SOPHIA

Sustainable Off-grid solutions for
Pharmacies and Hospitals In Africa

POLICY BRIEF

Natural Refrigerants in Africa

Acknowledgements

About the SophiA project

The “Sustainable Off-grid solutions for Pharmacies and Hospitals in Africa” project (SophiA) will enable more African people to access carbon-neutral energy for electricity, heating and cooling of medicine and food, as well as safe and clean drinking water, thereby improving the quality of life in a sustainable way.

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About the policy brief

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ACRONYMS

CFCs	Chlorofluorocarbons
GHGs	Greenhouse Gas
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HFOs	Hydrofluoroolefins
ODS	Ozone Depleting Substances
TFA	Trifluoroacetic Acid
RAC	Refrigeration and Air Conditioning
PFAS	per- and polyfluoroalkyl substances

01
Historical Perspective

Since the 19th century, the choice of refrigerant has evolved from natural refrigerants to synthetic ones due to environmental, climatic, safety and economic factors. In Ghana, for example, ammonia systems at the Tema fishing harbour were replaced by synthetic refrigerants in the 1990s, but ammonia is being reintroduced for its lower operating costs.

Advocacy for natural refrigerants is crucial in Africa to address environmental concerns and support the implementation of international agreements such as the Kigali Amendment to the Montreal Protocol.

01. Historical perspective

Since mechanical refrigeration was invented in the 19th century, the choice of refrigerant has evolved due to environmental, climatic, safety and economic factors [1,2]. As there was no chemical industry at the time, early refrigeration systems relied on natural refrigerants such as ammonia, carbon dioxide, dimethyl ether, sulphur dioxide, and water [3,4].

In the 1930s and 1940s, the invention of halogenated refrigerants contributed to the widespread adoption of refrigeration systems as these substances were then promoted as safe alternatives. In many applications – except for industrial refrigeration and refrigeration systems in the petrochemical industry, which continued to use ammonia and hydrocarbons respectively – natural refrigerants were replaced by synthetic ones based on chlorinated and/or fluorinated hydrocarbons, sometimes with added bromine atoms.

In Ghana, for instance, prior to the 1990s, central water-cooled ammonia plants dominated the cold storage facilities at the Tema fishing harbour. In the 1990s, the centralised ammonia plant from the cold store market was replaced by a condensing unit using synthetic refrigerants, which had the advantage of a lower initial cost [5]. In the 2010s, ammonia systems were gradually reintroduced at the Tema fishing harbour due to their lower operating costs in energy use and maintenance [6].

At the time, studies led by UNEP and UNIDO examined strategies and opportunities to overcome barriers to the uptake of low global warming potential (GWP) refrigerants – including natural refrigerants – in Article 5 countries [7,8]. They highlighted the importance of access to information and stakeholder engagement as instrumental in the uptake of natural refrigerants among industry and policy representatives in developing countries and emerging economies.

This policy brief aims to guide the technological adoption of natural refrigerants based on environmental, climatic, safety, and economic considerations. Advocacy for natural refrigerants in Africa is based on scientific evidence of the detrimental effects of synthetic refrigerants on the ozone layer, global warming, and other environmental impacts, and is considered as a key driver for the successful implementation of international agreements such as the Kigali Amendment to the Montreal Protocol.

A bird's eye view of the Tema port in Ghana © Shutterstock

02

Environmental impact of synthetic refrigerants

Africa is especially vulnerable to the effects of climate change, bearing high costs for adaptation measures. While global efforts under the Montreal Protocol have nearly eliminated ozone-depleting substances, HCFC-based systems still account for half of the African air conditioning market, highlighting the need for climate-friendly alternatives.

02. Environmental impact of synthetic refrigerants

Africa is one of the most vulnerable continents to the effects of climate change, bearing disproportionately high costs for essential climate adaptation measures [9]. African economies are heavily dependent on climate-sensitive sectors. In this context, the refrigeration and air-conditioning (RAC) sector is becoming a major, vital pillar for achieving sustainable development.

Unfortunately, synthetic gases used in refrigeration systems are a significant source of greenhouse gas (GHG) emissions. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are chlorine-containing refrigerants that damage the ozone layer. This threat to Earth's biosphere led to the signature of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987. Through its various amendments and universal ratification, CFCs and HCFCs have now been virtually eliminated from new refrigeration and air-conditioning systems – although the molecules will persist in the atmosphere for several decades.

According to UNEP, as of 2024, the Parties to the Montreal Protocol have phased out nearly 99% of ozone-depleting substances (ODS) globally compared to 1990 levels [10]. The ozone layer is currently on a path to recovery and is expected to heal back to pre-CFC and HCFC levels by 2100 [11]. However, in Africa, air conditioners containing the HCFC refrigerant R22 still account for nearly half of the market [12]. See Box 1 on the issue of environmental dumping of equipment containing obsolete refrigerants in Africa.

Hydrofluorocarbon refrigerants (HFCs) were introduced to the market in the late 1980s and early 1990s as ozone-safe replacements for CFCs and HCFCs. However, most HFCs and HFC blends have relatively high GWPs. Consequently, HFCs are being phased down and even phased out in some regions, according to the Kigali Amendment to the Montreal Protocol, adopted in 2016. As of 2024, 45 out of 54 African countries have ratified the Kigali Amendment, thereby pledging to reduce the production and consumption of HFCs by 80% by 2045 [13]. According to the HFC phase-down schedule, African countries – along with most developing countries, or Article 5 parties – are required to freeze HFC consumption in 2024 and begin a stepwise reduction starting in 2029, continuing through to 2045. Some regions of the world have implemented even stricter policies, such as the EU F-gas regulation, revised in 2024, which limits the amount of HFCs to be placed on the market to 2% of 2015 levels by 2048 [14].

As a consequence of the HFC phase-down, refrigerant manufacturers are commercialising hydrofluoroolefins (HFOs) – another class of fluorinated substances with very low GWPs. Recent studies have shown that during degradation in the atmosphere some HFO refrigerants can break down into R23, a potent and long-lived HFC greenhouse gas [15], or produce trifluoroacetic acid (TFA) [16]. TFA is the most widespread of the per- and polyfluoroalkyl substances (PFASs), also known as "forever chemicals". Due to the short atmospheric lifetimes of HFOs, it is reported that TFA formed during their degradation tends to accumulate in soil and surface water not far from the site of the refrigerant leak. TFA is a highly persistent pollutant and is suspected to negatively affect biological organisms at higher concentrations, including potential toxicity to reproductive systems [17]. Residues of TFA have been observed in water, air and soil samples worldwide, including in Africa (e.g. Malawi and South Africa) [16,17].

Several research studies have documented that the degradation of R1234yf – an HFO used to replace R134a (an HFC) in car air-conditioning systems – leads almost exclusively (~100%) to TFA within days, given its short chemical atmospheric lifetime [18]. Holland et al. claim that if all R134a emissions worldwide were replaced by R1234yf emissions, simulations predict a 33-fold increase in global TFA deposition (up to 250-fold increase over Central Europe) [19].

Ongoing studies are investigating the formation of TFA as a degradation product of HFOs. In contrast, it is well established that natural refrigerants do not form TFA in the atmosphere and are therefore less likely to be subject to future regulatory restrictions.

Old refrigerators freezers © Shutterstock

Box 1: Avoiding environmental dumping in Africa

Most new room air conditioners marketed in Africa are inefficient and operating with HCFC and HFC refrigerants scheduled under the Montreal Protocol for phase out and phase down, respectively [12]. The commercialisation of new and used sub-optimal appliances, which fail to meet efficiency and environmental standards in more developed and regulated markets, into regions where regulations are less stringent or not enforced has been described as environmental dumping. Environmental dumping not only impoverishes buyers unable to afford electricity, it also complicates compliance with the Montreal Protocol due to the introduction of refrigerants scheduled for phase-out or phase-down. Furthermore, it increases GHGs emissions [20] and creates air, water, and land pollution from toxic substances released when processing the waste and refrigerants from obsolete appliances [22].

Conference Room Papers (CRPs) were submitted by Ghana on behalf of the African States Parties to stop the harmful dumping of new and used inefficient refrigeration and air conditioning appliances in all Article 5 Parties [21]. These CRPs led to the Unanimous 2023 Decision XXXV(13) of the Montreal Protocol recognising shared responsibility of Parties to prohibit the export of cooling equipment that does not satisfy their national regulations or is inconsistent with their standards [22]. Shared responsibility of exporting and importing authorities also opens developing countries' markets to best available technology with climate-friendly refrigerants.

In December 2023, the United States Environmental Protection Agency (US EPA) finalised its HFC phasedown rule, including prohibitions on exporting factory-completed products not qualified for domestic sales [23]. In February 2024, the European Union (EU) adopted Regulation 2024/573 on fluorinated GHGs, EU F-gas Regulation, prohibiting the export of certain used and new equipment containing climate-damaging fluorinated GHGs [14]. Shortly thereafter, United Nations (UN) Secretary-General António Guterres in his Call to Action on Extreme Heat, spotlighted the importance of stopping the dumping in developing countries of new inefficient cooling appliances with obsolete refrigerants [24].

The next step is for responsible global manufacturers of energy efficient air conditioners using climate-friendly refrigerants to capture African and other developing country markets, through innovative financial mechanisms and through strategic partnerships that could include financing support from the Montreal Protocol Multilateral Fund for the Implementation of the Montreal Protocol (MLF).

03

Properties of natural refrigerants and applications in refrigeration systems

When properly selected for the appropriate application, integrated into well-designed systems and managed under strict safety protocols, natural refrigerants are safe, energy-efficient, and cost effective for use in state-of-the-art refrigeration, air-conditioning, and heat pump systems.

03. Properties of natural refrigerants and applications in refrigeration systems

Natural refrigerants, including ammonia, carbon dioxide, hydrocarbons, water, and air, are substances that exist in nature and are part of the biosphere. Moderate use and emissions of these substances do not cause unknown changes in the environment, such as those generated by CFCs, HCFCs, HFCs and HFOs. Although natural refrigerants are produced industrially, their CO_2-equivalent emissions during manufacturing are only a fraction of those of fluorinated substances [25] and they can also be derived from plant-based processes [26].

When properly selected for the appropriate application, integrated into well-designed systems and managed under strict safety protocols, natural refrigerants are safe, energy-efficient, and cost effective for use in state-of-the-art refrigeration, air-conditioning, and heat pump systems. Thanks to their favourable thermodynamic properties, natural refrigerants often allow systems to achieve higher energy efficiency than those using fluorinated refrigerants, thereby reducing indirect emissions associated with electricity generation. Table 1 summarises key characteristics of natural refrigerants compared to HFCs and HFOs (see IIR, 2016, for a full overview [27]).

As with CFCs, HCFCs, HFCs or HFOs, there is no one size fits all natural refrigerant. Each option must be evaluated based on factors such as availability, safety for the local and global environment, energy efficiency, cost, and other relevant criteria. Table 2 lists selected natural refrigerants along with their typical and potential future applications. Other hydrocarbons, not included in Table 2, are appropriate for specific applications such as pentane (R601) and isopentane (R601a) for high-temperature heat pumps, and ethane (R170) for ultra-low temperature systems.

Regarding future wider applications of hydrocarbons, for example in air-conditioning systems, extensive mitigation measures have been developed to address safety issues associated with flammability.

Table 1

Main characteristics of selected natural refrigerants, HFCs and HFOs

Refrigerant	GWP	PFAS	Flammable	Toxic	Comparative costs (2)	
					Refrigerant	Installation
HFCs	High	Some are and a few form TFA	No GWP < 750 Moderate	Low, but toxic fumes when burning	Moderate	Low
HFOs	Low (1)	Some are and several form TFA	Moderate	No acute, but toxic fumes when burning	High	Moderate
Hydrocarbons	Low	No	Yes	Low	Low	Moderate
Carbon dioxide	Low	No	No	Above 10%	Low	Moderate
Ammonia	None	No	Moderate	High	Low	Moderate
Water	None	No	No	No	Low	Moderate

Table 2

Selected natural refrigerants and their typical current applications as well as future applications

		Hydrocarbons			Ammonia	Water	CO2
		HC-290	HC-600a	HC-1270	R717	R718	R744
Sealed refrigeration appliances	Domestic refrigerators		✓				
	Commercial plug-in appliances	✓					✓ (2)
	Heat pump tumble dryers	✓					
Food retail	Stand-alone equipment	✓					✓ (2)
	Condensing units	✓	✓	✓			✓ (2)
	Centralised systems	✓ (1)		✓ (1)	✓ (1)		✓
	Distributed systems	✓		✓			✓
Transport refrigeration	Truck, trailer, vans	✓		✓			✓ (2)
	Rail refrigerated transport	✓		✓			✓ (2)
	Rail air conditioning	✓					
	Marine containers	✓		✓			✓ (2)
	Ships	✓		✓	✓		✓ (2)
Air-to air air conditioners and heat pumps	Small self-contained ACs	✓					
	Single-split ACs	✓					
	Multi-split ACs	(✓)		(✓)			
Applied building cooling systems	Ducted AC systems	✓ (1)		✓ (1)			
	Air conditioning chillers	✓		✓	✓	✓	
	VRF Air Conditioning (3)	(✓)		(✓)			
Mobile air conditioning and heat pumps	Internal combustion engine	(✓)					✓
	Electric vehicle	✓					✓
Industrial refrigeration and heat pumps	Food processing	✓		✓	✓		✓
	Cold storage	✓		✓	✓		✓
	Leisure applications	✓		✓	✓	✓	✓
	Process refrigeration	✓		✓	✓	✓	✓
	Industrial heat pumps and heat recovery	✓	✓ (4)	✓	✓	✓	✓ (5)
Heating only heat pumps	Heat pump water heaters	✓		✓			✓
	Space heating heat pumps	✓		✓			✓

1. Only in combination with heat transfer fluid, not in direct evaporation in public areas
2. Efficiency in hot ambient not as good as with other refrigerants due to transcritical operation; centralised R744 systems include technical features which make them efficient even in warmer climate
3. Direct expansion/evaporation in heat exchangers in the individual rooms/zones of a building
4. High temperature heat pumps for steam production
5. For water, fluid or product heating with large temperature changes (gliding temperature) of heated substance

(✓) Once obstructive charge limits in safety standards have been resolved

1. Some HFOs form HFC-23 as one of their atmospheric breakdown products. HFC-23 has a GWP100 years of 14 700

2. For information purpose only, costs strongly depend on the degree of market maturity.

04

Barriers to the adoption of natural refrigerants

The absence of an appropriate regulatory framework represents the greatest barrier to a wide uptake of natural refrigerants in Africa, leading to inadequate training and limited awareness among technicians. Limited access to natural refrigerants, along with associated components and equipment, further hinders the adoption of natural refrigerants.

04. Barriers to the adoption of natural refrigerants

Arguably, the absence of an appropriate regulatory framework represents the greatest barrier to a wide uptake of natural refrigerants in Africa, leading to inadequate training and limited awareness among technicians. Figure 1 presents challenges and barriers associated with the introduction and uptake of natural refrigerants across the region.

Technical issues and safety

- Natural refrigerants can cause safety issues for technicians or end users since hydrocarbons are flammable, ammonia is toxic, and carbon dioxide require high pressure, especially in hot climates.
- Fatal accidents have been reported in some countries.

Supply and availability

- High-purity natural refrigerants are not widely available in Africa because global suppliers are hesitant to supply a low consumption market.
- African technicians have limited access to the specialised tools and equipment required for handling natural refrigerants.
- High tariffs on refrigeration equipment make it difficult to import appliances or even work tools.
- Unavailability of spare parts significantly impacts equipment lifespan.

Finance

Local investment is needed, along with financial mechanisms and other incentives.

Market demand

Customer demand is limited by low consumer awareness of the benefits of natural refrigerants along with greater availability of cheaper competing products.

Information resources

- Technicians do not receive enough training or awareness-raising due to:
  - inadequate or nonexistent training facilities at the state or regional level,
  - inadequate or nonexistent training provided by manufacturers for technicians installing and commissioning their equipment.

Regulatory and quasi-regulatory

- There is no legal framework regulating the import of natural refrigerants and equipment containing them.
- African stakeholders such as national refrigeration associations are not involved in synthetic refrigerants elimination and management programmes, due to insufficient awareness-raising.

Figure 1

Challenges and barriers associated with the introduction and uptake of natural refrigerants in Africa

4.1. Absence of an appropriate regulatory framework

Most African countries have signed and ratified the Montreal Protocol and its Kigali Amendment. African countries have also adhered to the provisions of the United Nations Framework Convention on Climate Change by signing and ratifying its various international climate agreements, and many have included HFCs in their GHGs inventories. However, the related regulatory frameworks, restrictions, and instructions required to meet these targets are often not yet implemented or are slow to enforce due to limited understanding of the refrigeration sector, constrained technical and resource capacity, and/or insufficient political will.

Some countries, such as Senegal [28,29] and Kenya [30], have established regulatory frameworks to fulfil their international commitments to protect the ozone layer and combat global warming, specifically by phasing out HCFCs and regulating HFC imports. However, a legal gap remains in the regulation of natural refrigerants.

4.2. Limited access to adequate training

Although some African countries have technician programmes in place, such as the South African Qualification & Certification Committee [31], the refrigeration sector across Africa is overwhelmingly informal. Despite efforts by public authorities to establish formal training programmes, most workers still rely on "traditional apprenticeship" methods to obtain their professional qualification [32,33]. However, these apprenticeships lack clear curricula and formal organisation structures, operating largely outside the oversight of responsible training authorities. They are insufficiently and inadequately structured to meet the current qualification demands required for a rapid and safe transition to natural refrigerants [34].

Training gaps related to natural refrigerants are not only limited to the informal sector. While many public and private institutions do offer training in refrigeration and air conditioning, these programmes are generally not tailored to address environmental issues and refrigeration technologies that use natural refrigerants. The overall training offer in the field need to be reviewed, taking into account the specificity of the country.

4.3. Limited availability of components

Most African countries have no access to RAC manufacturing facilities and depend on imports. Unfortunately, high tariffs on refrigeration equipment – ranging from 40% to 111% in several countries – make it difficult to import appliances or even work tools. There are a few exceptions, countries where import tariffs on refrigeration equipment are lower than the regional average, such as Kenya (22%), Algeria (23%), and Morocco (23%) [35].

In the air conditioner market using HFCs and HCFCs, Egypt, Tunisia, and Nigeria are able to assemble and export air conditioners to the rest of the African market through partnerships and joint ventures with non-African RAC manufacturers [12]. However, such partnerships rarely extend to equipment that uses natural refrigerants, hindering initiatives to phase out HCFCs [36,37]. Consequently, African RAC technicians have limited access to the specialised tools and equipment required for handling flammable refrigerants.

4.4. Limited availability of natural refrigerants

In the absence of significant demand, high-purity natural refrigerants are not widely available in Africa at competitive prices. Global refrigerant suppliers are often reluctant to supply these refrigerants to African countries where consumption remains low or limited to pilot testing phases.

As an alternative, local production of natural refrigerants has been explored through pilot initiatives. In 2015, Nigeria commissioned its first plant producing high-purity hydrocarbon refrigerants using locally sourced liquefied petroleum gas as feedstock [38]. The Pamaque Nigeria Ltd plant has an annual production capacity of 200 tonnes each for R600a and R290, totalling 400 tonnes per year. The estimated investment cost for a plant producing 200 tonnes annually is approximately US$460,000, including expenses for testing and plant certification [39]. Ultimately, the cost of natural refrigerants is expected to be substantially lower than that of fluorinated refrigerants, as demonstrated in established markets such as Europe.

Pamaque Nigeria Ltd hydrocarbon production plant in Nigeria [39] © Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), United Nations Development Programme (UNDP)

05

Policy recommendations

In the African context, the successful transition to natural refrigerants will require proactive interventions from government and industry stakeholders, end-users, and development partners.

→ Setting up or overhauling training programmes
→ Raising awareness and providing guidance
→ Demonstrating technology development
→ Developing the natural refrigerants market in Africa
→ Unlocking access to financing
→ Developing regulatory infrastructure for natural refrigerants in Africa

05. Policy recommendations

Under the Kigali Amendment to the Montreal Protocol, the use of HFCs is being phased down across all ratifying countries, following different timelines. This global commitment has amplified, leading to widespread discussions on the adoption of alternative refrigerants. In the African context, the successful transition to natural refrigerants will require proactive interventions from government and industry stakeholders, end-users, and development partners.

5.1. Setting up or overhauling training programmes

The successful adoption of natural refrigerants requires proper training of all stakeholders – not only service and maintenance technicians, but also design engineers, production line and factory workers who build refrigeration systems, as well as sales and marketing staff. While this is true for any refrigerant type, it is particularly critical for substances that are flammable, higher toxicity, or operate under high-pressure conditions.

To address current training challenges, the following actions are recommended:

Strengthen the technical capacity of the training centres by equipping them with the necessary tools and technologies. Very few institutions have the necessary equipment to train future technicians in the use of natural refrigerants.

Support national refrigeration and air-conditioning associations to expand training capacity by leveraging international funding mechanisms such as the Multilateral Fund for the Implementation of the Montreal Protocol.

Provide training for trainers and technicians. It is essential to upgrade the knowledge of training professionals and technicians on emerging technologies and safety standards related to natural refrigerants.

Adapt curricula. Training programs should be reviewed to incorporate the latest technological advances, environmental standards and safety requirements, as well as energy efficiency considerations.

Develop continuing education programmes. Tailored training opportunities should be made available for technicians already active in the sector, enabling them to acquire the necessary skills and competencies to safely and effectively work with natural refrigerants.

Raise awareness among all refrigeration stakeholders about environmental issues. It is important to integrate an environmental dimension into all training courses to raise awareness among future professionals of the issues related to climate change.

Technician reading pressure levels on manifold gauges. © Shutterstock

Box 2: Case studies of training initiatives in Africa

Close to 300 African technicians trained through "REAL Alternatives for LIFE"

Launched in 2017, "REAL Alternatives for LIFE" is an EU-funded project which provides "train the trainer" sessions on low GWP refrigerants (hydrocarbons, CO_2, ammonia, HFOs) in order to ensure safe, efficient, reliable and cost-effective implementation. In partnership with IIR and U-3ARC, REAL Alternatives has issued over 1,800 certificates as of 2024, including training sessions for a little under 300 RAC technicians from Africa (Benin, Burkina, Cabo Verde, Egypt, Madagascar, Nigeria, Sudan, Togo, Tunisia).

REAL Alternatives training sessions cover the following main topics:

- Background on existing or upcoming regulations on HFCs and long-term alternative refrigerants, in order to anchor the importance of natural refrigerants.
- Key thermophysical properties of refrigerants
- Flammability and other safety hazards
- Working safely with natural refrigerants and reducing leak potential.
- System design. In the case of CO_2, this includes an explanation of transcritical operation, as well as cascade and booster systems.
- Installation and commissioning, as well as service and repair procedures.

Technicians from Burkina Faso, Cameroon, Mali and Senegal trained through GIZ ROCA

Between 2021 and 2024, GIZ Proklima ran the ROCA ("Refroidissement respectueux de l'Ozone et du Climat en Afrique de l'Ouest et Centrale") project, co-funded by the European Union and the German Federal Ministry for Economic Cooperation and Development (BMZ). The ROCA project aimed to promote natural refrigerants and expedite compliance with the Kigali Amendment in four francophone African countries: Burkina Faso, Cameroon, Mali and Senegal. Regional workshops were organised to train technicians in the safe handling of natural refrigerants in room air conditioners. For instance, 100 technicians were introduced to the use of natural refrigerants such as propane (R290) during a training course held from 29 January to 01 March 2024 at the Lycée Technique et Professionnel François Xavier Ndione in Thiès, Senegal [40].

Technical and engineering training in SophiA technologies

Within the framework of the EU-funded project SophiA – Sustainable Off-grid solutions for Pharmacies and Hospitals in Africa, the 2iE Institute organised a capacity-building session for local technicians and engineers in Burkina Faso in June 2024 and in Cameroon in January 2025. The training provided participants with an in-depth understanding of sizing techniques for solar cooling systems based on natural refrigerants, as well as skills in servicing and maintaining filter-based water treatment systems and solar heat processes. Future training sessions are planned in Malawi and Uganda.

5.2. Raising awareness and providing guidance

As with all other regions, the introduction of flammable refrigerants remains a subject of ongoing debate in Africa, where technicians express concerns due to inadequate training and tools. Where there is insufficient knowledge, training and suitable tools and equipment, technicians will not be suitably competent to address the hazards of handling of refrigerants.

Awareness-raising efforts should highlight the environmental, energy, technical, and economic including life-cycle cost benefits of natural refrigerants, encouraging decision-makers and stakeholders to adopt these solutions as part of broader climate action strategies. Such efforts can take the form of workshops or communication campaigns targeting various stakeholders through tailored messaging. Additionally, site visits can be organised to showcase equipment using natural refrigerants that is being developed or marketed in Africa or in other regions. This will help to build familiarity and confidence in these technologies.

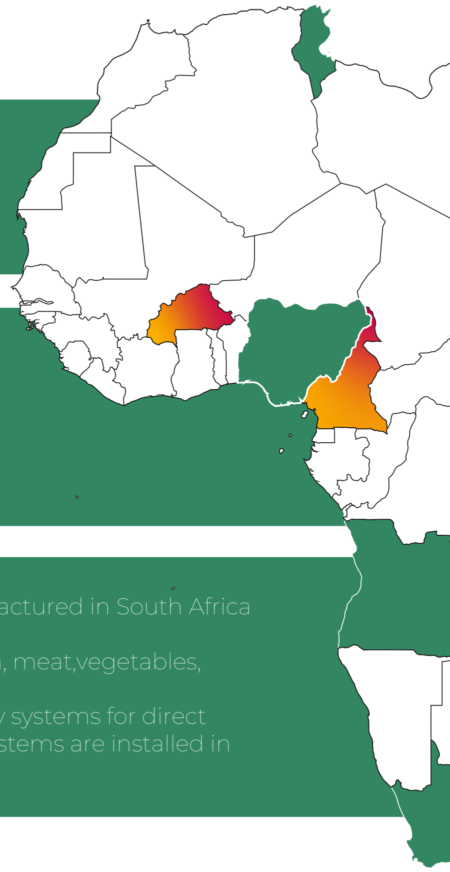
High quality industry guidance should be developed to support awareness-raising and training activities. These guides should address key topics, including national legislation, safe handling procedures, conversion guidelines for manufacturers, etc. Similar to awareness-raising and training initiatives, the guidance materials must be tailored to the specific needs of the different stakeholder groups.

5.3. Demonstrating technology development

Since the early 2010s, with the first production lines for hydrocarbon-based domestic refrigerators in South Africa [8] and Eswatini (formerly Swaziland) [41,42], the adoption of natural refrigerants has steadily progressed in the region, particularly in commercial refrigeration. Over 4,000 large industrial cold storage facilities using ammonia (R717) are currently in operation in South Africa, commonly used for frozen fish, meat, vegetables, poultry, and processed foods [43]. Over 220 transcritical CO_2 (R744) units were in service in the country as of 2020, twice as many as in 2018 [44].

Figure 2 presents examples of natural refrigerant-based systems currently operating in Africa.

Box 3: Natural refrigerant-based systems in operation in Africa



Tunisia

Ammonia plug-and-play chillers for air-conditioning installed in the 2010's at Nestle's plants.

R744 cold storage facility in the 2020's

Nigeria

ColdHubs Ltd. has been designing, installing, commissioning and operating solar-powered walk-in cold rooms since 2016. The 58 cold rooms currently operated by Coldhubs use propane (R290) along with latent thermal energy storage.

South Africa

Since 2017, all domestic refrigerators and freezers manufactured in South Africa used R600a.
Over 4,000 ammonia cold storage facilities for frozen fish, meat,vegetables, poultry and processed foods.
SophiA partner Everflo manufactures ammonia ice slurry systems for direct contact cooling of fish in Cape Town. The refrigeration systems are installed in several African countries.

SophiA containerised solar powered refrigeration systems

Cameroon

Solar-powered stand-alone refrigeration systems using propane .

Burkina Faso

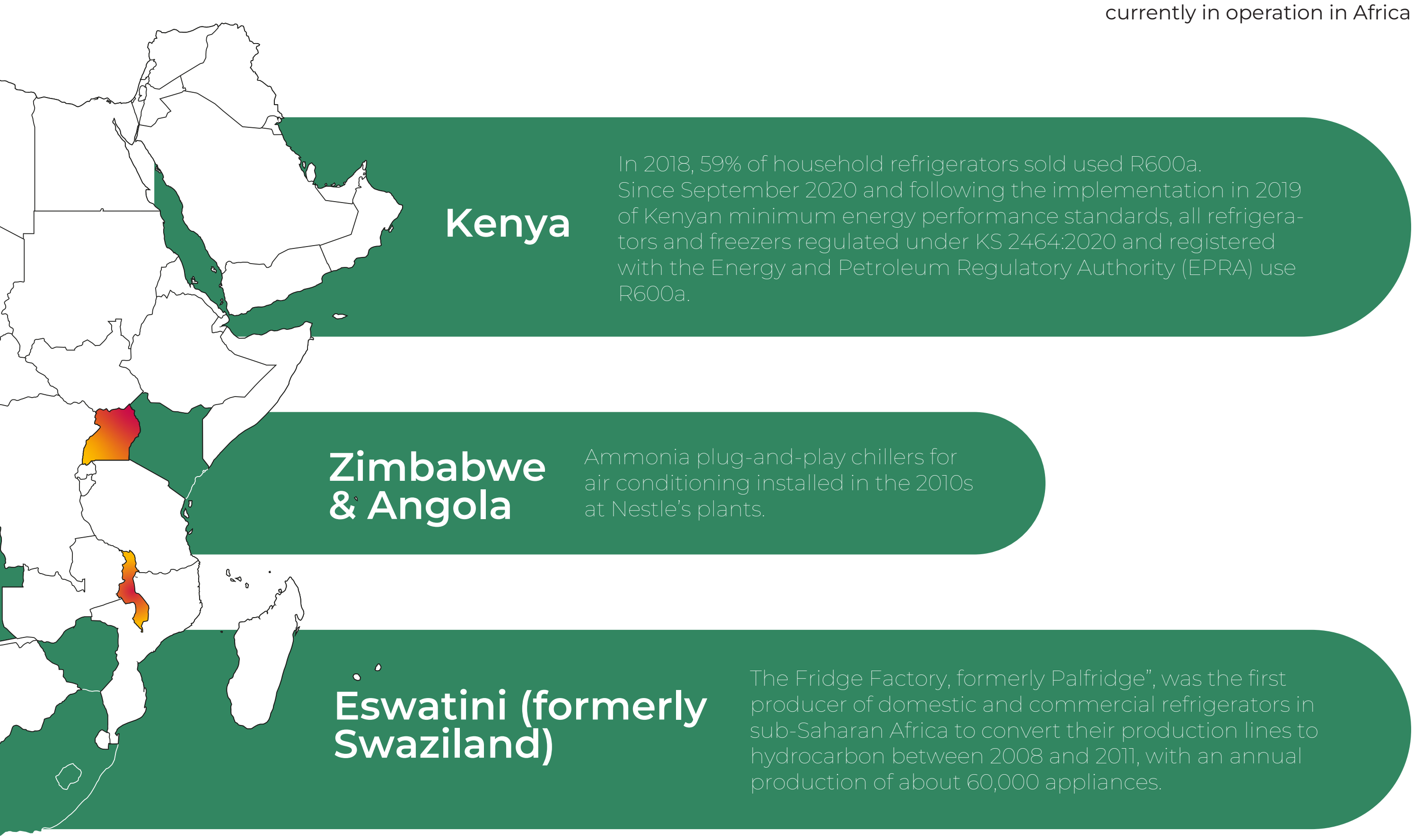
Containerised solar-powered refrigeration system.

Uganda & Malawi

Solar powered containers combining cooling and water treatment systems.

Figure 2

Examples of systems with natural refrigerants currently in operation in Africa



Further research and development activities are neededrequired to facilitate the uptake of natural refrigerants. Trials or pilot studies must be carried out to demonstrate the feasibility of these technologies under the specific African context and to identify opportunities for enhancing system performance, safety, and operability.

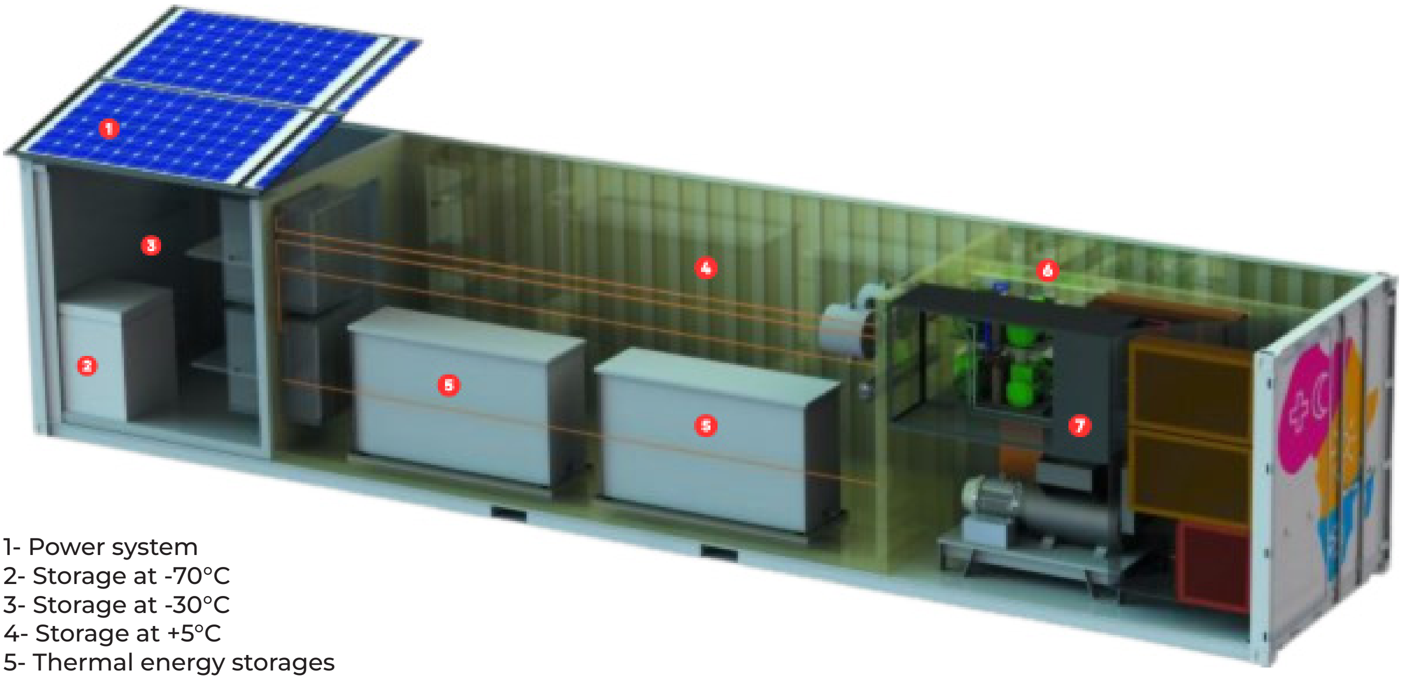
For example, as part of the EU-funded project SophiA ("Sustainable Off-grid solutions for Pharmacies and Hospitals in Africa"), a containerised solar-powered refrigeration system was installed in the Dr. Sedogo hospital in Léo, Burkina Faso. The container provides the hospital with cold storage facilities at +5 °C and –30 °C for ointments and blood plasma, respectively. A separate vaccine freezer operating at –70 °C was also installed, using ethane as the refrigerant.

The SophiA containerised refrigeration system consists of a propane-based upper stage in a cascade configuration, paired with R744 (CO_2) as the lower stage (see Figure 3). To minimise the size of the batteries for storing electrical energy, the SophiA system applies an ice bank storage system in the +5 °C cold room which at the same time is the cold surface cooling the +5 °C room, thus making a conventional fin-and-tube evaporator obsolete.

Following the SophiA demonstrator in Burkina Faso, second-generation solar-powered containers combining cooling and water treatment systems were installed in Uganda and Malawi. In Cameroon, solar-powered stand-alone refrigeration systems using propane were installed at the Ad Lucem hospital in Edéa in 2025.

Figure 3

SophiA containerised solar- powered refrigeration system as installed in Burkina Faso



1- Power system
2- Storage at -70°C
3- Storage at -30°C
4- Storage at +5°C
5- Thermal energy storages
6- Machinery room
7- Emergency lithium batteries

Inauguration of SophiA containers at Dr. Sedego Hospital in Léo, Burkina Faso.

5.4. Developing the natural refrigerants market in Africa

Increasing market demand for and access to natural refrigerants, along with associated components and equipment, require advocacy directed at political authorities to implement customs policies that facilitate the import of energy-efficient and climate-friendly refrigeration systems. At the same time, these policies should restrict the import of conventional systems based on high-GWP refrigerants. Furthermore, bilateral agreements between importing and exporting countries could play a vital role in regulating refrigerant types and setting minimum energy efficiency standards in line with international commitments.

To bridge the gap between international suppliers and buyers of natural refrigerants and related technologies, stakeholders should engage in networking through regional and international databases or directories [7]. Forming buyers' alliances to aggregate demand can enhance the attractiveness of the African market by enabling larger order quantities and stronger purchasing power [38].
Local development and manufacturing of systems and equipment using natural refrigerants must be promoted. Building on the example of the pilot hydrocarbon plant in Nigeria, African countries should explore local sourcing of hydrocarbons, CO_2, or ammonia as byproducts from agricultural processes, petrochemical plants, or methane gas extraction in order to produce high- purity refrigerants domestically [38].

5.5. Unlocking access to financing

Financial incentives are essential to overcoming a variety of barriers to the adoption of natural refrigerants. For instance, the Cooling-as-a-Service (CaaS) financial mechanism, driven by the Swiss-based Basel Agency for Sustainable Energy (BASE), has enabled financing for natural refrigerant projects in countries such as Nigeria and South Africa without the barrier of upfront investment [45]. In Nigeria, ColdHubs Ltd. has been designing, installing, commissioning, and operating solar-powered walk-in cold rooms using propane since 2016 through a CaaS mechanism [46].

At the national level, financial incentives may include subsidies or tax adjustments. Governments could offer financial subsidies for the purchase of natural refrigerants and related technologies. They can also introduce tax adjustments either on the refrigerant itself or on refrigeration systems. Such adjustments may apply to import duties, sales taxes, rebates, or elsewhere within the system.

ColdHubs, Cooling as a Service in Nigeria: a walk-in, modular, solar-powered R290 cold room for storing fresh produce in Nigeria © ColdHubs

5.6. Developing regulatory infrastructure for natural refrigerants in Africa

"Regulatory infrastructure" refers to various types of rules applied to safety and quality concepts and covers both legislation and standards (which are not necessarily mandatory).
The refrigeration industry relies heavily on safety standards to ensure compliance with good practices [47,48]. Beyond regulatory texts such as decrees or orders, which target market uptake, the development, manufacturing and operation as well as servicing of systems using natural refrigerants, requires the application of safety standards.

The lack of specific standards and regulations for natural refrigerants in Africa constitutes a significant obstacle to their widespread adoption and exposes users to considerable risks. Establishing an appropriate regulatory framework would facilitate the controlled expansion of natural refrigerants and support the formal organisation of the sector's related professions. Such a framework would also enable the implementation of rigorous certification and registration schemes for technicians, thus enhancing the expertise of RAC professionals and increasing the end-user confidence.

African countries must develop regulations and standards governing the storage, distribution, and handling of natural refrigerants, taking into account the specific African context. When adopting international or other national standards, tailoring them to local conditions may be necessary. It is essential to actively engage authorities and industry sub-sectors affected by these standards and guidelines to ensure diverse interests and expertise are well represented, and that the resulting regulations effectively support the safe and practical application of natural refrigerants.

A person working on a laptop with legal icons in holographic style. © Shutterstock

06. **References**

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