local subsidiaries. The evolution of CO_2 and hydrocarbon technology for supermarkets has paved the way for a wide range of new technology options and commercial products in recent years. The technology development has already reached some of the most challenging climate zones including Brazil, South Africa and Australia. Woolworths Holdings Ltd. reported energy savings of 30 % from its new Crawthorne store in Johannesburg even in temperatures of up to 50°C. This was achieved mainly using transcritical CO_2 technology with parallel compression (EIA, 2016).

The introduction of non-fluorinated alternatives using natural refrigerants has demonstrated very favorable results, due to the smaller and lighter design of the HFC-free solutions which use smaller refrigerant charges and advantageous physical properties of the alternative gases (Öko-Recherche, 2014). Installations so far have shown energy savings in the range of 20 to 30 % compared to conventional technology in most common cases and even above 40 % for some elaborate solutions with favorable conditions. Initial conversions by Musgrave to hydrocarbon integral

15 This approach gives only an estimate on emissions from the supermarket sector. However, the model could possibly also be used to explore various mitigation scenarios for an individual country.

16 Number of supermarkets according to various sources (USDA, 2013b, 2013a, 2015, 2016; Batmanghelidj, 2016).

	Philippines	Costa Rica	Grenada	Iran	Vietnam
Estimated number of supermarkets in 2015[16]	523	362	5	1,335	1,400
Estimated total emissions of RAC appliances in supermarkets in 2015 in t CO_2eq p.a.	64,004	14,052	596	193,563	153,239
BAU 2050 in t CO_2eq p.a.	124,725	27,384	1,161	294,632	228,190
Estimated mitigation potential in 2050 in t CO_2eq p.a.	28,505	9,906	267	82,566	70,429
Mitigation potential 2050 in %	23 %	36 %	23 %	28 %	31 %

Table 8: Overview of RAC-related supermarket emissions in C4 countries

units, for instance, have so far achieved energy savings of 40 % compared to previous centralised systems (EIA, 2014).

Installing doors in refrigeration compartments is one of the most effective energy-saving measures. The installation of thin single glazing already reduces the thermal infiltration into the cooled or refrigerated compartments. However, energy losses can be minimized further by using double glazing with greater thickness. EIA reports an average saving of 54 % among all literature findings (EIA, 2014). A German manufacturer claims energy savings up to 55 %: Double glazing of 22 mm is promoted to more than triple the saving effect compared to 6 mm single glazing.[17] Special coatings and use of non-reflective material accomplish further improvements (REMIS, 2017).

The payback period of the investment is typically below five years and in some cases even below two years. Therefore, the shift to technology using natural refrigerants allows for long-term savings and benefits shareholders and end consumers alike (EIA, 2014, 2016, 2017).

Barriers and solutions

To successfully introduce climate-friendly and energy-efficient solutions, existing barriers need to be identified and systematically addressed on a country-specific basis. General remarks on barriers and strategies for interventions encouraging private sector participation are presented in Chapter 5.

Specifically concerning CO_2 technologies for commercial refrigeration, high ambient temperatures represent a barrier for retailers in hot countries. However, a breakthrough has been achieved for application of CO_2 technology in warmer climates by adopting transcritical CO_2 systems. This progress has become visible in France, Italy, and Spain. Transcritical CO_2 technology is predicted to continue taking a growing market share in the future: Shecco estimates an additional 6,000 new stores each year in 2018 and onward (shecco, 2016).

The case of the EU can serve as a good example where alternative low-GWP RAC technologies have been successfully introduced to the supermarket sector through regulation, incentive structures, and technology advances. With the advancement of technologies in Europe, other regions have also followed the trend. Japan as one of the technological leaders stands out with large numbers of technology shifts to alternative, non-fluorinated systems in recent years. However, no actions have been registered in the MENA region, Central Africa, and Central America up to date (shecco, 2016).

17 Comparison based on the achieved U-values: 1.1 W/m2K for triple-glazing and 3.7 W/m²K for single glazing. U-value in W/(m²K) defines the heat transition between both surfaces of a constructive element. In the EU, U-values are standardized by EN 673.

18 http://corporate.walmart.com/2016grr/enhancing-sustainability/reducing-energy-intensity-and-emissions.

19 http://www.carrefour.com/combating-waste/producing-clean-refrigeration, last access July 2018.

4.2.4. Scalability and Relevance in C4 Partner Countries

The multiplication effect of large food retail chains, e.g. Walmart[18] or Carrefour[19], can support the transformation of the entire sector to alternative low-GWP technologies for new installations and, to a significant extent, also the retrofitting of their existing systems. Cooperation with global players experienced in the use of non-fluorinated gases could close knowledge gaps and give regional and local actors access to recent technological advances.

Retailer chains which act regionally and locally in developing countries probably do not have similar access to matured technology already operating in other countries and will more likely depend on additional support e.g. by means of technology cooperation or recognized sector networks. Direct subsidiary stores and subsidiary companies of large global players based in industrialized countries are in a better position to access sustainability guidelines and corresponding technologies. The US American chain Walmart and some European chains such as Carrefour and METRO are strong players with high presence in different regions of the globe, the Japanese chains Aeon and Lawson are active in South East Asia (Food Retail World, 2012; EIA, 2014, 2016, 2017).

The C4 partner countries are primarily served by a mix of several chains at regional and local level and few subsidiary stores operated by large global players. Regarding the supply of technologies, most commercial RAC equipment is imported to C4 partner countries from the large manufacturers in each respective wider region (UNDP, 2017b, 2017a).

Relevant networks

Initiatives and networks such as the CGF provide a platform for discussion of alternatives and showcasing good examples; some are already quite well established with focus on commercial RAC equipment:

- Especially the CGF is a relevant network in the supermarket sector encouraging all actors to shift to HFC-free alternatives.
- The governments of Costa Rica and the Philippines are partners of the HFC initiative by the CCAC which pursues the promotion of climate-friendly alternatives to high-GWP HFCs.
- Various platforms (hydrocarbons21, R744.com) and activities (Atmosphere conferences etc.) provided by shecco represent a variety of system and component manufacturers providing valuable information and case studies for supermarket operators.
- Refrigerants, Naturally! is a relevant platform for the supermarket sector as it showcases the technical and economic feasibility of natural refrigerants in commercial refrigeration – with a focus on stand-alone refrigerators and freezers.

Overview 2: Climate-friendly and energy-efficient cooling in Hotels

Reduce heat load, switch to high efficient technology options using natural refrigerants and improve operations for green cooling

Increase awareness

by promoting and supporting green cooling

Information

Eco Labelling

Reduce heating of building

by improving the building insulation with foam using low-GWP foam blowers and making use of shadowing and natural ventilation

Natural foam blowing agents

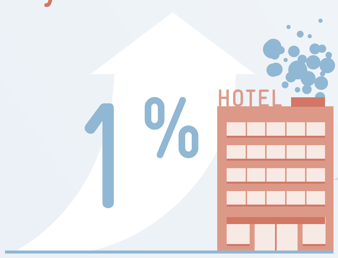
Improve window insulation

by better insulating window frames and heat-repellent windows

Double or triple glazing

Sun films

Key facts



The hotel industry accounts for around 1 % of global emissions and this is set to increase as the demand continues to grow.

Reduction: **10 – 20 %**

Improvement of technical equipment and operation can save at least 10 to 20 % of energy.

Cooling often makes more than 50 % of the energy consumption in hotels in tropical regions.

Cooling: **50 %**

Avoid refrigerant leakage

by servicing equipment with trained and certified RAC technicians, ensuring efficient operation

Use green air conditioning

by switching to energy-efficient Split Air Conditioners with low-GWP refrigerants in hotel rooms

R290	R600a	R717
R1270	R601a	CO_2

Cooling Source   Heat Source

Reduce unnecessary cooling

by integrating autonomous temperature control

Smart energy management

Use green refrigerators

by switching to energy-efficient refrigerators with low-GWP refrigerant and climate-friendly panels

Cylopentane

R290 | R600a | R717 | R1270 | R601a | CO_2

Improve coldroom insulation

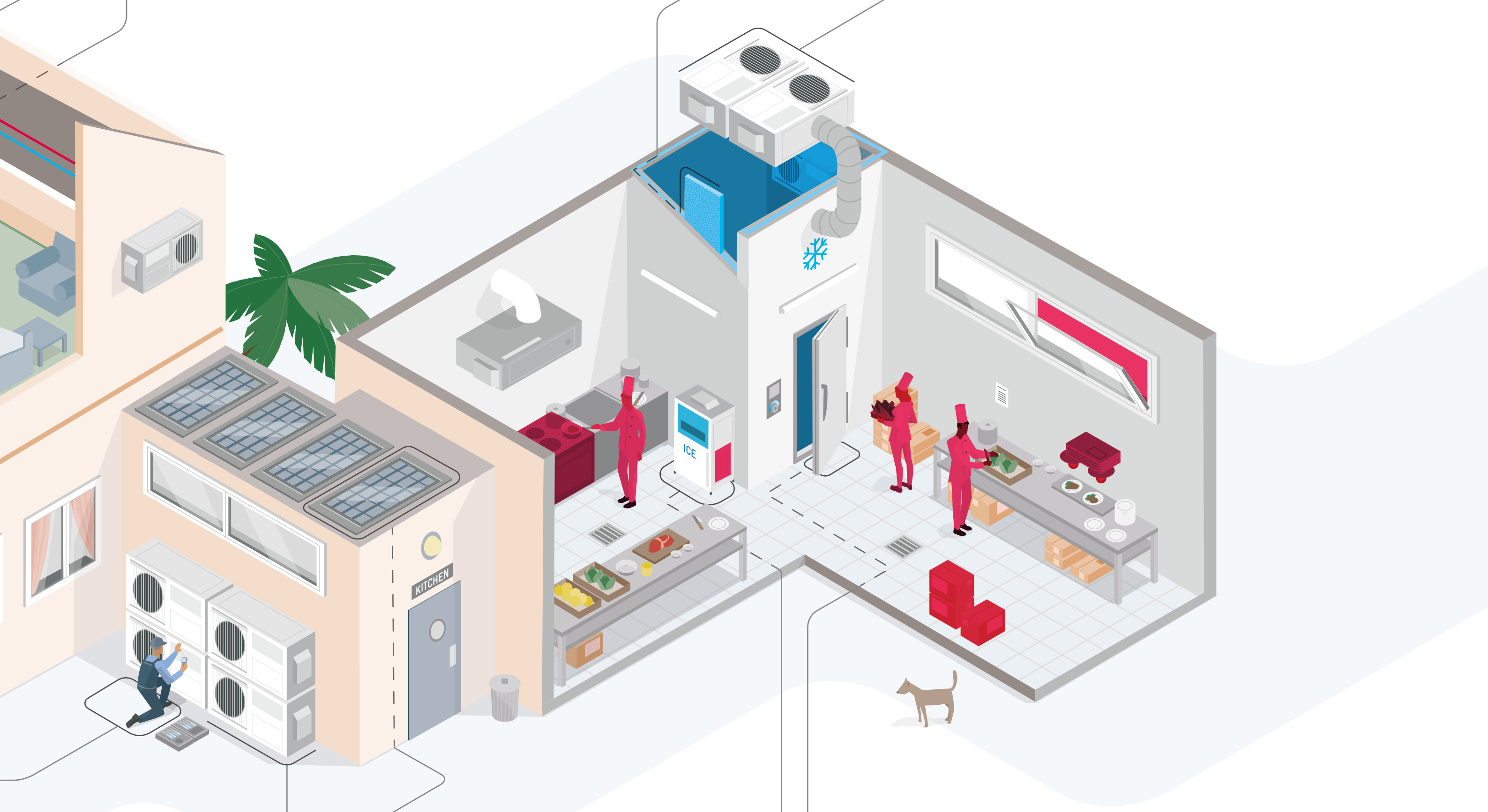
by switching to efficient coldroom climate-friendly panels

Cylopentane

Use green refrigeration

by switching to energy-efficient chillers and appliance with low-GWP

R290 | R600a | R717 | R1270 | R601a | R744



Supply system with green energy

by using renewable energy systems and heat waste recovery to further reduce indirect emissions

Photovoltaic systems

Reduce additional heat load

by minimizing time and frequency of open door

Use green cooling appliance

by switching to energy-efficient ice maker with natural refrigerants

R290 | R600a | R717 | R1270 | R601a | CO_2

4.3 Focus Sector: Hotels

4.3.1. Brief Sector Description

Hotels primarily provide lodging for tourists and business travellers. They may also provide restaurant services and other services to their guests. They range from individual, family run businesses to multinational chains. The sector is part of the hospitality or wider tourism industry. Hotels are usually classified from 1 to 5 (or above) stars. Hotels with 3 stars and above are in focus here. They typically have central air conditioning and ventilation systems. Smaller hotels in warmer climates also have room air conditioning systems. Many hotels have room (minibar) and central refrigeration systems.

To show the cooling related mitigation potential in hotels, in the following, we analyze first the structure of the hotel sector and existing initiatives in the sector to lower the carbon footprint. Exisiting and potential measures to lower the carbon footprint specifically from cooling are identified, particular in the hotel sector specifically in the C4 countries

Structure and size of hotel sector

Several major players dominate the hotel industry worldwide. They have large market shares in metropolitan centres and touristic prime destinations of virtually all countries of the world. Their hotels' capacities usually range between fifty and several hundred rooms. In the America's, chain hotels have an average 117 rooms, while independent hotels have 65 rooms on average (Ivanova, Ivanov and Magnini, 2016). The world's largest hotels – most of them in Las Vegas – have several thousand rooms. Most hotels are owned and operated by the same owner or owner group. However, leased and franchised estates also form part of managed properties. Table 9 presents the 10 largest hotel groups with number of properties they own. Most of them are US American enterprises. Most of the large hotel groups also have hotels operating in the C4 partner countries. In addition to international groups, there are thousands of regional and national players with few estates or even just one which compete to varying extents in metropolitan areas but dominate more rural areas as well as more individual touristic destinations.

Rank	Hotel Chain	Number of Properties
1	Wyndham Worldwide	8,092
2	Choice Hotels	6,429
3	Marriott International	5,974
4	InterContinental Hotels Group	5,070
5	Hilton Worldwide	4,727
6	ÂccorHotels	4,200
7	Best Western Hotels	4,196
8	Jin Jiang International	3,090
9	Home Inns	3,000
10	Motel 6	1,330

Table 9: List of largest hotel chains worldwide (Worldatlas.com, 2017)

Due to different existing ownership models in the hotel industry, the decision-making process may vary between different hotels and related chains. It usually involves a combination of general manager, owner and operator. Decisions on RAC equipment are likely to be taken through consultation with the technical facility management and, if available, environment, sustainability and corporate responsibility managers.

The general manager is the key position in a hotel, but the scope of their decision-making autonomy varies. Owner and operator have authority over several aspects of hotel operation which restrict the general manager's responsibility. In many hotels, the general manager is employed by a hotel operating firm and thus functions as an agent of the operator, owner, or both. Further important factors for the decision-making authority are the ownership structure of the hotel; i.e. whether it is independent or chain managed. Considering relevant functional areas, chain general managers have relatively greater autonomy in human resources, marketing and strategy but restricted decision-making authority in finance and operations (Hodari and Sturman, 2014).

HVS (Goldstein and Primlani, 2012) found that sustainability-related improvements in facility management are largely focused on optimizing efficiency and thereby saving operational costs in the areas of energy, water, and waste. They also identified sustainable procurement, indoor environmental quality, and staff training programmes as emerging focus areas of facility development and operations. As there is often no central procurement authority for environmental equipment and technology, the article also recommends streamlining of procurement and project implementation processes to facilitate the design and bidding and thereby achieve a greater number of retrofit projects (Goldstein and Primlani, 2012).

Initiatives and policies

In the year 2012, the Hotel Carbon Measurement Initiative (HCMI) was launched in collaboration with 23 major global hotel chains. HCMI represents a unique voluntary initiative to calculate and communicate the carbon footprint of hotel stays and meetings. A joint Carbon Measurement Working Group agreed on a standardised methodology and metrics. The initiative provides additional guidance on how to calculate hotel greenhouse gas (GHG)

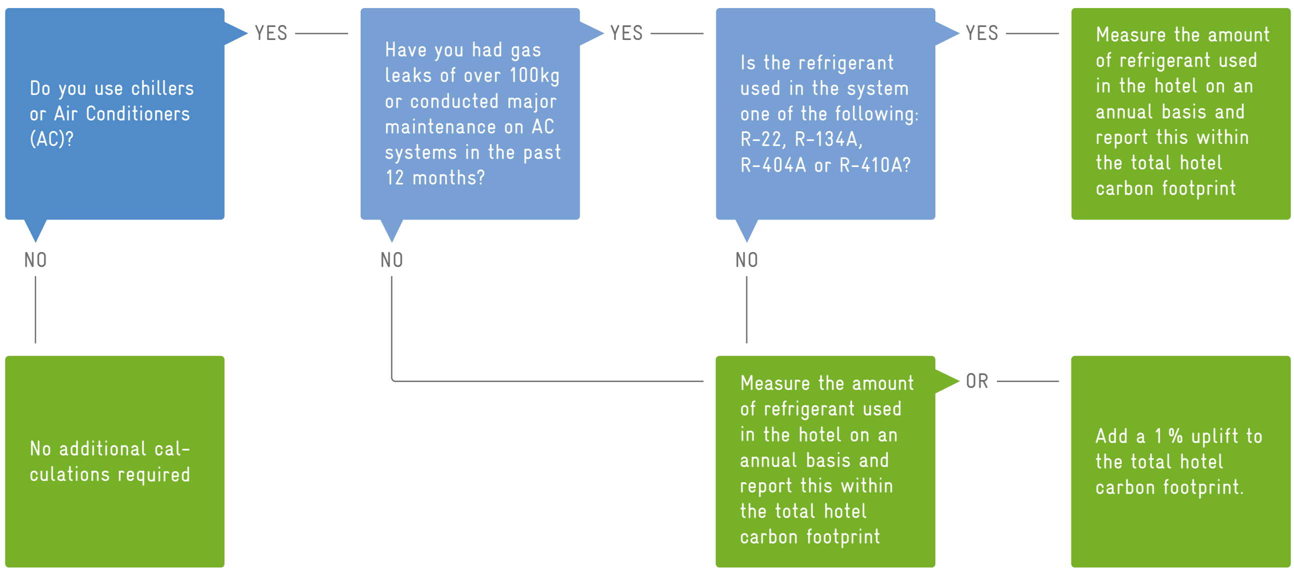


Figure 3: Decision tree for the calculation of refrigerant related emissions of a hotel's carbon footprint (WTTC, 2013)

emissions. Figure 3 shows the decision tree for including refrigerant related emissions from refrigeration and air conditioning into a hotel's carbon footprint. HCMI key benchmarking metrics are the hotel's carbon footprint per occupied room on a daily basis. It also considers meeting space (WTTC, 2013).

Hotel industry related sustainability programmes and initiatives are numerous. They include the following, most of them offering consultancy with benchmarking, reporting, technical guidance and environmental certification services:[20]

- Green Key Global:
  Environmental certification program for hotels;
- Sustainable Tourism Eco-Certification Program (STEP): certification, also providing guidance, self-assessment tool;
- Green Globe Certification Standards;
- Global Sustainable Tourism Council (GSTC): coalition of organisations working on sustainable tourism principles and providing certification;
- Earthcheck Assessed and Earthcheck Certified: consultancy, benchmarking, reporting, technical guidance, certification via GSTC;
- Greenleaders by TripAdvisor (distinguishes hotels with green initiatives);
- Benchmarkhotel by International Hotels Environmental Initiative (IHEI): energy performance tools for different climate zones, specifically for hotel buildings under consideration of different hotel categories (Xuchao, 2007).

Most of the above initiatives are not only open to large hotel groups, but offer also smaller hotels the opportunity to upgrade their green image and their attractiveness for eco-conscious tourists.

General green building programmes also have high relevance in the hotel sector, with the US American Leadership in Energy and Environmental Design (LEED) being the most prominent certification. Energy Star, Green Seal and Greenguard are examples of further product-specific standards and certifications.

Some international hotel chains have started to implement dedicated programmes to establish global environmental standards and certifications. A good example is Marriott, which benchmarks energy consumption and carbon emissions, among others, for cooling appliances between its different hotels in the group. The performance of the technical management is also linked to achieving the benchmarks. Further, technical managers meet on a regional basis to compare the performance of their hotels and to exchange on the use of specific appliances and

20 Goldstein and Primlani (2012) identified most of these and further environmental programmes with high relevance for the hotel industry.

technologies (Marriott International, 2016, 2017; and interviews with the group in Viet Nam).

A survey among 51 resorts focusing on the US hotel industry provides another perspective across the hotel industry (Smerecnik et al., 2009). About 33 % of the participants reported to have adopted energy certifications such as LEED or Energy Star. However, only a minor group reported significant renewable energy production (8 %), purchase of renewable energy from a utility (12 %) or sustainable-focused remodelling policies (8 %). Motivations for the adoption of sustainability practices included senior management pressure (51 %), cost-savings (47 %), costumer-demand (42 %), regulatory compliance (38 %), maintaining rapport with local government agencies and NGOs (33 %), and board member requirements (27 %).

Mainstreaming Energy Efficiency through Business Innovation Support (MEET-BIS) is an example of a national initiative in Vietnam. The project was funded largely by the EU and involved the Vietnam Hotel Association. The use of outdated and inefficient technology had been identified as an obstacle in the tourism sector, given the cost-intensive operation. Therefore, the initiative promoted energy efficiency and water conservation in Vietnam by addressing the private sector via small and medium-sized enterprises (SMEs) (Switch Asia, 2014). The Vietnam Hotel Association has since integrated a “Green energy” tab on their website[21].

Common system types and refrigerants

The key RAC equipment in hotels relates mainly to air conditioning, which is very common for larger hotels. In addition, hotels usually operate refrigeration equipment in hotel rooms as well as for restaurants and bars. Refrigeration equipment includes small hotel room refrigerators, condensing units, bottle coolers, and freezers.

The air conditioning is usually generated by centralized systems, chillers, particularly for larger hotels with more than 100 rooms. Medium to small hotels with less than 100 air-conditioned rooms rather use multi-split systems for air conditioning. AC in small hotels or hotels with several different buildings can also be supplied by single-split systems, if at all air-conditioned. Especially in hotels catering to tourists where individual huts or bungalows are common, some rooms can be furnished with AC equipment and others without.

Regarding the demand side set-up of air conditioning equipment, different variations are common. Air-conditioned guest rooms may be furnished with individual air outlets such as fan coils or with an AC evaporator unit, the latter being the option to combine with multi or single-split AC systems. Larger common areas such as lobbies or restaurants are typically served with air handling units. Meeting or conference spaces hosted by most large hotels may use either standard evaporator units or individual outlets, depending on the room and related cooling capacity (Xuchao, 2007).

As sector inventories reveal, chillers for air conditioning mostly use R-22 or HFCs such as R-134a as refrigerant, while split ACs still use mainly R-22 or R-410a as refrigerant. R-134a is still used in most of the refrigerators and condensing units.

Some relevant standards for RAC equipment in the hotel industry are:

- IEC 60335-2-24 and 60335-2-89 on household and commercial refrigeration systems;
- EN 378 or ISO 5149 on important safety and for environmental specifications for chillers;
- IEC 60335-2-40 on room air conditioning systems;
- ATEX directive on the design requirements of electrical components of cooling systems, with special relevance for hydrocarbon chillers;
- ISO 14064 on voluntary verification of GHG emissions reports.

A Building Energy Efficiency Code (BEEC) is a legal requirement that regulates the energy performance of building designs and controls their compliance during construction. Government intervention through mandatory BEECs has proved to be an effective tool for lowering energy demand of new buildings. BEECs are broadly accepted in industrialised countries today. Several developing countries began to adopt BEECs but many have not succeeded to put the requirements into force. The market availability of necessary, technically advanced components is a major requirement to enforce mandatory regulations in the construction sector. In prominent cases, compulsory requirements just address specific sectors or are on voluntary basis (Liu, Meyer and Hogan, 2010).

Examples of BEEC enforcement in C4 countries include the Philippines with the voluntary commercial code 1989 and Vietnam with its mandatory commercial BEEC 2003. The latter is not yet implemented due to lack of compliance documentation (Liu, Meyer and Hogan, 2010)

4.3.2 Mitigation Potential

Key measures to lower the carbon footprint of hotels related to cooling in particular are lowering the cooling demand through improved building shells, the use of energy efficient cooling appliances, the use of low-GWP[22] refrigerant and the energy supply through renewable energy sources. To lower the cooling demand, suitable measures are an optimal architecture of the building using natural ventilation and shadowing, good insulation, and building material limiting the heat influx into the building.

21 http://vietnamhotel.org.vn/en/nangluong/328/Green-Energy.vha, last access November 2017.

22 Low-GWP refrigerants are understood here as refrigerants with a GWP below 10.

The cooling demand of a building can be reduced best with the optimal design for newly built hotels. Measures to reduce the cooling demand of existing buildings, i.e. through reflective rooftop paintings are also possible but often relatively less effective or costlier than considering optimized buildings during the design phase.

Once a building has been constructed, the resulting cooling demand is met with the cooling system (e.g. air conditioners) with the appropriate cooling capacity. Minimizing the carbon footprint of the resulting cooling systems can be carried out by mitigating direct and indirect emissions.

To reduce direct emissions, cooling appliance replacement needs to come with a change from high-GWP refrigerants to low-GWP refrigerants. Common low-GWP natural refrigerants are:

- R-290 instead of R-22, R-410A or R-32 for split ACs;
- R-290 or R-717 or H_2O/lithium bromide for AC chillers;
- R-600a for refrigerators;
- R-600a or R-744 for condensing units.

There are also alternatives using synthetic refrigerants such as HFOs. Cooling systems with HFOs can achieve high energy efficiency performance. Still, there are issues concerning the long- term effects of leaking HFOs, from operations or at the end-of-life of the appliances. HFOs can form persistent trifluoroacetic acids (TFAs) where the long-termeffects are not fully known[23].

To reduce indirect emissions, the energy efficiency of installed appliances needs to be improved or they need to be replaced by more efficient appliances.

In warm climates, such as in Sri Lanka, about 50 % of energy consumption in the hotel industry accounts for RAC equipment (Oppelt, Radermacher and Munzinger, 2017). The use of inefficient appliances, which often occurs in developing countries, and the relatively high cooling demand due to warm climates, lead to situations where air conditioning alone may easily contribute 50 % to the total energy consumption (Xuchao, 2007). Frequently, 10 to 20 % of energy savings or more can be accomplished by technical improvement of plant equipment and operations (Goldstein and Primlani, 2012). This range coincides well with Marriott's actual savings of 13.2 % in 8 years and its ambition until 2020. Marriott so far focused on lighting and improvements of laundry operations, thus improvements potential in RAC equipment is still largely unexplored.

Suitable thermal insulation of the building envelope, including adequate windows (e.g. double glazing), is the first principal measure to reduce the energy demand for cooling. For any hotel, adequate orientation to the sun, suitable sizing and orientation of glazing surface and use of natural shading are essential measures during planning and construction to reduce the cooling demand (Anunobi et al., 2015). Especially for small hotels, methods of natural ventilation (e.g. cross ventilation by placing windows on opposite sides of rooms) may be applied, which may in certain cases even lead to making AC equipment completely unnecessary. Remaining minor cooling needed may be provided by ceiling fans. This aspect is reflected by increasing ecotourism trends in many countries. To ensure suitable energy performance, RAC equipment should only be operated when needed. It requires strict scheduling and effective control systems. For larger hotels, intelligent building management systems are standard and may require improvement measures. Xuchau (Xuchao, 2007) found that occupancy rates and energy consumptions are largely decoupled; only at occupancy rates below 70 %, room occupancy tends to be more closely related to energy consumption. This finding underlines the importance of adopting adequate operating schemes and corresponding control systems. According to Bohdanowicz (Bohdanowicz et al., 2011), 20 to 30 % of energy for space air conditioning can be saved by zoning and/or using autonomous temperature control systems in individual rooms.

Fan coils are established as the preferred option for air supply to guest rooms due to their high degree of flexibility which facilitates controlling possibilities and thus improves the overall energy performance of controllable AC chillers (Xuchao, 2007).

Emissions and mitigation scenarios

For a simple modelling of emissions and mitigation scenarios, an average set of RAC equipment was assumed for an exemplary 3, 4 and 5-star hotel[24,25]. More details on the example of a 3-star-hotel such as could be found in Iran is provided in Table 10. The direct and indirect emissions were calculated based on an estimated set of parameters, such as cooling capacity, run-time per year, COP, lifetime and refrigerant charge, for each equipment type.

For the mitigation scenario, a reduction of direct emission using alternative green technologies, i.e. a change of refrigerants to natural refrigerants and a reduction of indirect emissions through a 20 % improvement of the energy efficiency (COP) were considered.

The following set of conventional technology equipment is assumed for the exemplary 3-star-hotel with 80 rooms and a total area of around 5,000 m²:

23 http://www.green-cooling-initiative.org/technology/overview/refrigerants/, last access July 2018.

24 A related GIZ project analysed a Sri Lankan hotel group's use of RAC equipment in detail (Oppelt, Radermacher and Munzinger, 2017). This example has been adapted to develop a simple model to estimate emissions from the hotel sector in the C4 countries.

25 Although there is no worldwide common nomination for hotels, many hotels worldwide use similar kinds of star or diamond ratings which are used here as proxy for different hotel categories. The higher number of stars indicate a more spacious hotel and/or more facilities and thereby higher energy consumption per m².

Equipment type	COP	number of units	cooling capacity (kW) per unit	refrigerant	GWP	charge (kg)	runtime per year (h)
chiller	4.5	1	425	R-22	1,810	47	3,200
split	3.1	10	3.5	R-22	1,810	0.72	2,600
room refrigerator	3.5	12	2	R-134a	1,430	0.4	2,025
Condensing unit	1.7	3	3	R-22	1,810	2.6	4,000

Table 10: Assumed parameters for exemplary 3-star-hotel

Indirect emissions: Considering the cooling capacity, average COP, and runtime of the equipment, the hotel would consume 366,639 kWh/a. Considering Iran's grid emission factor (Brander et al., 2011), this amounts to indirect emissions of 366 t CO_2eq per year.

Direct emissions: Considering the type of refrigerant, charge, emission factors (1 % at manufacturing, 100 % at disposal, estimated annual servicing emissions of 3 % for refrigerators, 25 % for condensing units and chillers, and 10 % for split ACs), direct emissions amount to 32.9 t CO_2eq per supermarket.

Mitigation potential: If the same exemplary 3-star-hotel used R-290 as a refrigerants and increased energy efficiency by 20 %, the overall emissions would be reduced from 400 t CO_2eq per year to 305 t CO_2eq per year or from 7,711 t CO_2eq to 5,912 t CO_2eq considering the lifetime of the equipment as shown in in Figure 4:

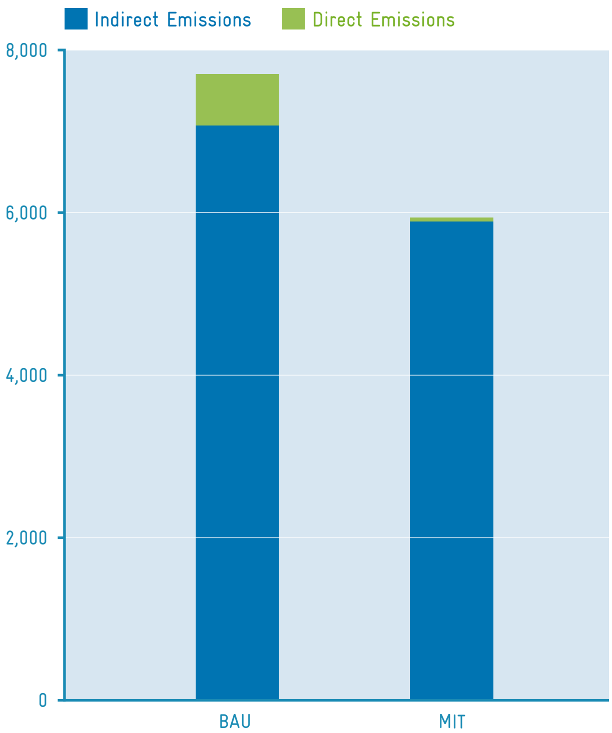


Figure 4: Mitigation potential of exemplary 3-star-hotel considering equipment lifetime

For the selected country cases, Vietnam, the Philippines, Costa Rica, Grenada and Iran, the country-specific grid emission factors (Brander et al., 2011) were taken into consideration. The emissions of the exemplary hotel were then multiplied by the number of hotels. The process was replicated for typical 4- and 5-star hotels. These were also assumed to comprise 80 guest rooms but equipment handling larger cooling demand as for example more or all rooms will be air conditioned in contrast to the 3-star hotel where only some rooms are air-conditioned.

The BAU- and MIT-scenarios assume that

- the total number of hotels increases by 10 % every 5 years;
- all new hotels are equipped with the energy-efficient systems using low-GWP natural refrigerants;
- old equipment is replaced with new technologies in 20 % of the old hotels (existing in 2015) every 5 years (reaching 100 % in 2035 and all hotels having the green cooling technology from 2035).

The following table provides an overview of the estimated number of hotels, current total emissions of the hotel RAC sector and its share of the country's overall emissions as well as the estimated mitigation potential for the C4 countries in 2050[26]:

4.3.3 Ease of Implementation

Technology trends – availability and financial implications

RAC equipment used in the hotel industry is usually produced in industrialized countries with some involvement of emerging economies. There is an increasing trend of commercial refrigeration to run on natural refrigerants, mainly R-290, R-600a and CO_2 with some relevance for the refrigeration appliances in hotels. Regarding air conditioning, hydrocarbon systems are still in the beginning of their evolvement with some installations reported in other sectors such as retail (see chapter 4.2). The Indonesian RAC manufacturer AICOOL, in cooperation with GIZ

	Philippines	Costa Rica	Grenada	Iran	Vietnam
Estimated number of hotels in 2015[27]	1,544	698	28	286	2,123
Estimated total of RAC-related emissions for hotels in 2015 in t CO_2eq p.a.	428,742	73,816	8,870	100,764	568,159
BAU 2050 in t CO_2eq p.a.	835,496	143,846	17,284	196,360	1,107,181
Estimated mitigation potential in 2050 in t CO_2eq p.a.	223,978	62,855	4,456	48,599	302,243
Mitigation potential 2050 in %	27 %	44 %	26 %	25 %	27 %

Table 11: Overview of RAC-related emissions for hotels in C4 countries

launched an initiative to introduce R-290 chiller technology in the region, focused on the commercial sector. MBS (MBS, 2005) reported the installation of three 127 kW hydrocarbon chillers in a government building in Westminster, London back in 2005, and identified the following four key systematic features to have achieved energy savings above 50 %:

- More favourable thermodynamic characteristics of hydrocarbon refrigerants compared with other refrigerants.
- Use of a fully flooded evaporator to achieve zero superheat, by means of a plate suction liquid heat exchanger with the phial of the expansion valve located downstream of the heat exchanger.[28]
- Floating head pressure control allows the condensing temperature to fall as low as 20°C, if ambient conditions allow it, instead of the normal 40°C.
- At part-load, the voltage and current to the compressor motor are modulated to reduce losses in the motor core and windings. The payback on such control is typically less than 18 months.

As another alternative, absorption chillers using a H_2O/lithium bromide solution as refrigerant can be installed. Absorption technology requires thermal energy at temperatures above 70°C. Solar thermal collectors can be installed on the rooftops for combined use for warm water and to provide the required driving energy for the absorption chillers. The availability of substantial waste heat at the adequate temperature level (> 70°C), as e.g. laundry services may provide, present another option to be used for absorption chillers. However, absorption cooling technology is relatively complex for hotels given the fact that thermal energy supply is more fluctuating than for industrial applications where absorption cooling is more common. Corresponding to their complexity, absorption technology solutions are rarely economically feasible. Falahatkar (Falahatkar, 2011) studied the potential of absorption chiller technology for an office building in Teheran under consideration of solar thermal collectors and natural gas as heat sources and thermal storage, with resulting payback periods exceeding 10 years. Sri Lanka's hotel chain Jetwing may have resolved the difficulty of a stable heat source by using locally abundant biomass waste material. Currently, absorption chillers in four hotels are fuelled by cinnamon wood. Within the International Climate Initiative (IKI) of the German Federal Environmental Ministry (BMUB)) and supported by GIZ, Jetwing plans to expand the technology shift AC systems with natural refrigerants or absorption chillers as replacement to old chiller systems for its hotels operated in Sri Lanka (Oppelt, Radermacher and Munzinger, 2017; Times Online, 2017).

Especially hydrocarbon refrigerants offer significant energy efficiency improvement over HFCs or HCFCs. R-290 and R-22 both have excellent thermodynamic performance, i.e. they perform similarly well in terms of energy. HFCs on the other hand perform increasingly poorer at increasing ambient temperature. This correlation is illustrated in Figure 8 in Chapter 4.4.3 (Öko-Recherche, 2014)[29].

The adoption of comprehensive general energy efficiency measures can generate energy savings of up to 20 % (Goldstein and Primlani, 2012). This energy conservation can be further enhanced by a technology shift to cooling systems running on natural refrigerants. Following the Westminster installation described above, the associated improvement measures, namely flooded evaporator, floating head pressure, and modulated compressors for part-load operation (or in other words, variable speed control) enable to further boost the energy savings.

26 This approach offers only an estimate on emissions from the hotel sector. However, the model could possibly also be used to explore various mitigation scenarios for an individual country.

27 http://www.delta-check.com/en/hotel-database-worldwide/, accessed on 23 July 2018.

28 The lower condensing temperature compared with R-22 improves the efficiency of the internal heat exchanger. Heat is transferred between the liquid upstream of the expansion valve and the vapour upstream of the compressor, further improving the COP.

29 While R-290 and R-22 stand out for EER values above 3.9 at 35°C ambient temperature, R-32 and R-410A perform at EERs below 3.7. In the same manner, the EERs of both HFCs fall below 3.0 around 43°C and below 2.5 around 50°C, whereat R-290 and R-22 maintain EERs above 3.3 and 2.9 respectively at the same ambient temperature levels.

Correspondingly, payback periods well below five years are possible. Currently, the investment costs for hydrocarbon and absorption chillers are still slightly elevated in comparison to massively produced HFC chillers. Regarding equipment for refrigeration, technology using natural refrigerants is well established. Greenfreeze, a technology innovation launched by Greenpeace in the early 1990s has a market share of 35 to 40 % of domestic refrigerators and freezers today, with more than 800 million refrigerators in use worldwide (Greenpeace, 2016). Regarding the financial incentive, Greenchoices (Greenchoices, 2017) indicates that it pays off to replace refrigerators that are more than 10 years old, as energy efficiency has increased by 25 % since 1990. The platform presents the top 10 of the most energy-efficient refrigerators on the market.

Barriers and solutions

To successfully introduce climate-friendly and energy-efficient solutions, existing barriers need to be identified and systematically addressed on a country-specific basis. General remarks on barriers and strategies for interventions encouraging private sector participation are presented in Chapter 5.

The organizational structure of the hotel sector, where often the ownership of the building is separate from the operator of the hotel chain, stands out as a specific barrier to technology innovation. As high-end technology is less disseminated in developing countries, the actors on the market lack relevant information on new cost-saving measures and climate-friendly possibilities in the RAC sector. Individual small players, being less interconnected, may lack awareness of their options. The same applies to local or regional subsidiaries of larger global chains, which may not all be treated with the same priority as their counterparts in industrialised countries regarding corporate responsibility issues. Moreover, implementing and maintaining technology is usually more expensive in developing countries. Therefore, new technology investments can prove a considerable hurdle for small hotels due to the proven track on achieved operational cost savings.

Availability of competent personnel for the operation and maintenance of new technology is another barrier, especially for climate-friendly RAC systems (Oppelt, Radermacher and Munzinger, 2017; Times Online, 2017). Technical barriers also exist regarding the use of low-GWP natural refrigerants. Hydrocarbons are flammable and ammonia can be toxic to humans.

4.3.4 Scalability and Relevance in C4 Partner Countries

Commonly, the market is equally distributed between some global or superregional hotel chains with high presence in metropolitan areas and tourist resorts as well as numerous small local players. Evidently, the major players in the hotel industry are better interconnected and can be reached more easily to initiate the technology shift to non-fluorinated refrigerants. Moreover, the direct impact is expected to be relatively high due to numerous guest rooms. Replication is possible, assuming the actor operates further hotels in the country or region. In contrast, competing local players are often owners of single hotels or rather small estates. Therefore, both the direct impact and the replication effect are low.

Hotels are highly interested in improving and maintaining a positive image. As sustainability efforts are high in the hotel sector with numerous initiatives providing ecolabels or certifications, chances are good to further highlight the impact of cooling equipment in terms of indirect and direct emissions. Networks can contribute to the scaling up of sustainability efforts. The following networks operate on a worldwide scale and might offer starting points to extend global initiatives on certification and labelling stronger to developing countries:

- International Tourism Partnership (ITP);
- World Travel & Tourism Council (WTTC).

It is noteworthy that hotel-specific networks do also exist on national and regional levels. Such associations aim to strengthen the domestic hotel and tourism sector and to represent interests, including when it comes to legal affairs and dealing with the government. Further objectives are to provide useful information to travellers as well as the fulfilment and enhancement of standards to improve touristic services. The associations listed below have been identified in C4 countries. They provide a potential starting point for reviewing sustainability focus and conducting pilot activities towards climate-friendly RAC equipment.

- Costa Rica Hotel Association (CCH)[30];
- Caribbean Hotel and Tourism Association (CHTA), with Grenada among their members[31];
- Iran Hotel Association (IHA)[32];
- Hotel and Restaurant Association of the Philippines (HRAP)[33];
- Philippine Hotel Owners Association (PHOAI)[34];
- Vietnam Hotel Association[35].

30 http://www.camaradehoteles.com/acerca-de, last access July 2017.

31 http://www.caribbeanhotelandtourism.com/about-chta/, last access July 2018.

32 http://www.safar.me/en/tag/iran-hotel-association/, last access July 2018.

33 https://tpb.gov.ph/about/mission-and-vision/, last access July 2018.

34 http://www.philhotelowners.org.ph/about-us/, last access July 2018.

35 http://vietnamhotel.org.vn/Default.aspx, last access July 2018.

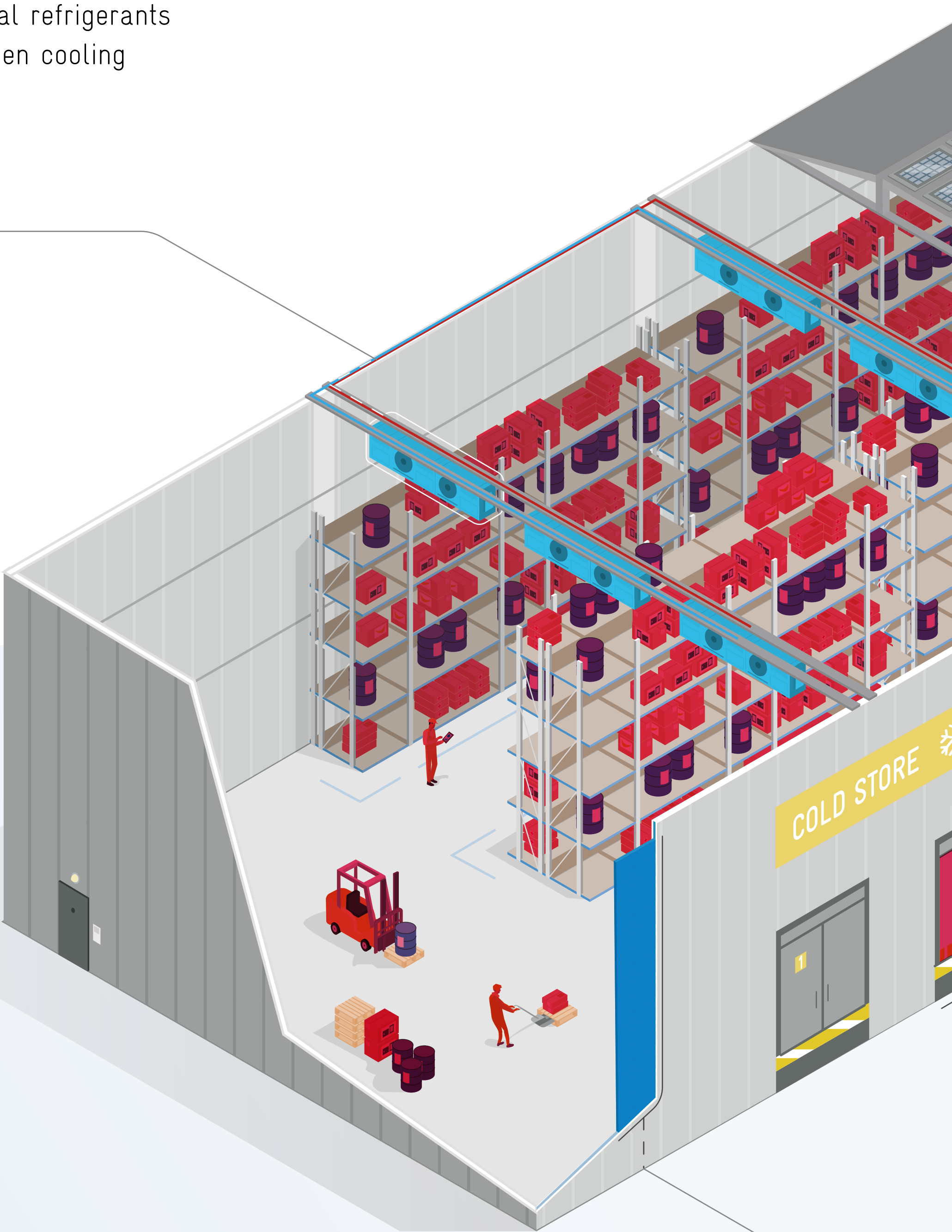
Overview 3: Climate-friendly and energy-efficient cold stores

Reduce heat load, switch to high efficient technology options using natural refrigerants and improve operations for green cooling

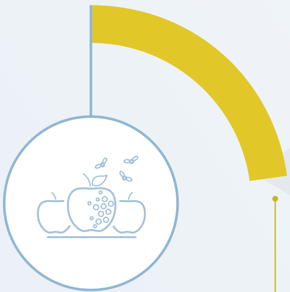
Use green cooling appliance

by switching to energy-efficient chiller with low-GWP refrigerants

R744	R744	cascasde systems
R1270	R717	
R290	R600a	R717
R1270	R601a	CO_2



Key facts



About 23 % of losses of perishable food can be accounted to lack of refrigeration.

Food Loss: **23 %**

Combined energy optimization of the equipment's energy performance, its operation, and improved insulation can save 30 to 40 % of energy

Reduction: **30 – 40 %**

In emerging economies and developing countries, global cold store capacity is growing by 8.6 % annually.

Capacity Growth: **8.6 %**

Cooling Source

Heat Source

Supply system with green energy

by using renewable energy systems and heat waste recovery to further reduce indirect emissions

Photovoltaic systems

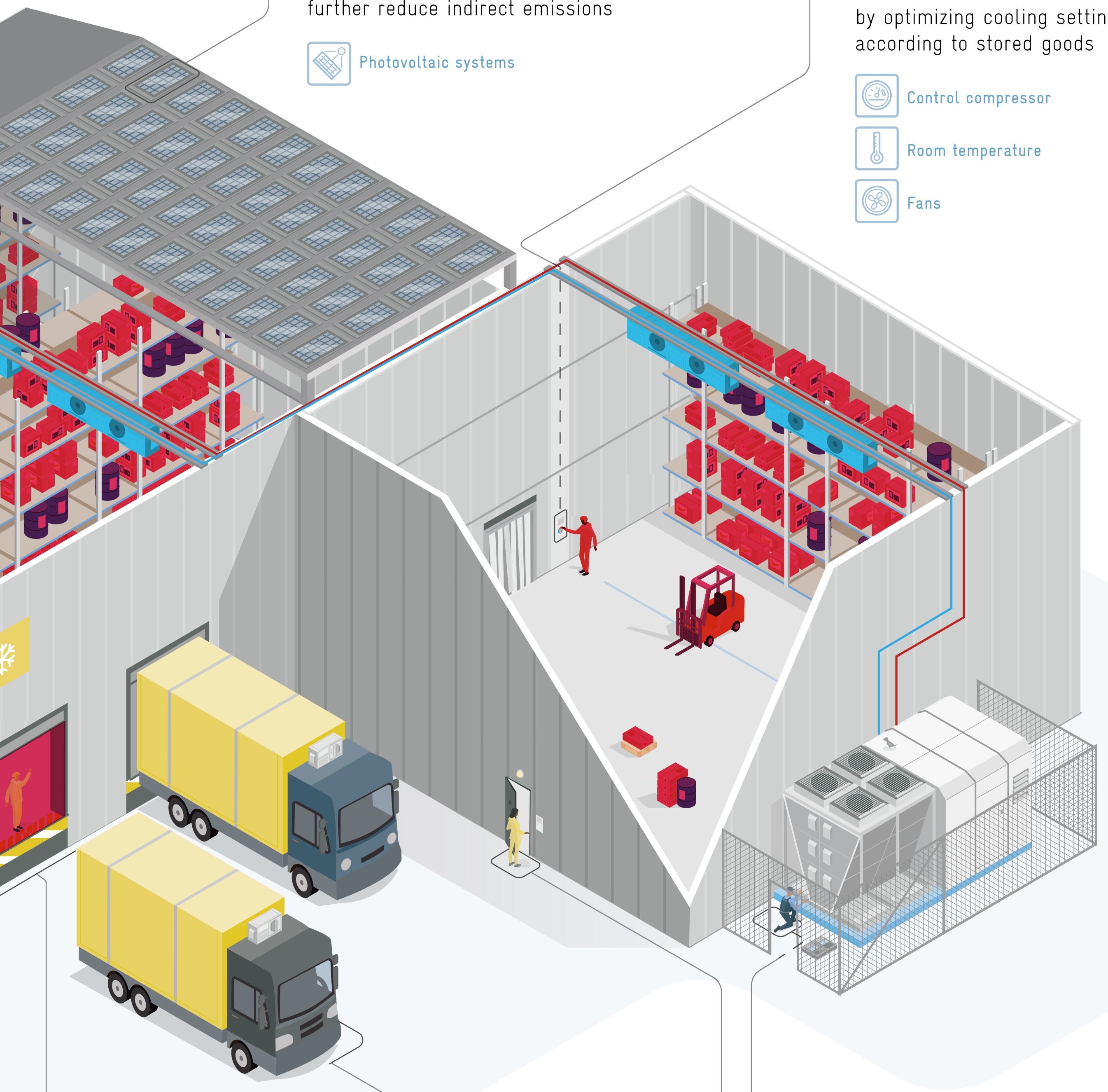
Reduce unnecessary cooling

by optimizing cooling settings according to stored goods

Control compressor

Room temperature

Fans



Avoid refrigerant leakage

by servicing equipment by certified RAC technicians, ensuring efficient operation

Reduce additional heat load

by minimizing time and frequency of open door

Remove heat

by precooling goods before storage

Reduce heat load of building

by improving thermal insulation of walls, floor and ceiling using low-GWP foam blowing agents

Natural foam blowing agents

Ensure professional handling

by training staff to optimize energy-efficient operation and cooling load in storage facility

4.4 Focus sector: Cold Stores

4.4.1 Brief Sector Description

As defined in chapter 4, cold stores considered here are commercial establishments in the cold chain that store food and other perishable products in one or more controlled temperature zones (frozen food at up to -20°C, chilled food at 0 to 4°C, flowers typically at 5 to 7°C) for preservation. They range in size from small (<10,000 m^3) to medium (10,000 to 40,000 m^3) to large and very large cold stores (>40,000 m^3).

The cold stores considered in this paper are separate warehouses and distribution centers located along the cold chain in between the production and the delivery to the retailer or end-user. Walk-in cold storage rooms that are part of supermarkets, hotels, or food production facilities are not considered.

Structure and size of cold store providers

Billions of tons of food products are lost due to poor cold chain systems in developing markets each year - almost half of all food is wasted and the global food industry suffers losses above $750 billion annually (Miller, 2016). Cold stores, as the interface between transport and distribution stages, play a crucial role for the reduction of product losses. Investments to maintain the cooling technology in adequate conditions are important economic considerations. Cold stores are present all along the cold chain, from shortly after harvest until purchase by the end-user. Products pass through a varying number of cold stores from pick-up points through distribution stages and their presentation at supermarkets or restaurants. An exemplary cold chain is shown in Figure 5, illustrating the variety of possible routes through a cold chain network that a chilled product may pass. According to the complexity of the cold chain with varying cooling needs, volumes and logistics structures, cold stores differ largely in size and distribution of different temperature zones within each facility. Their function is to maintain perishable products well within their tolerable temperature and humidity range to prolong their shelf life. Due to varying temperature needs of different products, large refrigerated warehouses are typically distributed into different temperature zones (further details see section: System types and refrigerants).

Regarding the ownership, processing factories usually have its own cold stores within its facilities. Logistics companies often have their own warehouses, which in many cases contain cold stores. Large players in the food and beverage industry tend to have their own cold store estate as well. Many retail chains have their own separate estate of warehouses with cold stores. Independent cold stores also exist, especially within ports and other intermodal transhipment stations, which are necessary hubs for transport overseas.

Decision makers for RAC technology and innovation of cold stores are typically the (technical) directors or technology & innovation managers of the warehouse groups and general managers from the cold store operating companies

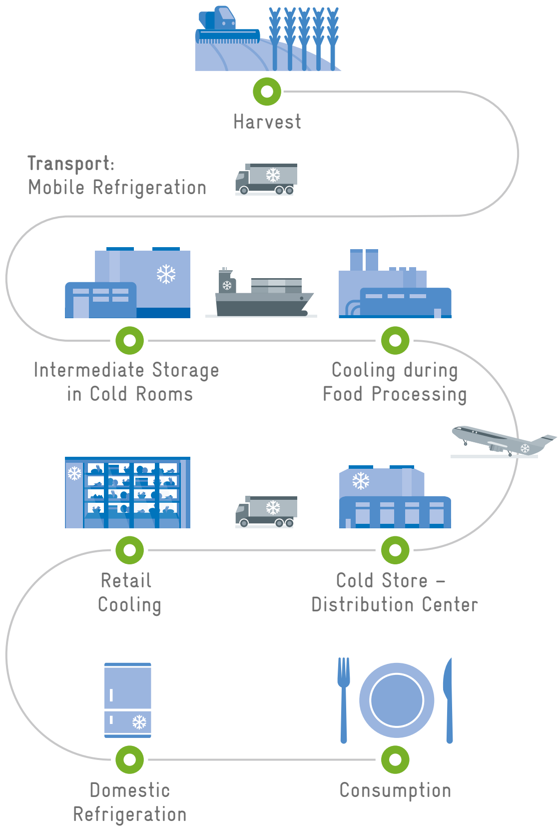


Figure 5: Sample cold chain diagram with cold stores/refrigerated warehouses (Miller, 2016)

on the other hand. Their individual decision-making authority commonly depends on their qualification and experience. Depending on the internal structures, these may have to forward technical proposals to their managing director or board of directors for final decisions.

In the following sub-chapter, we explain the structure of the cold chain business worldwide. Many global cold chain operating companies are based in industrialized countries and are expanding into the C4 countries. From a non-state actor perspective, to the extent these groups have advanced standards regarding their energy savings standards and use of refrigerants, this could have a positive impact on the level of practice carried out in developing countries, including the C4 countries.

Market share and growth, barriers

The worldwide cold store market is currently dominated by US players as shown in Table 12. Business in some other regions around the globe and local affiliates of the global players incorporate another major market share.

In countries with fully developed cold chains, outsourcing of supply chain operations to third-party logistics providers (3PLs) or other cold chain service providers is common. This business of so-called integrated warehousing and transportation services in one is dominated by Central and

Cold storage provider	Base country	Storage volume (in million ft³)	Sales revenues (in million USD)
Americold	U.S.	992	2,430
Lineage Logistics	U.S.	600	206
Swire Group	UK	335	n/a
Preferred Freezer	U.S.	258	441
Nichirei Logistics	Japan	152	188
Kloosterboer	Netherlands	124	n/a
VersaCold Logistics	U.S.	119	419
Partner Logistics	U.S.	101	n/a
Interstate Warehousing	U.S.	83	n/a
AGRO Merchants	U.S.	80	76
Nordic Logistics	U.S.	70	100
Cloverleaf Cold Storage	U.S.	65	39
Burris Logistics	U.S.	72	2,630

Table 12: Major cold store operators by storage volume (Miller, 2016)

Provider	Base country	Sales revenue (in billion USD)	References showing increasing activities of the 3PLs on cold chain activities
DHL Logistics	Germany	37.5	http://www.envirotainer.com/top-News/Newsletters1/Active-Thinking---Test/DHL-DB-Schenker-Swiss-WorldCargo-and-CAL-Cargo-Air-Lines-expand-their-QEP-network/
Kuehne + Nagel	Switzerland	23.4	https://de.kuehne-nagel.com/de_de/branchenlosungen/frischelogistikperishables/
DB Schenker Logistics	Germany	19.0	https://www.dbschenker.com/global/industry-solutions/perishables
C.H. Robinson	U.S.	11.9	https://www.chrobinson.com/en-us/resources/white-papers/?d=294
DSV	Denmark	8.7	http://www.dsv.com/road-transport/trailer-types-and-dimensions/reefer-trailers
CEVA Logistics	Netherlands	7.9	https://www.cevalogistics.com/frozen-potatoes
Panalpina	Switzerland	7.3	http://www.panalpina.com/www/global/en/home/industry_verticals/perishables.html
Dachser	Germany	7.1	http://www.dachser.com/de/de/Warehouse-Logistics_102.htm
Expeditors International	U.S.	6.6	https://www.expeditors.com/industries/healthcare
SNCF Geodis	France	5.8	https://www.geodis.com/temperature-controlled-forwarding-@/en/view-6184-article.html/3850

Table 13: Major third-party logistics providers (3PLs) by revenue (Miller, 2016)

Western European players over U.S. American companies, as depicted in Table 13. Although only a small share of these companies' activities is cold chain related, the role of 3PLs in the cold chain is growing. Relevant activities with the references are shown in Table 13.

Besides the advantages of offering several services from one provider, cold chain operations benefit from the logistics network strength of established 3PLs. So far, this business model plays only a minor role in developing countries. Nonetheless the International Trade Administration (ITA)

Country	Total cold storage volume	Important cold store companies
Costa Rica	0.35 Million m³ (53,000 pallets) in 2010. Growth rate ca. 100 % (period 2008-2010) (Salin, 2010)	Leaho, Refritec, Frionet Corporation, Codiproal, Red Frigorífica Nacional del Centro Nacional de Abastecimiento y Distribución de Alimentos[36]
Grenada	n/a	The yellow pages have two companies listed[37]: Country Cold Store Ltd, Donna's. No classification found.
Iran	14 million m³ in 2014[38]	List of 156 local and regional cold store companies featured by Kompass (2017)[39]. No classification found.
Philippines	n/a	Jentec Cold Storage Inc, Glacier, Polar Bear Freezing and Storage Corp, Royal Cargo, Vifel Ice plant and Cold Storage, Igloo supply chain, Royale Cargo[40]
Vietnam[41]	349,000 pallets in 2015	Pham GIA Trading Joint Stock Company, Preferred Freezer Services Co., Ltd, Ctcbio Vietnam JSC, Lotte Sea Logistics co., Ltd, Swire Cold Storage Viet Nam Co.,Ltd

Table 14: Countrywide cold store volumes and dominant cold store companies in C4 countries (Sources: see footnotes)

predicts this trend to continue which is partly due to increasing relevance of omni-channel retailing, especially in fast growing Southeast Asian markets (Miller, 2016).

Most emerging economies and developing countries are characterized by strong growth of their cold chains. As recorded by GCCA's 2016 Global Cold Storage Capacity Report, global cold store capacity was 600 million m³ in 2016, which corresponds to an increase of 8.6 % in two years. From 2012 to 2014, the capacity grew by 20 %. The report pointed out that a large share of the capacity growth came from emerging economies such as China and India whereas some European countries underwent a decline of cold store capacity in 2016. The report also described the correlation between cold store and supermarket growth, stating that in countries where the rate of supermarket expansion exceeded 25 % per year, the refrigerated warehouse market penetration per capita grew by 20 % or more (GCCA, 2016). Table 14 shows the cold store volumes and dominant cold store companies in the C4 countries.

Poor cold chain services and infrastructure are a major challenge in many developing countries in terms of complexity and investment. Contrary to the large global players, the large investments required prevent local small and medium size enterprises from entering the market. Given this limitation, foreign direct investment is an effective way to boost local cold chain services. Being typical for lower and middle-income economies, protectionist measures by the local government may restrain foreign services activities (Miller, 2016).

Lack of information is another significant challenge. Even in Europe, few comparisons between different cold stores have been drawn, and the above-mentioned study in New Zealand represents a unique effort. Cold store owners are likely to be reluctant towards technology investments when the predictions of achievable energy savings are too vague.

Initiatives and policies

Under the initiative 'Improving Cold Storage Equipment in Europe' (ICE-E), the energy assessment of a total of 329 cold stores across Europe was published. It also included benchmarking of the audited facilities by means of energy labels in the same format known for household appliances such as refrigerators. The survey of cold stores identified a significant energy saving potential. The benchmarking survey also covered the use of refrigerants. This activity in the cold store sector represents a unique effort in this regard (findings from that study see section on energy efficiency below) (Evans, 2013).

In fact, cold chain systems serve as a business function for the global value chain. Mainly, they have been working as a self-regulated mechanism through required product quality standards and corporate responsibility towards their customers. Therefore, policy intervention is a relatively new issue in the cold chain industry (Miller, 2016). Currently, a few rules and regulations already exist. However, it is not clear to which extent their enforcement is binding as well

36 http://qcostarica.com/costa-rica-with-increased-demand-for-cold-storage/, last access July 2017.

37 https://www.findyello.com/Grenada/White-Pages/Cold-Storage, last access July 2017.

38 http://images.magnetmail.net/images/clients/GCCA/attach/SelectCharts_Media_2014IARWCapacityReport.pdf, last access July 2017.

39 https://ir.kompass.com/en/a/warehouses-cold-storage/75900/, last access July 2017.

40 https://www.kenresearch.com/automotive-transportation-and-warehousing/logistics-and-shipping/philippines-cold-chain-market-report/8219-100.html, last access July 2017.

41 https://biinform.com/Reports/168-vietnam-cold-storage-market-2016-.html, last access July 2017.

as whether and/or how enforcement is monitored. The following are relevant standards and regulations on global level:

- ISO 22000: required for all commercial actors in the food chain, deals with food safety management systems.

- Hazard Analysis and Critical Control Point (HACCP): established since several decades as a recommendation for all commercial participants in the cold chain. HACCP offers a comprehensive concept for self-control by providing a logical control sequence and includes assessment of microbiological, chemical and physical risks. Several national regulations have taken up this method for binding enforcement.

- International Featured Standards (IFS) Certification: contains the IFS Logistics standard, which is a risk-based standard designed to provide assurance to customers by maintaining a high quality of food safety and quality all along the cold chain. IFS works rather as a reputational instrument and is implemented by more than 1,000 actors in the food logistics sector worldwide.

In the EU, the following additional standards are relevant for cold storage of perishable products:

- Regulation EC 852/2004 on the hygiene of foodstuffs;

- EN 12830 on temperature recorders for the transport, storage and distribution of chilled and frozen food and ice-cream;

- EN 13485 on thermometers for measuring the air and product temperature for the transport, storage and distribution of chilled and frozen food;

- EN 378 and IEC 60335 on refrigeration systems including important safety and environmental specifications for chillers.

4.4.2 Mitigation Potential

Alternatives and efficiency improvements

Alternative refrigerants include the hydrocarbons HC-290 (propane) and HC-1270 (propene), the latter being more suitable for deep temperature storage. For the use of hydrocarbons, special attention is required to comply with relevant safety code because of the hydrocarbons' flammability. R-717 (ammonia) represents an important non-fluorinated alternative, which also offers deep supply temperature levels. Advanced CO_2 technology is suitable for small and medium-size cold stores and is experiencing rising demand, particularly in regions with not too high ambient temperatures, such as Sweden or Japan where ambient temperatures stay below 30°C all year round (McLaughlin, 2017; Yoshimoto, 2017).

Ammonia21 (2017) reported the installation of an R-717/CO_2 packaged refrigeration system in Japan. The refrigeration system combining two natural refrigerants accomplishes a cooling capacity of 80 kW at a storage temperature of -25°C for frozen goods. Additional features are the installation of a CO_2 heat pump desiccant dehumidifier systemfor adequate dehumidification of the stored goods, utilisation of waste heat, 'electric movable rack' system and LED lighting for energy efficiency improvement and solar power capacity of 615 kW from 2,088 solar panels (Okabe, Yoshimoto and Dusek, 2017).

Energy efficiency

Regarding energy efficiency, adequate thermal insulation is extremely important due to the very low temperature ranges. The cooling system typically consumes 60 to 70 % of the overall electricity consumption of a cold storage facility (Evans, 2013). An interviewee from Iran even assumes that their cooling equipment consumes 80 % of the total energy used by the facility. Figures from a conference paper at the 2011 International Congress of Refrigeration (ICR) indicate that cold stores generally (294 data sets from cold stores, out of which 70 % from EU countries, remaining part from the U.S. and New Zealand) consumed between 30 and 50 kWh/m³ electricity per year in 2002 (Evans et al., 2011). However, poorly performing cold stores, which are typical in developing countries, might easily consume double of this indicative range. The given numbers suggest that Europe's cold storage for food alone with a capacity of 60 to 70 million m³ consumed at least 2,600 GWh of electrical energy each year. Combined energy optimization of the equipment's energy performance, its operation, and improved insulation could save 30 to 40 % of energy (Evans et al., 2011). The assessment under the ICE-E initiative concluded that up to 72 % of energy can be saved by considering all energy relevant aspects which include the refrigeration system, thermal insulation and lighting (Evans, 2013). Figure 6 demonstrates all energetic issues raised by the energy audits including the particular associated energy saving potential.

Furthermore, adequate management of operations for the handling of goods has special importance. The opening of doors can highly affect energy consumption. The importance of flexible operation modes for part load demands has received more awareness in recent years. Continuously variable speed drives are the high-tech upgrade to multistage compressors, which would only allow the system to respond to few different load cases without excess electrical consumption. The compressor technology itself has achieved technological advances recently, e.g. for scroll compressors and particularly for chillers using hydrocarbon refrigerant. In this case, reduction of refrigerant charge not only represents a necessary safety precaution but also benefits the energy efficiency of the cooling system. Significant reduction of refrigerant charges are possible for R-717 systems (Miller, 2016), which also allows for energy performance improvements. As in any other refrigeration system, the minimization of leakage is another crucial consideration. Given the significant size of cooling systems in larger cold stores, there are correspondingly large quantities of refrigerant that need to be regularly refilled. ICR's 2011 conference paper revealed that refrigerant leakage in industrial plants is likely to exceed 17 % (Evans et al., 2011) which incorporates industrial cold stores for food processing. Accordingly, even higher leakage rates can be expected for poorly serviced cold stores in developing countries.

Due to their size, the roofs of refrigerated warehouses offer great potential for on-site energy generation. Swire News (SwireNews, 2017) reported a 1 MWp solar PV installation in Sri Lanka expected to cover 27 % of the cold store's electricity demand and to save 900 tons of CO_2 emissions per year.

Typical challenges found in many developing countries are poorly designed systems and outworn equipment, both at the expense of poor energy performance. Power back-up is an important measure to minimize the risk of product losses, not only because of unstable power supply – if applicable – but also to prevent technical failure of particular technical components of the refrigeration system. This back-up necessity stimulates the consideration to utilize alternative energy sources, giving additional value to renewable energies. Most refrigerated warehouses have large available flat roof areas that may be used to collect solar energy and to provide a substantial share of the required electricity for cooling. Moreover, refrigerated warehouses have a high demand for maintenance and repair services. Adequate planning and design is needed to respond to the complex and fluctuating operations at cold chain logistics. The integration of suitable warehouse IT and managing software with controlling equipment is standard for advanced and energy-efficient solutions and certainly will attract attention in underdeveloped cold chain markets sometime soon. Lack of infrastructure beyond the road network, for example power hookups for refrigerated trailers, represents another barrier and may hamper foreign investments. Competency and adequate training of all personnel involved in cold chain logistics is a crucial element in order to maintain high energy efficiency of all operations in cold stores.

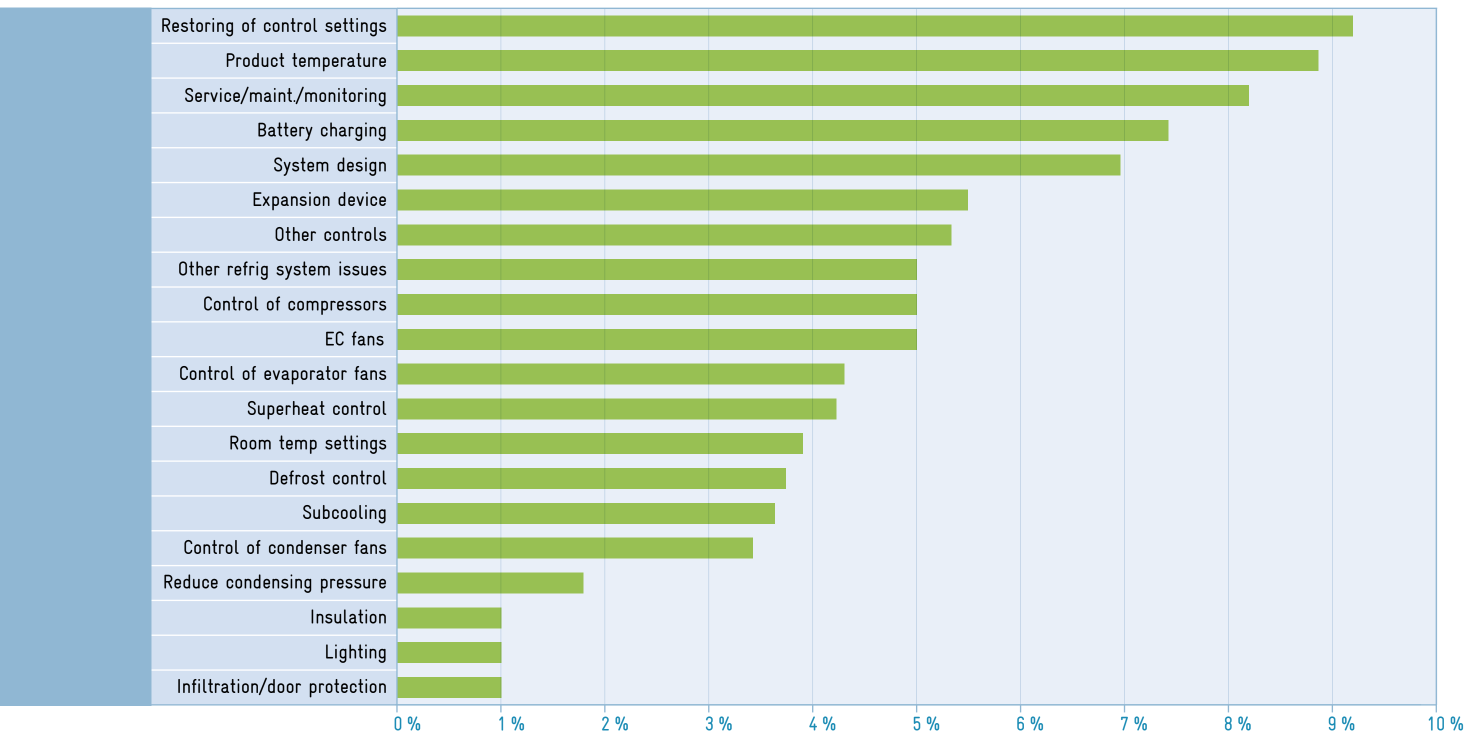


Figure 6: Identified issues with associated energy savings potential (Evans, 2013)

Equipment type	number of units	COP	cooling capacity (kW) per unit	refrigerant	GWP	charge (kg)	runtime per year (h)
chiller	2	3.5	100	R-22	1,810	35	4,500
condensing unit	2	1.7	10	R-22	1,810	2.6	6,500

Table 15: Assumed parameters for exemplary cold store

Emissions and mitigation scenarios

For a simple modelling of emissions and mitigation scenarios, an average set of RAC equipment was assumed for an exemplary cold store, such as could be found e.g. in Vietnam (Table 11). The direct and indirect emissions were calculated based on an estimated set of parameters, such as cooling capacity, run-time per year, COP, lifetime and refrigerant charge, for each equipment type.

For the mitigation scenario, a reduction of direct emission using alternative green technologies, i.e. a change of refrigerants to natural refrigerants, and a reduction of indirect emissions through improvement of 20 % of the energy efficiency (COP) were considered.

The assumption for the exemplary cold store in Vietnam using conventional technology is that the following equipment is in use to provide cooling for three different temperatures zones. The three parts of the store have an accumulated size of 60,000 m^3, i.e. a storage capacity of approximately 15,000 tons.

Indirect emissions: Considering the cooling capacity, average COP, and runtime of the equipment, the market would consume 333,613 kWh/a. Considering Vietnam's grid emission factor (Brander et al., 2011), this amounts to indirect emissions of 155 t CO_2eq per year.

Direct emissions: Considering the refrigerant type, refrigerant charge, estimated emission factors (1 % at manufacturing, 100 % at disposal, 25 % at servicing), direct emissions amount to 40 t CO_2eq per cold store per year.

Mitigation potential: If the same exemplary cold store used R-290 as a refrigerant and increased energy efficiency by 20 %, the overall emissions would go down from 374 t CO_2eq per year to 278 t CO_2 eq, per year or from 7,490 CO_2eq to 5,560 CO_2eq considering a 20-year lifetime of the equipment as shown in Figure 7.

42 Taking the number of cold stores in Iran and its relation to the population as a basis, this factor was used to estimate the number of cold stores in the Vietnam, the Philippines, Costa Rica and Grenada. Based on https://knoema.com/atlas/Iran/ranks/Cold-storage?origin=knoema.es, accessed 1 August 2017.

43 This approach gives only an estimate on emissions from the supermarket sector. However, the model could possibly also be used to explore various mitigation scenarios for an individual country.

44 own estimation on the basis of the 2006 number for Iran.

For the purpose of this paper, a simple model was built to estimate emissions from the cold store sector in the selected countries[42]. The country-specific grid emission factors (Brander et al., 2011) were taken into consideration and the emissions of the exemplary cold store were then multiplied by the number of stores. The BAU- and MIT-scenarios assume that:

- the total number of cold stores increases by 10 % every 5 years;
- all new cold stores are equipped with the energy efficient systems using low-GWP natural refrigerants;
- old equipment is replaced with new technologies in 20 % of the old cold stores (existing in 2015) every 5 years (reaching 100 % of the old cold stores in 2035 and all cold stores having the green cooling technology from 2035).

Table 16 provides an overview of the assumed number of cold stores, the estimated current total emissions of the supermarket RAC sector and its share of the country's total emissions as well as the estimated mitigation potential for the C4 countries in 2050[43].

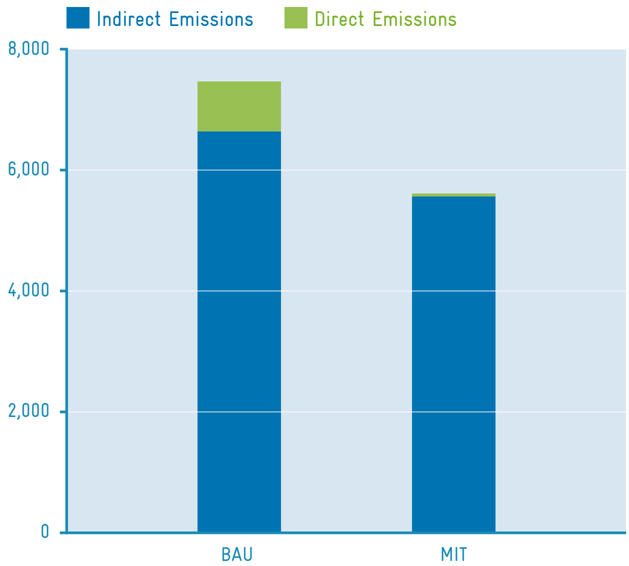


Figure 7: Lifetime mitigation potential of an exemplary cold store

	Philippines	Costa Rica	Grenada	Iran	Vietnam
Estimated number of cold stores in 2015[44]	895	43	2	707	815
Estimated total emission of cold store RAC sector in 2015 in t CO_2eq p.a.	193,662	2,663	423	177,748	160,038
BAU 2050 in t CO_2	377,393	5,189	824	346,381	311,869
Estimated mitigation potential in 2050 in t CO_2eq p.a.	122,289	3,718	270	104,645	106,059
Mitigation potential 2050 in %	32 %	72 %	33 %	30 %	34 %

Table 16: Overview over cold store RAC sector emissions in C4 countries

4.4.3 Ease of Implementation

Technology trends

Components of relevant cold store refrigeration systems are usually produced in industrialized countries with some involvement of emerging economies. There is an increasing trend of refrigeration systems running on natural refrigerants, mainly R-290, R-1270, CO_2 and ammonia. The technological complexity and related implementation of safety measures favour their use in large-scale industrial applications, as it is the case for cold stores. The necessary construction investments pay mostly for larger cooling systems considering large cooling loads and many operating hours. In contrast to direct evaporator systems, chillers allow for relatively high refrigerant charges because the chilled water circuits are separated from the refrigerant circulation by heat exchangers. In case of restricted refrigerant charge size, several compressors with their respective refrigerant loops may be combined to one larger chiller setup. Considering energy performance, R-290 performs better than prominent HFCs with increasing ambient temperature, as illustrated in Figure 8.

Furthermore, ammonia is another good alternative to HFC refrigerants. With ammonia, typically energy efficiency improvements of 10-15 % over HFC can be achieved.[45]

Investment costs for hydrocarbon and ammonia chillers are higher due to additional costs for safety applications or the use of stainless steel (ammonia) in comparison to current mass production of HFC chillers. However, as cold stores require relatively large refrigerant charges for refrigeration

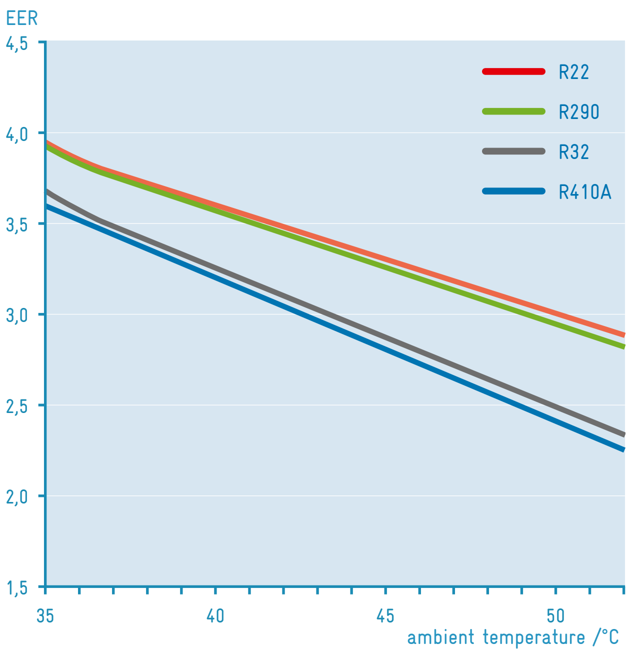


Figure 8: Energy performance of refrigerants against ambient temperature (Öko-Recherche, 2014)

45 https://www.newfoodmagazine.com/article/8684/packaged-chillers-with-ammonia-as-a-refrigerant-the-natural-choice/, last access July 2018.

and have long run-times, short payback periods of few years are possible considering the cheaper prices of natural refrigerants and higher energy efficiencies.

Barriers and solutions

To successfully introduce climate-friendly and energy-efficient solutions, existing barriers need to be identified and systematically addressed on a country-specific basis. General remarks on barriers and strategies for interventions encouraging private sector participation are treated in chapter 5.

A specific barrier in the sector may be that it is not so common for cold storage providers to communicate sustainability efforts directly to customers and that customers on the other hand have no or little influence on the provider. While customers may choose or prefer a specific hotel or supermarket due to a creditable ecolabel, they are usually not in a position to decide on which cold storage provider to trust. Where such pressure from the customers' side is lacking, an option may be that supermarkets establish criteria for their cold storage providers.

The extremely high upfront costs for cooling equipment in relation to the entire investment is also noteworthy for the cold store sector. In addition, uncertainty of savings that new technology investments will actually achieve raises doubts and limits the decisiveness of relevant actors (Evans, 2013). Private sector engagement seems unlikely without financial support from the government's side.

In this specific sector, it is crucial to address the entirety of encountered barriers and consider the role of a cold store being linked within the cold chain to achieve a desired technology shift. Larger companies often do not only operate cold stores but also the related logistic services.

Some aid agencies and organizations at governmental and private level have been engaged in improving the cold chain to alleviate the enormous food wastage, and tackle malnutrition in developing countries. However, those initiatives often failed to achieve widespread cold chain development. This seems to originate in disconnected approaches that lacked to recognize the cold chain as a value chain and disregarded the return on investment required for any measure to bring long-lasting effect (Miller, 2016).

4.4.4 Scalability and Relevance in C4 Partner Countries

Cold store market in C4 countries

The Logistics Performance Index (LPI) by the World Bank is a general performance and trend indicator of national trade logistics, including cold chains. The LPI score ranges from 1 (= low) to 5 (= high) and compares the performance quality of listed countries. This has been compared for C4 partner countries and some key economies in Table 17. From the LPI performance of all C4 countries below 3.00 we can conclude that there is significant improvement potential, specifically in the categories customs, infrastructure, international shipments, logistics competence, tracking & tracing and timeliness which the LPI score is based on:

Country	LPI Score	LPI Rank
Germany	4.23	1
U.K.	4.07	8
U.S.	3.99	10
China	3.66	27
India	3.42	35
Mexico	3.11	54
Vietnam	2.98	64
The Philippines	2.86	71
Costa Rica	2.65	89
Iran	2.60	96

Table 17: Logistics Performance Index (LPI) for C4 and selected additional countries (The World Bank, 2016).

Vietnam's and Costa Rica's growth rates in the cold store sector are remarkable (see chapter 6). For instance, food spending and pharmaceutical sales in Vietnam each have projected growth rates above 10 % each year. E-commerce is also experiencing strong growth with a current internet penetration of above 45 % in the market (Miller, 2016). While little information is available about other C4 countries, a similar trend may be expected to take place in other C4 countries with varying dimensions of growth as well as the degree of process (technological and infrastructural advances).

Relevant networks

The Global Cold Chain Alliance (GCCA), together with its core partner World Food Logistics Organization (WFLO), offers a knowledge and research platform on cold chain-relevant operations including storage, handling and transport. GCCA also partners with a few associations which facilitate networking with relevant industry actors: The International Association of Refrigerated Warehouses (IARW) and the International Association for Cold Storage Construction (IACSC). The International Warehouse Logistics Association (IWLA) is another network which mainly connects among the North American warehouse industry.

Modern Materials Handling is a cold chain relevant platform which focuses in knowledge exchange.

Cold Storage Chain is a platform offering networking without conditions with currently some hundreds of actors registered for refrigerated warehouse services. The following actors have been identified in C4 countries[46]:

- Costa Rica: Pima- Red de Frio, Corporacion Frionet S.A.;
- Philippines: Koldstor Centre Philippines Inc., Crystal Cold Storage, Big Blue Logistics Corporation; organized through the Cold Chain Association of the Philippines, Inc.[47];
- Iran's: Tehran Cold Storage Organization[48].

The Food and Agriculture Organization of the United Nations (FAO, 2017) pursues several strategic priority areas in C4 partner countries. Initiatives for food security and against food loss are largely present among C4 partner countries. In specific, the following priorities with relevance for the cold chain were detected:

- Costa Rica: Raising the level of competitiveness of the food sector in all modes and scales of production through the adaptation and delivery of efficient services;
- Grenada: food and nutrition security through targeted market driven production; health and safety standards in the agricultural and fisheries sectors;
- Latin America and the Caribbean in general: initiatives to combat food loss;
- Iran and Vietnam: food security and food safety;
- Philippines: Improving food and nutrition; enhancing agricultural production and productivity and ensuring efficient and streamlined supply chain.

Initiatives of 'going green' are slowly picking up in the cold store sector. Prominent measures within corporate sustainability programmes are rooftop solar system installations, more careful selection of materials and single energy efficiency measures such as more efficient lighting fixtures, control improvements, replacement of condenser fans, and optimization of logistics operations.

IWLA launched the Sustainable Logistics Initiative in North America for its members in 2011 (MMH, 2011). The primary objective is efficiency improvement of warehouse operations to achieve sustainable logistics practices. Participants obtain certificates. The initiative addresses corporate responsibility in the areas of environmental (electrical use, fuel, water consumption, recycling), social (safety, community activity measurements) and economic (cost savings) matters.

46 http://www.coldstoragechain.com/ad-category/warehouse-supply/, last access July 2018.

47 http://www.ccaphils.org, last access July 2018.

48 https://irn.bizdirlib.com/node/11743, last access July 2018.

5. Encouraging Participation

Based on the focused sector analysis, options for national policymakers can be considered with a view to actively engaging non-state actors in end-user industries on additional HFC efforts. On the one hand, it can be demonstrated why non-state actors are engaging in the topic based on existing evidence and which challenges they face, i.e. where increased government action can be most effective to help non-state actors overcome barriers for enhanced action that goes beyond current policies. Therefore, it is useful to take a closer look at existing initiatives to identify success factors and to draw lessons for future involvement of the private sector in these initiatives. Against this background, opportunities for governments to encourage private sector participation and build alliances both within and across the identified key industry sectors can be laid out. However, it is equally important to always keep in mind the wider challenges around non-state action and its limits.

Opportunities for non-state actors in RAC end-user industries

Non-state actors can benefit from multiple opportunities when taking action on HFCs beyond what is mandated by national policies. On the one hand, in a rapidly changing regulatory environment where companies can expect

Barrier category	Specific barriers	Options for governments to support increased participation of non-state actors
Regulatory	Unclear policy environment in the RAC sector	• Clarify government's position on the use of refrigerants and energy efficiency • Clarify targets, timeframes and transition phases for HCFC phase out, HFC phase down, planned introduction of energy efficiency standards, and planned electricity price increases • Clarify support schemes if any
	Restrictive or lack of supportive regulatory framework	• Introduce positive incentives (e.g. tax breaks, temporary subsidies) to support uptake of alternative refrigerants and energy-efficient technology • Introduce negative incentives (e.g. increasing electricity prices, removal of subsidies) to discourage business-as-usual • Remove competing or misplaced incentives (e.g. fossil fuel subsidies)
	Lack of clear national requirements for adequate safety standards for the safe handling of low-GWP/ flammable refrigerants	• Create voluntary frameworks (e.g. minimum training requirements for technicians at company/ business organisation level) • Raise awareness for existing voluntary frameworks
	Lack of voluntary frameworks/ lack of awareness for voluntary frameworks	• In cooperation with existing trade and business organisations, create new qualification and certification programmes • Integrate new requirements into existing qualification and certification programmes
	Lack of qualification and certification programmes	• Adapt existing or introduce new safety standards, in line with international best practice; make clear what national requirements exist to meet standards.
	Lack of adequate Minimum Energy Performance Standards (MEPS) and labels	• Gradually introduce MEPS/ efficiency labels, based on international good practice • Inform on plans for expansion of MEPS/ efficiency labels
Market/ Technology	High upfront and transaction costs	• Introduce mix of positive and negative economic incentives (e.g. tax breaks, temporary subsidies, rebates, fees or pollution taxes) to support investments into alternative refrigerants and energy-efficient technology
	Lack of capacity regarding installation, operation and maintenance of alternative RAC technology	• Create adequate training infrastructure to ensure safe installation, operation and maintenance of alternative RAC technology (e.g. through qualification and certification programmes)
	Lack of suitable IT systems and management software needed for operating and controlling alternative RAC technology	• Promote cooperation with other countries/ business organisations/ global players to facilitate access to recent IT developments
	Lack of leakage controls	• Introduce mandatory reporting for the use of (high GWP) refrigerants (e.g. refrigerant registry) and leakage testing for operators and service companies

Table 18: Overview of barriers and options to increase action fromend-user industries in the RAC sector

additional and strengthened national and international regulation limiting the use of F-gases and requiring higher efficiencies, taking timely action helps non-state actors to stay ahead of the curve (Green Cooling Initiative, 2015). By doing so, companies can mitigate profit risks that otherwise might result from delayed action and they can secure themselves sustainable competitive advantages in the market. Furthermore, early movement can help to ensure that necessary innovation is taking place within the company in order to maintain the beneficial status in the long-term.

At the same time, non-state actors that are active in the RAC sector can also benefit from a series of economic savings. These include a decrease of operational costs in the long-term through the replacement of high-emitting refrigeration technology with climate-friendly and energy-efficient alternatives. This in turn can result in lower energy costs for customers or higher profit margins for end-user industries. It also reduces the need for end-users to invest in an expansion of their energy supply infrastructure.

For example, improving the energy efficiency of air conditioners and using lower GWP refrigerants offer tangible economic savings. Some estimates point to emissions savings of up to 40 % at a global level by 2030 against a business-as-usual scenario (Green Cooling Initiative, 2015) and the avoidance of close to 100 billion tonnes of CO_2eq emissions by 2050. In addition, energy savings due to a peak load reduction of between 540 and 1,270 GW by 2050 are predicted (Shah et al., 2015).

Barrier category	Specific barriers	• Options for governments to support increased participation of non-state actors
Market/ Technology	Limited access to capital markets	• Introduce adequate finance instruments (e.g. subsidised loans, dedicated credit lines, guarantees, risk sharing facilities, grant schemes, etc.) • Promote co-investment schemes (e.g. public-private partnerships)
	Limited availability of alternative, energy-efficient technology/ low-GWP refrigerants	• Introduce economic incentives to support technological innovation and R&D • Promote cooperation with global players to give regional and local actors access to recent technological developments, e.g. through awareness raising and information dissemination • Promote cooperation with global players to give regional and local actors access to recent technological developments, e.g. through awareness raising and information dissemination • Introduce mix of positive and negative economic incentives to increase demand for energy-efficient technology and alternative refrigerants • Introduce incentives for companies to engage with their supply chain/ across the entire value chain
Information/ Awareness	Lack of knowledge on environmental an d/ or economic benefits of alternative RAC technologies	• Create information material for distribution among end-users in the RAC sector • Engage with business organisations/ academia to conduct studies on the business case of low-GWP refrigerants and energy-efficient technology • Engage with business organisations on outreach to their members/ awareness campaigns
	Lack of knowledge exchange	• Invite existing non-state initiatives to hold workshops/ knowledge-sharing events in the country • Organise peer-to-peer learning events at the sector- and sub-sector level • Support the creation of networks, associations, platforms at the sector- and sub-sector level • Support awareness campaigns
	Safety concerns	• In cooperation with existing trade and business organisations, create new qualification and certification programmes • Integrate new requirements into existing qualification and certification programmes • Ensure that alternative RAC technology conforms to international best practice standards on safety for installation, operation and maintenance
	Lack of effective Monitoring, Verification and Enforcement (MVE)	• Consider sharing regional testing facilities for effective MVE or start introducing them in the country (costly solution)

Non-state actors who show themselves committed to act on HFCs can additionally profit from reputational benefits. Recognition as a sustainable and trustworthy company can yield additional client demand and allow to sell more expensive products and services.

A small but growing part of the finance community is also asking for information from potential investee companies about how they integrate climate into their business strategies and to what extent they are prepared for transition risks. Taking action on HFCs could therefore help secure investments.

In the long run, transition to the use of natural refrigerants may also increase long-term security in terms of resource availability. Since natural refrigerants are naturally occurring substances, their handling cannot be restricted by patents and they can be sold and purchased by any company in any country (Green Cooling Initiative, 2015).

Barriers and challenges

At the same time, non-state actors can face a series of barriers when looking for low-GWP alternatives and energy-efficient cooling solutions. Barriers and their relative importance may vary depending on the country context and the end-user industry.

Table 18 illustrates major barriers to take increased action in the RAC sector (regarding both refrigeration and energy efficiency) as well as possible solutions for governments to support non-state action in this field.[49]

It is important to highlight, once again, that the focus is placed on additional non-state action, i.e. measures taken by end-users that are additional to what is regulated or mandated by national governments.

Creating alliances

Considering the main barriers and potential solutions illustrated in Table 18, it becomes evident that in order to effectively address the main barriers faced by end-user industries in the RAC sector, a range of stakeholders must be involved and brought together. Consequently, there is an opportunity to build alliances both within and across different industry sectors to encourage additional efforts for the introduction of alternative refrigerants and energy-efficient technology by non-state actors.

Alliances can be powerful in addressing several of the above-mentioned challenges and barriers. For example, the Alliance for Responsible Atmospheric Policy in the US coordinates industry participation in the development of reasonable government policies at the nexus of ozone protection and climate change.[50] At the global level, the prominent CCAC's HFC Initiative has significantly contributed to the information exchange on policy and technical issues and engaged in various capacity building efforts to disseminate information on emerging and good practices in the RAC sector (CCAC, 2017). Taking a closer look at existing non-state initiatives provides insights on success factors of alliances. Policy makers can use these insights to incentivise the creation of new alliances, including with non-state actors and initiatives. In fact, alliances can significantly contribute to market transformation and technology shifts. They can help to monitor and analyse market trends, conditions and trade practices in the RAC sector as well as new or proposed legislation in a specific industry sector. They can also set up conferences or trade events and may participate in stakeholder consultations (on behalf of their members) on refrigeration related regulations (GIZ Proklima, 2014). While the majority of non-state initiatives and alliances originate in developed countries, more and more initiatives are being created in or extended to developing countries. In addition, non-state initiatives aimed at engaging supply chains can also be applicable to companies operating in developing countries.

Analysis shows that the mitigation impact of non-state initiatives targeting HFCs is highest where they have global reach and where a specific end-user sector commits to transit to low-GWP solutions, providing that alternatives are available. This also means that, ideally, climate change considerations are embedded into supply chains as these play a key role in phasing out HFCs and increasing overall energy efficiency in the RAC sector (Climate & Clean Air Coalition and BSR, 2016).

Against this backdrop, policy makers can and should encourage greater participation of national end-user industries in existing and new initiatives. They can do so for example by organising workshops where participants of initiatives lay out the reasoning of why they joined the initiative in the first place and the experiences they have made since joining. National industry organisations and academia can also be engaged to produce evidence on the business case of adopting energy-efficient cooling solutions and replacing current high GWP refrigerants.

In addition, the power of the supply chain can be more effectively capitalised. It was pointed out by some interviewees that the technological choice of RAC end-user industries is often driven by recommendations of manufacturers rather than RAC end-users themselves.

Green or more sustainable procurement practices in end-user industries can yield additional economic and environmental benefits as was mentioned by some interviewees, especially in the context of energy-efficient cooling appliances. This in turn can work as a powerful demand driver for suppliers and manufacturers of low-GWP refrigerants and energy-efficient appliances and contribute resolving one of the main barriers, the lack of available technology alternatives.

49 Information in Table 19 is informed by a series of interviews that were carried out by GIZ in 2017 and asked non-state actors in the hotel, supermarkets and cold stores sectors about the main barriers for low-GWP alternatives and energy-efficient cooling solutions.

50 See: https://www.prnewswire.com/news-releases/refrigeration-industry-leaders-organize-global-refrigerant-management-initiative-276705661.html, last access July 2018.

Other factors that generally increase the likelihood of success of non-state initiatives include: clear ownership, regular monitoring of targets, technical capacity, sufficient funding, conducive political environment, financial health of companies and regulatory support (ICAT, 2017). Policy makers should bear this in mind when creating or supporting the creation of alliances. They could also show public support for existing initiatives.

Finally, existing non-state initiatives without a specific HFC target but with a potential to include HFCs on the agenda could be approached through national trade associations and/ or the government itself to explore options for an expansion of scope. Already established initiatives can offer a good opportunity to leverage sector specific mitigation efforts with the objective to tackle GHG emissions in the RAC sector more comprehensively.

Limits of non-state action

While the creation of alliances and the encouragement of increased participation of non-state actors in existing initiatives may help governments overshoot existing emission reduction and energy efficiency targets, governments also need to bear in mind that voluntary non-state action can be less effective than mandatory regulation and on its own is not sufficient.

For example, there is a risk of green washing and of companies not following through on their commitments. At a time when there is no entity holding companies accountable for their voluntary actions, companies may decide to abandon their plans later. Therefore, some governments might want to seize the opportunity of increased non-state action to put in place more ambitious policies in order to secure the progress made or expected under non-state action over the long-term. As an example, one of the major impediments mentioned by interviewees are the low or heavily subsidised electricity prices leading to market distortions and ultimately to a situation where there is less demand for energy-efficient cooling solutions. A small increase in electricity tariffs might prove sufficient to incentivise end-user industries to reconsider their technology choices and autonomously move ahead with the transformation of the RAC sector.

6. Recommendations for C4 Partner Countries

Based on a thorough analysis of the general role and relevance of non-state action for ambitious emission reductions in the RAC sector, followed by a detailed assessment of the potential for non-state action in three end-user industries (supermarkets, hotels and cold stores), this section summarises central results and recommendations for the C4 partner countries Costa Rica, Grenada, Iran, Philippines and Vietnam.

The sector assessment in Chapter 4 offers some insights into three end-user sectors and their specificities. For all countries, more detailed analysis and consultation with experts of the local markets need to take place to identify the most promising options for non-state action. General questions to be addressed include:

- Is the government aware of non-state action in the country? Does the government have an overview of non-state action (that goes beyond current policies)?
- Which non-state initiatives exist in the country?
- Which companies are involved in local non-state action? Which regional or global chains do they belong to, if any?
- What are major barriers for the introduction of green cooling technologies in the country and in the specific end-user sector? Are non-state alliances promising options to handle some of these barriers?
- Which opportunities exist to work with the present initiatives listed in the mapping in Chapter 2? Are local stakeholders already involved in any of the listed activities?

Overall, three central conclusions can be drawn from the analyses of the three focus sectors across all countries:

1. While showing differences in the shares of total emissions and in total mitigation potentials, all five partner countries display a significant mitigation potential across the analysed end-user industries.
2. There are different ways to leverage the existing mitigation potential: on the one hand, it is important that governments address mitigation potentials where they see them arise through increased and targeted regulation. On the other hand, governments, as well as existing initiatives, can encourage additional action by non-state actors ('non-state action'). Ideally, both ways are combined. Governments can incentivise additional non-state action and put in place more ambitious policies that ensure that rigorous emission reductions are achieved and maintained.
3. Alliances can support both, the government in the formulation and enforcement of effective regulation, and non-state actors in the identification and realisation of their potentials.

The following sections outline the relevance and mitigation potential of supermarkets, hotels and cold stores in the RAC sector for each country.

6.1 Costa Rica

With the large number of almost 700 hotels in Costa Rica, the hotel sector has the highest of emissions compared to the other two sectors.

The emissions from RAC equipment in this sector alone amount to currently 73,816 t CO_2eq. For 2050, a mitigation potential of 62,855 t CO_2eq is predicted.

	Estimated number	Estimated total emissions of specific RAC sector 2015 in t CO_2eq p.a.	BAU 2050 in t CO_2eq p.a.	Estimated mitigation potential in 2050 in t CO_2eq p.a.	Mitigation potential 2050 in %
Supermarkets	362	14,052	27,384	9,906	36 %
Hotels	698	73,816	143,846	62,855	44 %
Cold stores	43	2,663	5,189	3,718	72 %

Table 19: Emissions and potentials in the three end-user industries in Costa Rica

In addition to the hotel sector, both the supermarket and the cold stores sector offer potential to initiate and advance non-state-action in Costa Rica. The following Table 20 summarises relevant facts for each of the end-user industry in Costa Rica and corresponding recommendations to lower GHG related to cooling in the sectors.

End-user group	Situation	Recommendations
General	Costa Rica pursues the goal to become carbon neutral in 2021 (Fletcher et al., 2014). Costa Rica was the first country in the world to cover 100 % of its electricity demand by renewable energy for 75 days in 2015 and an estimated 90 % of electricity can be generated continuously without burning fossil fuels (Fendt, 2015).	
Supermarkets	The lion's share of Costa Rica's supermarket stores is distributed among five large retailers, including the US American chains Walmart and PriceSmart, the rest covered by regional and local chains (USDA, 2013a). Regarding availability, only minor local manufacturing activity of small freezers for commercial refrigeration was reported. Concerning the wider region, Fogel de Centroamérica operates a production site for commercial refrigeration in Guatemala which fabricates freezers, display refrigerators and bottle coolers, exporting at large amounts to other American and some transcontinental countries. Fogel already initiated a gradual shift to natural refrigerants by adding HC-290 and CO_2 to their production lines and is in exchange with Mexican actors for extension of knowledge (UNDP, 2017b, 2017a).	As the Palí stores are rooted in Walmart's corporate structure, and in this context, are expressing a commitment to sustainable practices in their central American farm program, this could be a starting point for the adoption of green cooling technologies through the Walmart group and their operation in Costa Rica. The cooperation between local store and the regional supplier Fogel could be strengthened for the deployment of F-gas free and energy-efficient commercial refrigeration equipment.
Hotels	More than half of Costa Rica's hotels are small establishments and family-run structures, while the others correspond to large chain hotels, with a larger number of rooms (Central America Data, 2017). Among the largest hotels are Four Seasons, Starwood and Marriot (Costa Rica Guide, 2015). Strong tourism sector and particularly eco-tourism trend. 25 % of land area covered by national parks. Costa Rica receives more than 1.7 million tourists yearly, and this number has been growing by 7 % annually (Costa Rica Guide, 2015). WPI created a new energy efficiency label for household appliances as recommendation while they found that the existing implementation of labels is inefficient (Fletcher et al., 2014).	Work with CCH specifically to get access to the many small hotel owners and establish initiatives for them (e.g. establishing exemplary energy audits with focus on cooling and refrigerants, benchmarking with internationalbest practices,and advise for integrating green cooling technologiessee Green Cooling Roadmap forJetwing[51]).Some measures(mainly for newconstructions) are avoidance of cooling appliance where possibleas wellasdeploymentof HFC-free air conditioners with naturalrefrigerants (with the hydrocarbon R290 asrefrigerant). Other measures are the localdeployment of PV solar technologiesto provide fordaytimeelectricity supply for air conditionerand refrigerator. The electricity use of the hotelscouldbe benchmarked e.g. through the CCH,initiallysupported with instruments provided through the C4 project,to drive energyefficiency. A local Green Cooling eco-labeli.e. supported through CCHor an independentlocalinstitute could be developed as an endorsementlabelfor hotels avoiding the use of high-GWPrefrigerants.
Cold stores	In recent years, significant increase ofcold chain activitieswasregistered in Costa Rica. In particular, the companyFrionet expanded theircold storage by400 %in the last5 years. The service provider Leaho reported that services in industrial refrigeration increased by300 %in the past5 years(FernándezMora, 2015).	Work with cold store operators to find out level ofawarenessand potentialto establish pilotgreen cooling warehouse,including the possible electricity supply through roof-top installed PVsolar panels.

Table 20: Status and recommendations for the three end-user industries in Costa Rica

51 https://www.giz.de/expertise/downloads/giz2017-en-gci-green-cooling-hotel-roadmap.pdf, last access April 2018.

6.2 Grenada

In Grenada, the hotel sector is the most significant in terms of emissions compared to the other sectors. 28 hotels correspond to emissions of 8,870 t CO2eq. For 2050, a mitigation potential of 4,456 t CO_2eq has been calculated with the introduction of low-GWP cooling solutions. Therefore, it is assumed that the hotel sector offers the greatest potential for non-state action. The following table summarises relevant facts each end-user industry in Grenada and corresponding recommendations.

	Estimated number	Estimated total emissions of specific RAC sector 2015 in t CO_2eq p.a.	BAU 2050 in t CO_2eq p.a.	Estimated mitigation potential in 2050 in t CO_2eq p.a.	Mitigation potential 2050 in %
Supermarkets	5	596	1,161	267	23 %
Hotels	28	8,870	17,284	4,456	26 %
Cold stores	2	423	824	270	33 %

Table 21: Emissions and mitigation potentials in the three end-user industries in Grenada (Source: own calculations based on the introduction of low-GWP cooling solutions).

End-user group	Situation	Recommendations
General	Regarding availability, Grenada as a small tri- island state with some 110,000 inhabitants and is characterized by import dependency.	Initiate networks between end-users of various Caribbean states to address overseas technology suppliers.
Supermarkets	The retail market in Grenada consists of only a handful of supermarkets and several convenience stores which are mainly distributed between local private owners (USDA, 1997, 2015).	Initiate networks between supermarket providers of various Caribbean states to address overseas technology suppliers.
Hotels	In 2016, the Caribbean Clean Energy Program was agreed to improve energy efficiency in the Caribbean's hotel sector, the largest electricity consumer sector in the region. The programme includes Grenada and there are approximately 2,500 hotels in the Caribbean that can profit from this initiative (CariCom, 2016).	Work with CHTA to get access to the individual hotel owners and establish initiative for them to get access to best practices and advise for integrating green cooling technologies. With the programs of CHTA and CariCom (Carribbean Community), volunteering Grenada hotels could take the role of front-runners and demonstrate the transition to low-GWP, natural refrigerants with highly energy-efficient cooling appliances.
Cold stores	The yellow pages have two companies listed[52]: Country Cold Store Ltd, Donna's.	Initiate networks between cold store operators and other cold chain service providers establish benchmarking among operators, good practices and introduce green cooling technologies, i.e. also from European suppliers. Similarly, such activities can be established locally. Local operator network are the main beneficiaries and should take ownership to drive the initiative.

Table 22: Status and recommendations for the three end-user industries in Grenada

6.3 Iran

In Iran, the hotel sector is estimated to have the highest mitigation potential, with 184,436 t CO_2 in 2050. In contrast to the other countries, Iran's hotel sector is less important. After a long phase of international isolation, foreign tourism only recently initiated noticeable growth (Pemberton and Leach, 2015; Porter, 2015). Also, foreign cold chain investors only recently spotted the Iranian market. Until recent years, food supply has presumably been dominated by local level, i.e. mainly small markets and short transport distances (Bord Bia, 2017).

52 https://www.findyello.com/Grenada/White-Pages/Cold-Storage, last access July 2018.

While the cold store sector was estimated to have the highest impact, all three sectors can be assumed to offer quite good potential for non-state action in Iran.

The following table summarises relevant facts for each end-user industry in Iran and corresponding recommendations.

	Estimated number	Estimated total emissions of specific RAC sector 2015 in t CO_2eq p.a.	BAU 2050 in t CO_2eq p.a.	Estimated mitigation potential in 2050 in t CO_2eq p.a.	Mitigation potential 2050 in %
Supermarkets	1,335	193,563	294,632	82,566	28 %
Hotels	1,085	382,456	745,298	184.436	25 %
Cold stores	707	177,748	346,381	104,645	30 %

Table 23: Emissions and potentials in the three end-user industries in Iran

End-user group	Situation	Recommendations
General	Iran only had restricted access to Western technologies over a longer period. Iran is worldwide one of the countries with the lowest energy efficiency ratios and highest dependences on fossil fuels. Historically energy and electricity had been highly subsidized. It has not changed up to today. With the lifting of sanctions, it can be expected that modern technologies, including climate-friendly and energy-efficient RAC technologies, can increasingly be introduced in Iran and local companies will increasingly be able to catch up with the advanced international technology standard. Iran belongs to Group 2 of the A5 countries. These countries can phase out HFCs with a further delay compared to other A5 developing countries.	The new situation offers a good opportunity for technological advances, the deployment of energy-efficient and climate-friendly RAC appliances and non-state actor initiatives. The possible success of deploying low-GWP refrigerants in Iran can be highly important to demonstrate the technical and economic feasibility of transitioning to non-HFC appliances, also in a high ambient environment. In this table below for each sub-sector possible non-state initiatives are highlighted under which climate-friendly green cooling technologies can be promoted.
Supermarkets	Iran's retail market is dominated by local chains, only Carrefour has recently opened a few stores under the subsidiary company Hyperstar (Bord Bia, 2017). The number of local super market chains significantly increased during recent years. Initially three local supermarket chains were dominating, Refah, Shahrvand and Ekta. During recent years additional chains have opened, including Hyper star, Hyper me, Ofogh Kouroush, Gambo, Seven, Bama	Establish a collaboration with Carrefour as local international player to establish a pilot project in a supermarket using natural refrigerants to demonstrate feasibility and energy savings. As in the case of cold store such a pilot can serve as a national benchmark for the transition to low-GWP solutions in the sector.
Hotels	Starwood and Hilton had managed hotels in Iran before its international isolation, same as InterContinental, which is currently operated by the Iranian Laleh group. An Iranian firm signed an agreement with French hotel giant AccorHotels to use the Novotel and ibis brands for 15 years. Abu Dhabi based Rotana hotels group is opening four hotels (Porter, 2015). Iran aims to host 20 million tourists a year by 2025. With its 19 UNESCO World Heritage Sites, Iran has top historical highlights. Currently, Iran lacks sufficient accommodation and transportation for that number of tourists; Iran therefore aims to increase its 4 and 5-star hotels from 130 to 400 in 10 years (Pemberton and Leach, 2015).	Work with Iran Hotel Association (IHA) to establish low-GWP model hotel cases having low energy use benchmarks (kWh/m2) and using exclusively natural refrigerants. Such hotel cases could be established at highly visible cultural heritage sites attracting tourists.
Cold stores	Cold storage capacity is increasing strongly (60 % from 2013 to 2017). About 40 % of all cold storage facilities are located in Tehran (Financial Tribune, 2017).	Work with Tehran Cold Storage Organization[53] to get better insight into the sector and which individual players are involved and could be mobilised. Measure to initiate energy efficiency for cold stores could be the auditing of representative cold store to establish national benchmarks for low electricity use and the deployment of natural refrigerants.

Table 24: Status and recommendations for the three end-user industries in Iran

53 https://irn.bizdirlib.com/node/11743, last access July 2018.

6.4 Philippines

With over 1,500 hotels and corresponding RAC emissions of currently 428,742 t CO_2eq, the hotel sector has the highest emissions compared of the analysed sectors. The mitigation potential in this sector alone is 223,978 t CO_2eq in 2050.

Therefore, it can be assumed that the hotel sector offers the greatest potential for non-state action. However, the cold store sector should not be neglected either. The following table summarises relevant facts for each end-user industry in the Philippines and corresponding recommendations.

	Estimated number	Estimated total emissions of specific RAC sector 2015 in t CO_2eq p.a.	BAU 2050 in t CO_2eq p.a.	Estimated mitigation potential in 2050 in t CO_2eq p.a.	Mitigation potential 2050 in %
Supermarkets	523	64,004	124,725	28,505	23 %
Hotels	1,544	428,742	835,496	223,978	27 %
Cold stores	895	193,662	377,393	122,289	32 %

Table 25: Emissions and potentials in the three end-user industries in the Philippines

End-user group	Situation	Recommendations
General	Energy Efficiency and Conservation Roadmap 2011-2030 formulated energy savings equal to 10 % of annual final energy demand as a goal (Reyes, 2013). National Energy Efficiency and Conservation Program (NEECP) includes Standards and Labeling for Household Appliances, Energy Management / Energy audit / ESCO Accreditation (Reyes, 2013). Philippine Energy Efficiency Project (PEEP) includes Efficient Lighting Initiative and Efficient Building Initiative (Reyes, 2013).	Through its ambitious climate agenda, ambitious mitigation goals and relatively high energy prices, the Philippines offer a good starting point for non-state initiatives. In the following, possible non-state actions through the different focus sectors are outlined
Supermarkets	The Philippines hypermarket stores include 12 subsidiary stores by METRO. Many primarily small local chains provide regular large format supermarkets, the largest being Robinsons Supermarket with 136 stores which stands out for being a registered member of the CGF. There is also a remarkable market for small supermarkets and convenience stores in the Philippines with more than 2,600 stores in total. (USDA, 2016). The Philippines are largely dominated by local and regionally developed technologies, which partly do not reach advanced international best practices regarding the deployment of low-GWP refrigerants or high energy efficiency standards. (Food Retail World, 2012).	The involvement of METRO as a proponent of low-GWP refrigerants is an opportunity to penetrate the retail market with climate-friendly technology solutions. Work with METRO and Robinsons who are already CGF members. Foster cooperation with international producers of best practice technologies. Promote initiatives with the industry on voluntary standards regarding the energy efficiency of appliances and the use of low-GWP, natural refrigerants.
Hotels	Tourism and hospitality industry are booming: Foreign visitor arrivals increasing by an average of 8 % per year in the past five years, estimated 10 million foreign tourists by 2020. 37 hotel projects and 10,713 rooms in its hotel construction pipeline. In 2017, about 4,200 new hotel rooms are projected to be delivered (The Hotel Show, 2017). Some of the most booked hotels in the Philippines are New World Makati Hotel, Crimson Resort and Spa, Sofitel, Radisson Blu, Marriott (Philippines Hotels, 2017).	Work with the HRAP and the PHOAI to identify existing sustainability efforts related to RAC equipment and possibly introduce initiative, promote Green Hotel awards and promotions regarding climate-friendly and energy-efficient cooling.
Cold stores	Due to relatively high energy prices in the Philippines, energy-efficient appliances pay off well. As heavy electricity users, cold stores in the Philippines move early for the use of ammonia as a natural refrigerant for cold stores. The current deployment of ammonia may have reached a penetration of up to 50 % in cold stores. The higher upfront investments into ammonia chiller systems pay off well through lower electricity operating costs.	Contact Cold Chain Association of the Philippines (CCAP) to get access to the various providers and possible introduce green cooling as a topic in their conferences or seminars. It could be considered to have mandatory energy audits for medium size to larger cold stores. As basis of the energy audits the energy used of different cooling system alternatives could be evaluated and benchmarked against each other. The benchmarking of cold stores can then identify higher energy efficiency systems (such as those seen with ammonia systems) and serve as a basis to promote these further.

Table 26: Status and recommendations for the three end-user industries in the Philippines

6.5 Vietnam

With over 2,000 hotels and corresponding RAC emissions of 568,159 t CO_2eq, the hotel sector has the highest emissions compared to the other sectors. The estimated mitigation potential in this sector alone in the year 2050 is 302,243 t CO_2eq.

It can be assumed that the hotel sector offers the highest potential for non-state action. However, the cold store and supermarket sectors should not be neglected either. The following table summarises relevant facts for each end-user industry in Vietnam and corresponding recommendations.

	Estimated number	Estimated total emissions of specific RAC sector 2015 in t CO_2eq p.a.	BAU 2050 in t CO_2eq p.a.	Estimated mitigation potential in 2050 in t CO_2eq p.a.	Mitigation potential 2050 in %
Supermarkets	1,400	153,239	228,190	70,429	31 %
Hotels	2,123	568,159	1,107,181	302,243	27 %
Cold stores	815	160,038	311,869	106,059	34 %

Table 27: Emissions and potentials in the three end-user industries in Vietnam

End-user group	Situation	Recommendations
General	Law on Energy Saving and Efficiency (No.50/2010/QH12) enforced since 2011 (Energy Efficiency and Conservation Office, 2012) The Vietnam Energy Efficiency and Conservation Program (VNEEP), objective was 5 to 8 % of total energy consumption in the period of 2011 to 2015 compared to BAU (Energy Efficiency and Conservation Office, 2012).	The update of the Vietnamese NDC offers a chance to integrate specific goals on the RAC sector and its equipmen.
Supermarkets	Vietnam is mainly supplied by local retail chains. However, the German wholesaler METRO owns 19 stores, also a local joint venture with the French Casino Group contributes 27 stores of different sizes. A local particularity is the participation of six state-owned supermarket chains in retails. Two regional chains contribute a few more stores. (USDA, 2013b). Certain restrictions on foreign direct investment in Vietnam detain some retailers from market entry (Miller, 2016). Regarding the technology supply, the situation is similar to the Philippines. (USDA, 2013b).	Seek cooperation with international groups such as METRO and Casino to support cooperation with international producers of best practice technologies.
Hotels	The tourism sector served more than 7.94 million foreign visitors and 57 million domestic tourists last year. More than 3,000 new hotel rooms were installed in 2015 (VietNamNet Bridge, 2016). Some of Vietnam's most booked hotels are: Sofitel, InterContinental, Rex Hotel, Hyatt (Hotels.com, 2017).	Work with Vietnam Hotel Association to identify existing sustainability efforts related to RAC equipment and possibly introduce initiative. Front running eco-hotels could be identified with an interest on energy savings and transition to low-GWP refrigerants. If there is sufficient support a Green Cooling endorsement label could be promoted with participating hotel groups.
Cold stores	Expenses on food are predicted to increase by 10.5 % per year. Agricultural and seafood dominate the local production for exports and create additional cold chain demand. Currently, foreign logistics companies hold 80 % of market share worth $48 billion and growth in the cold chain is expected to continue. The recent market entry of large supermarket chains is driving demand in cold chain services. Among the largest cold store operators, the U.S. American cold store provider Preferred Freezer as well as servicing companies of Swire Group are active in Vietnam. Preferred Freezer operates one of the most modern refrigerated warehouses in the country that utilizes state of the art automation technology and advanced inventory tracking methods (Miller, 2016).	Work with organisers and speakers of Vietnam Fresh & Cold supply chain conference, including Carrier, towards increased input on green cooling in future conferences and network activities[54].

Table 28: Status and recommendations for the three end-user industries in Vietnam

54 http://vietnamsupplychain.com/en/learn/events/view/vietnam-fresh-cold-supply-chain-conference-2017/533, last access July 2018.

7. Conclusions

The Kigali Amendment and the Paris Agreement are different treaty regimes that offer potential for synergies in an effort to close the global emissions gap. Even though the exact impact of the Kigali Amendment in terms of emission reductions is still unclear, it can work alongside the Paris Agreement and provide an additional framework for mitigation by locking-in effective action on HFCs and energy efficiency, leading the way to the global 2°C goal.

To date, top-down measures neither under the ozone nor under the climate regime have yielded the required results in terms of limiting global warming to 2°C. There is a need for enhanced bottom-up activity to fill the current emissions gap. Non-state action that goes beyond current regulatory and policy requirements set by national governments can play an important role in tapping the additional mitigation potential in the RAC sector.

Important non-state actors in the RAC sector are end-users of cooling technologies. Through technology choices that take the use of natural refrigerants in refrigeration and air conditioning as well as energy efficiency into account, end-user industries can have a substantial impact on national GHG emissions and emission reductions in the RAC sector. In supermarkets, cold stores and hotels, RAC equipment is an important energy consumer that can be responsible for more than half of the overall energy consumption of a company. Apart from energy-related emissions, the leakage of high-GWP refrigerants causes additional emissions. Thus, the use of energy-efficient equipment with low-GWP refrigerants can substantially lower the carbon footprint of supermarkets, cold stores and hotels.

So far, only a few bottom-up non-state actors or initiatives specifically target the RAC sector by defining explicit targets for HFCs or energy efficiency. Most information on bottom-up non-state actor activities is specific to certain sectors, such as supermarkets and food processing or beverage companies. For other RAC subsectors such as cold stores and hotels, only a few non-state actor initiatives target the RAC sector so far.

Taking timely action on HFCs beyond what is mandated by national policies can bring multiple benefits for end-users of cooling technologies. Non-state action can help secure competitive advantages of being an ‘early mover’, mitigate profit risks caused by delayed action, derive economic savings from improved energy efficiency and increase reputational benefits which in turn can increase profits.

Non-state actors still face many barriers and challenges when engaging in mitigation action in the RAC sector. These barriers can exist in the regulatory field, e.g. due to an unclear or restrictive policy environment; in the market and technology field, e.g. due to limited availability of alternative technologies or high upfront costs; or in the field of information and awareness, where a lack of knowledge on technology alternatives and their benefits may inhibit mitigation action. Governments have several options to address these barriers and actively increase participation from end-user industries in the RAC sector.

Alliances can be powerful in supporting non-state action to leverage the full mitigation potential in the RAC sector. Networks of non-state actors can help monitor and analyse market trends, trade practices or legislative progress in a specific industry sector and encourage additional efforts for the introduction of alternative refrigerants and energy-efficient technology in that sector.

Policy makers, academia, and industry organisations can actively encourage greater participation of end-user industries in new or existing alliances. They can provide platforms, develop ideas and share knowledge and experiences, for example on the business case of refrigerant replacement and the adoption of energy-efficient cooling technologies. While supermarket and hotel operators often value reputational benefits, cold store operators are likely to be more susceptible to economic advantages since they are part of a complex supply chain and do not directly communicate a 'green' image to their customers.

Non-state action has its limits! Voluntary non-state action is not per se more effective than mandatory regulation, and on its own it is rarely sufficient. Governments should seize the opportunity of non-state action in a specific industry sector to establish more ambitious policies that secure the progress made by non-state actors over the long-term.

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