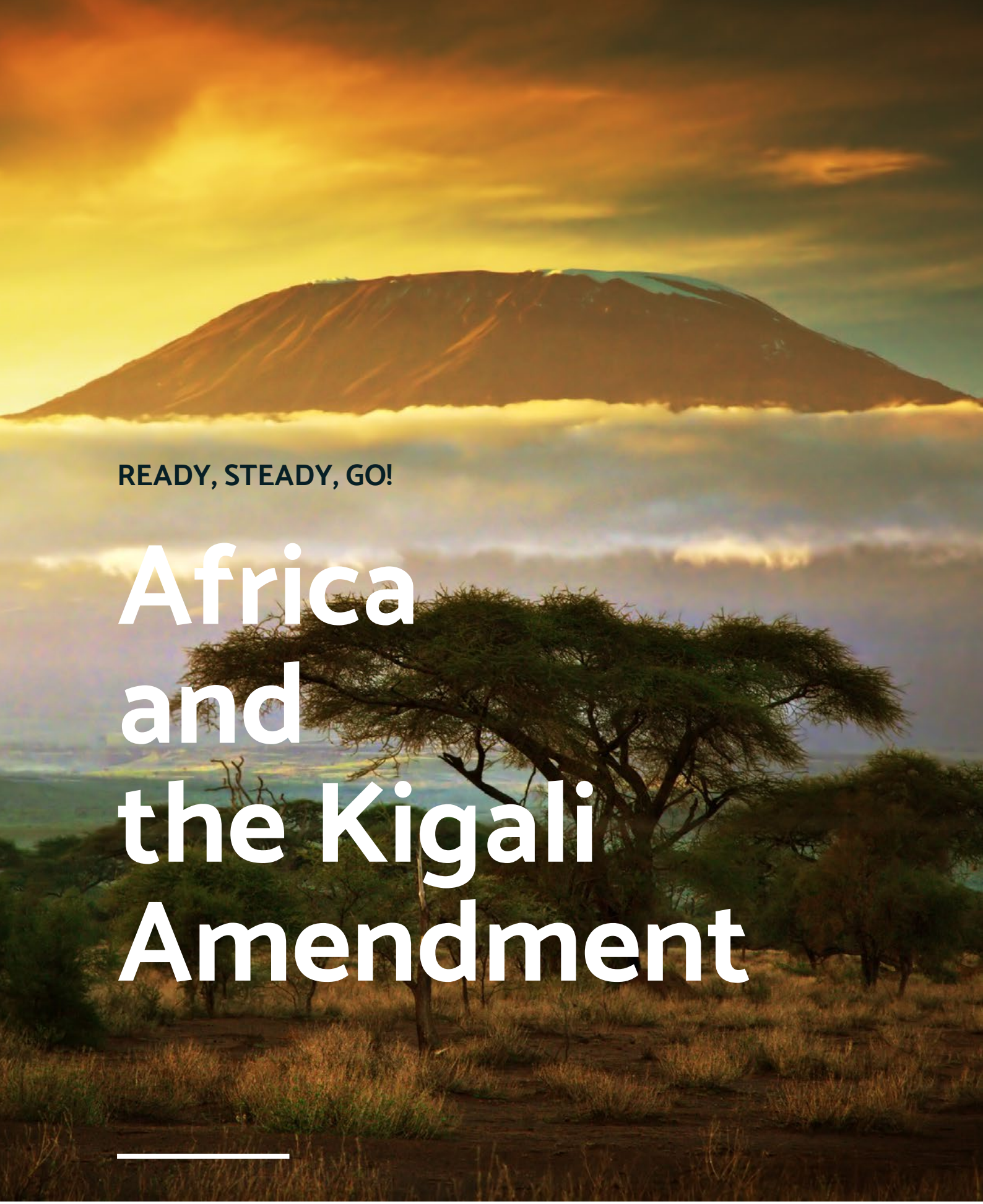

READY, STEADY, GO!

Africa and the Kigali Amendment

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READY, STEADY, GO!

Africa and the Kigali Amendment

This document has been developed by The Montreal Protocol Division of the Environment Department of UNIDO with the support of the government of Italy - Italian Ministry for the Environment, Land and Sea.

This project was managed by the following team at UNIDO:
Stephan Sicars
Ole Nielsen
Riccardo Savigliano
Franziska Menten
Andrés Celave

This document was researched and written by:

Lead Author & Research: **Nina Masson**

Tech Specs & Scientific Review: **Dr Fabio Polonara**

This document was reviewed by:

Dr. Cristiano Piacente, focal point for the Montreal Protocol, Italian Ministry for the Environment, Land and Sea – Technical Assistance Unit Sogesid S.p.A.; Directorate General for Sustainable Development,Environmental Damage, European Union and International Affairs; Division III - International Affairs

D.ssa Elisabetta Colaiacomo, Italian Ministry for the Environment, Land and Sea – Technical Assistance Unit Sogesid S.p.A.; Directorate General for Sustainable Development,Environmental Damage, European Union and International Affairs; Division III - International Affairs

Dr. Marco Strincone, National Research Council – Institute of Atmospheric Pollution Research

Editor: **Alice Miller**

Design by: **Mehdi Bouhjar & Olivia Delemontex,** Bureau 42

Photo cover: **NiseriN**

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Statement by Italy

The year 2015 represented a historic moment for the international community. The third UN Conference on Financing for Development in Addis Ababa in August 2015, the UN Summit on Sustainable Development in New York, including the adoption of the 2030 Agenda for Sustainable Development, and the historic adoption of the Paris Agreement under the UN Framework Convention on Climate Change, all set the path to follow for a fairer, climate resilient and sustainable world.

One year later, the adoption of the Kigali Amendment to the Montreal Protocol added a further historic achievement to the international agenda.

The Amendment represents one of the most significant actions that governments have taken to limit the warming of our planet for future generations, and to protect the climate at the global level. The Amendment will set countries on the right path to achieve the Paris Agreement goals collectively.

HFCs are highly potent greenhouse gases that have significant global warming potential. Their reduction can prevent the emission of 70 billion tons of CO_2 equivalent by 2050. Phasing down HFCs could avoid 0.5˚C of global warming by the end of this century. These figures are too high not to be properly addressed.

We are now in the "post-Kigali era". Concrete initiatives to significantly reduce emissions and ensure a cost-efficient approach to reduce HFCs must be identified and implemented.

This is the right moment to identify zero or low-GWP alternatives to avoid the introduction of high-GWP HFCs. The demand for air conditioning and refrigeration is constantly growing, particularly from developing countries. The introduction of environmentally friendly solutions will allow the Parties to comply with the downstream obligations under the Montreal Protocol.

With the New York Declaration of 22 September 2016, a group of 16 donor countries, including Italy, announced the intention to provide consistent additional financial and technical support through the Multilateral Fund of the Montreal Protocol to support a rapid implementation of the Amendment. The Italian Ministry of the Environment has transferred the promised additional contributions to the Fund.

The bilateral cooperation represents a concrete and specific instrument to achieve these goals, according to the rules of international treaties, such as the UNFCCC negotiations and the Montreal Protocol. These rules can be the starting point for bilateral projects, contributing to meeting international commitments.

In recent years, Italy has signed many technical bilateral environmental agreements. More than 50 Memoranda of Understanding have been signed, including about 15 with African countries.

Environmental cooperation with Africa is a clear priority for Italy, to promote sustainable economic growth in Sub-Saharan Africa, with positive consequences for environmental, social and economic dimensions, which are also forcing people from the African Continent to risk their lives through uncontrolled migration flows.

Africa is a huge continent characterized by enormous geographical and political differences. The needs of each country are different.

The scope of the present work is to hear the voices of African countries, and to identify their specific needs, concerns and challenges in effectively implementing the Kigali Amendment.

I am sure that together we will be able to achieve our goals with the same sense of belonging that the "ozone family" has shown for 30 years.

Francesco La Camera

Director General for Sustainable Development, Energy and Climate at the Italian Ministry of Environment, Land & Sea

Welcome message from UNIDO

Here at UNIDO, we see the Kigali Amendment as not just a challenge, but an opportunity for African countries. It is our goal to ensure that these countries are well-equipped to face this challenge, and to identify and take advantage of every opportunity.

This journey began in Africa. In Kigali, Rwanda, in October 2016, the 197 Parties to the Montreal Protocol agreed to an Amendment to phase down HFCs, which are potent greenhouse gases. The agreement was a significant victory in the fight against climate change.

Here at UNIDO, we are well placed to help with the phase down. For 50 years, UNIDO has been assisting developing countries to safeguard the environment and promote inclusive sustainable industrial development. For 25 years, we have been an implementing agency of the Montreal Protocol, assisting developing countries to phase out harmful substances to protect the environment and human health, while also supporting industry. Implementing the Kigali Amendment to phase down HFCs is an exciting new challenge for us – but it is also a natural progression from all that we have done before.

The phase down will have a significant impact on African countries, and particularly on the available options for refrigeration and air conditioning technology. African countries will have to import technology from outside, in order to support the transition away from HFCs towards greener, climate friendly alternatives.

We wanted to better understand the priorities and needs of developing countries for this transition. That's why in June of this year, we organized the Kigali Amendment: Vienna Talks, where 75 participants from 55 countries came to UNIDO headquarters in Vienna to join in discussions about the future.

These talks included a special Africa workshop. Supported by the government of Italy, the workshop included representatives of Botswana, Burkina Faso, Cameroon, the Congo, the Democratic Republic of the Congo, Egypt, Ethiopia, the Gambia, Lesotho, Libya, Mali, Morocco, Niger, Nigeria, Rwanda, Senegal, Sudan, Tanzania, Tunisia and Uganda. Follow up interviews were also held. This report collects these voices to identify the main priorities and needs for African countries during the phase down, and what we need to concentrate on in the future.

Those discussions and the corresponding report take us a few steps on the path towards effective, ongoing implementation. The path continues, and we at UNIDO will be there for the whole journey.

Stephan Sicars

Director, Department of Environment

Why this report?

The Kigali Amendment to the Montreal Protocol was adopted in Rwanda by 197 nations in October 2016. Building on 30 years of the successful elimination of ozone-depleting substances, the amended Montreal Protocol now aims for a worldwide phase down of the potent greenhouse gases, HFCs, thereby preventing the direst consequences of climate change. African countries are among those already hit hardest by the growing consumption of high Global Warming Potential (GWP) substances, which impact human health, security and economic growth. However, African countries also face a unique opportunity to directly switch to solutions that do not harm the environment, and to help move towards a sustainable economic transition and positive societal change.

This report summarizes current needs, concerns and challenges faced by African nations in making the Kigali Amendment a success. It also provides general guidance on the Amendment's major obligations, deadlines and opportunities. Finally, the report suggests possible sets of activities to be adopted for a smooth and effective KA ratification, implementation and enforcement.

Where the data comes from

The data feeding into this report's analysis and recommendations stem from various sources:

- **Pre-event survey:** An online survey was conducted in June 2017 among 31 respondents from Africa, mostly from National Ozone Units (61 per cent), other government representatives (23 per cent), and UNIDO country offices (13 per cent).[1] Data was not distinguished by country, so the results serve to highlight expectations for a more effective KA implementation for the continent overall.

- **Kigali Talks & Africa Workshop:** From 13-15 June 2017, 75 participants from 55 countries accepted UNIDO's invitation to join the "Kigali Amendment - Vienna Talks." The event brought together government representatives from Africa, Asia and Latin America, but also experts from academia and the private sector. A special Africa workshop supported by the government of Italy gathered immediate feedback from Botswana, Burkina Faso, Cameroon, the Democratic Republic of the Congo, the Congo, Egypt, Ethiopia, the Gambia, Lesotho, Libya, Mali, Morocco, Niger, Nigeria, Rwanda, Senegal, Sudan, Tanzania, Tunisia and Uganda. These voices are captured throughout the report by means of interventions and direct quotes.

- **Follow-up interviews among African NOUs:** To deepen the understanding of items with highest perceived urgency or importance, follow-up interviews were conducted among representatives of National Ozone Units from Burkina Faso, the Democratic Republic of the Congo, Egypt, the Gambia, Nigeria, Senegal, Sudan, and Tunisia. Please note that the opinions expressed do not constitute an official country statement and cannot be interpreted as representative of the African continent at large. However, the individual input is mentioned throughout the text to provide additional evidence for possible priority areas in those countries under the KA, and might also give some indications on general challenges and opportunities for other states.

- **UNIDO experience & expertise:** This publication has been informed by the analysis and interpretation of raw data from UNIDO, based on vast project experience in Africa, contacts and communication with country representatives.

1 The other participants were independent experts (3 per cent).

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A note on direct and indirect emissions

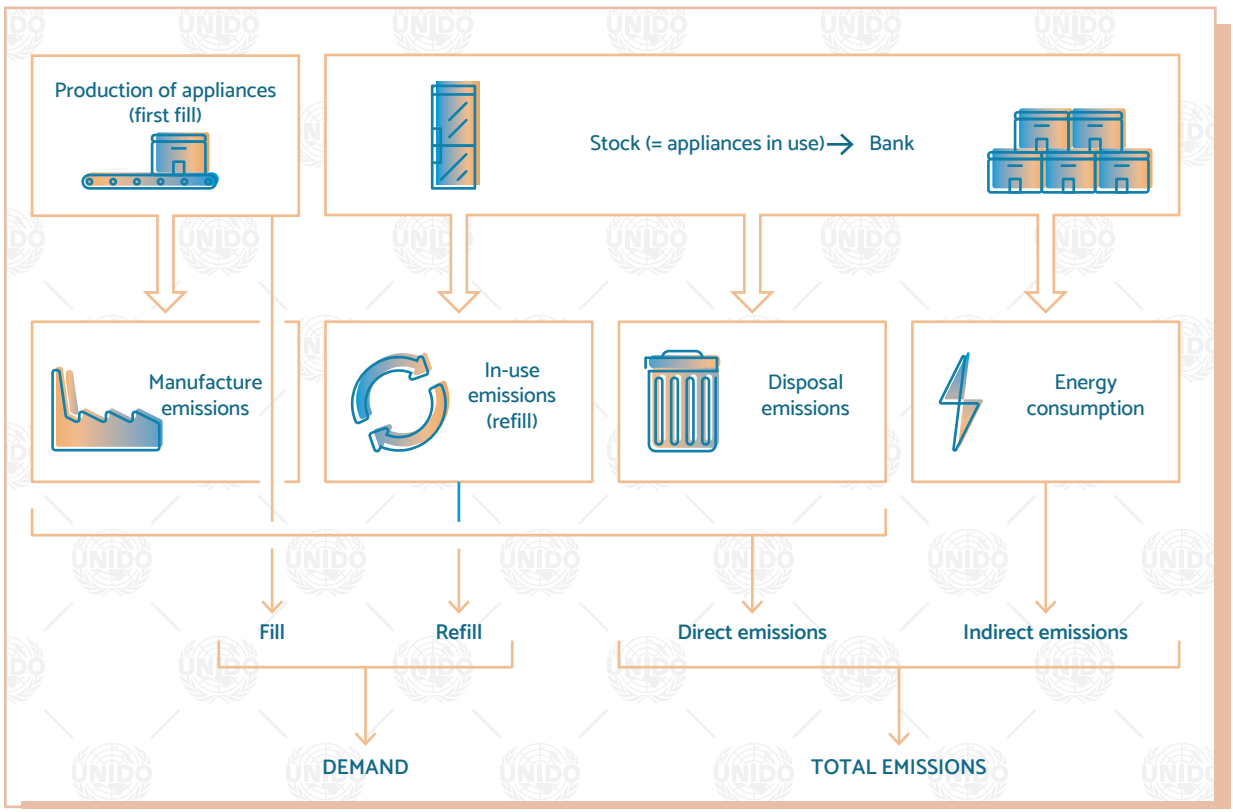
In Africa and beyond, the successful implementation of the Kigali Amendment (KA) requires addressing two types of emissions that result from refrigeration and air conditioning (RAC) equipment:

Direct emissions, from refrigerant gases, foams or solvents, contribute to climate change when fluids with Global Warming Potential (GWP) are released into the atmosphere. The higher the GWP (reference value is CO_2 = 1), the stronger the negative climate impact[2].

Indirect emissions are produced when RAC equipment consumes energy, resulting in the emission of greenhouse gases (GHG) from power plants. As energy production is the primary factor in the emission of GHG in the atmosphere, energy use is a key consideration.

In fact, direct emissions only make up 10 to 40 per cent of **total climate impact**, while the remaining 60 to 90 per cent are indirect emissions related to electricity consumption. Over the lifetime of RAC equipment, both direct and indirect emissions occur during stages of production, operation, maintenance and end-of-life treatment (see Fig. 1). Therefore, the effectiveness of the KA in driving down GHG emissions hinges on a nation's ability to effectively address **both direct and indirect emissions** in national strategies.

Fig. 1: Direct and indirect emissions



2 Please note that wherever the term "low-GWP" is used throughout this report, for reasons of simplicity it also includes "zero-GWP" substances with a GWP = 0 (like ammonia R717, water R718, or air R729 as a refrigerant)

CHAPTER 1

Cut out for success:

Africa's needs for the Kigali Amendment

The Kigali Amendment – and its measures for effective ratification, implementation and enforcement – poses opportunities and challenges for African countries. Besides the political and administrative barriers slowing down the KA adoption, the need for enabling activities, institutional strengthening and financial support takes priority.

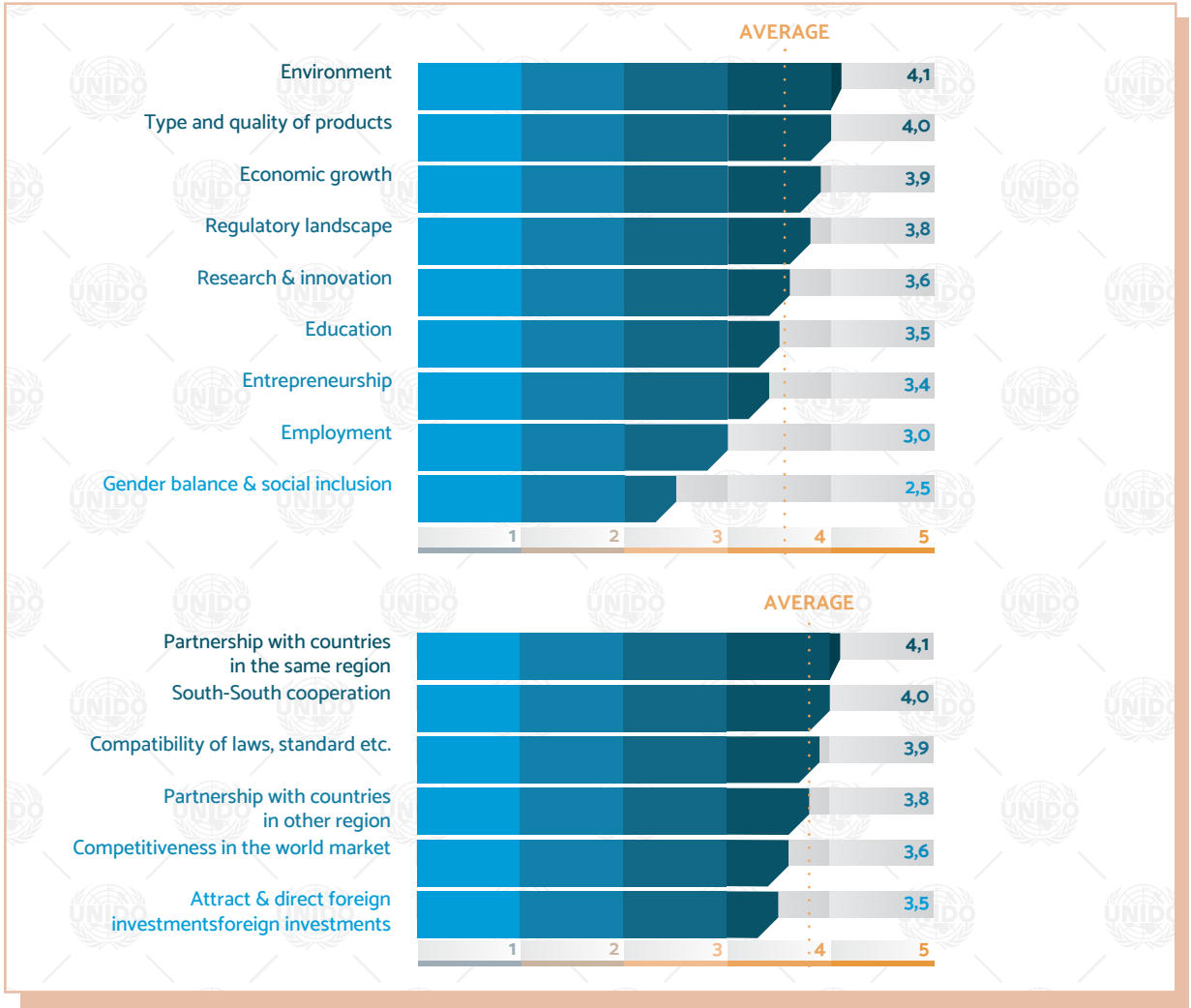
CONDITIONS FOR A SUCCESSFUL KIGALI AMENDMENT & RATIFICATION

KA will affect Africa on environment, policy, partnerships & economic growth

For African countries and their partners to adopt an effective strategy for the KA, one first needs to better understand the countries' basic expectations. In the surveys, **African respondents** were asked how the KA might affect their countries' relationship to other countries, as well as their domestic markets (see Fig. 2). It was found that Africa attaches strong importance to **partnerships with countries in the same region** and with other A5 countries within a **South-South cooperation**. It is also believed that the KA will decisively affect **product quality** and **economic growth** overall, suggesting that any programme to support the process should simultaneously foster industrial development.

Fig. 2: Impact of the KA on African countries

What degree of impact would the KA have on the following areas?



Legend: 1 = Very low impact 5 = Very high impact

> **"And here we are right now; thanks to the call of unity and focus, we got the Amendment we were all working towards. Ambitious as it is, I congratulate every one of us for having done such a great job. Now we need to make it a reality."**
> Juliet Kabera, Rwanda

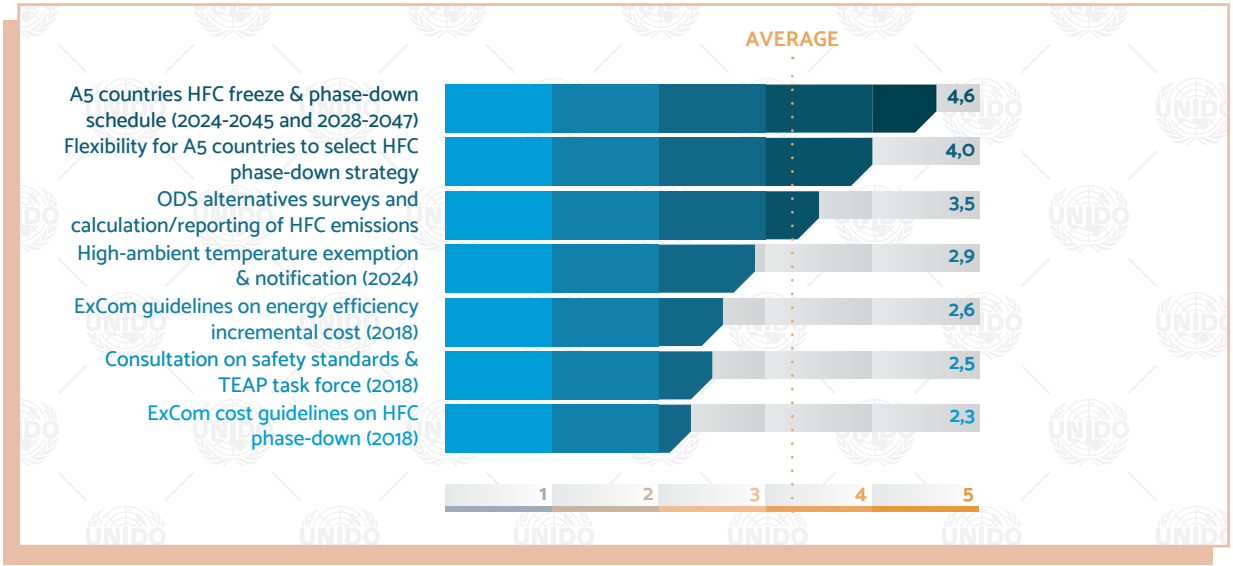
Beyond these findings, it is important to highlight some of the peculiarities of the African continent – as distinct from other world regions – that will influence the way that the KA is enforced. As only a few African countries have a refrigeration and air-conditioning (RAC) manufacturing sector, **Africa mostly relies on the import of RAC solutions from outside the continent**. As a consequence, product strategies adopted by major RAC exporters – in China, Japan, Europe or the USA – have a decisive impact on the adoption of low-GWP technologies in Africa. Moreover, the i**mport of second-hand or pre-charged equipment with high-GWP refrigerants can represent a challenge** for the adoption of low-GWP alternatives. The importance of **establishing partnerships within the region or with other A5 countries, entering into bilateral agreements with RAC exporting countries, and relying on strong public procurement rules to foster low-GWP solutions** cannot therefore be underestimated. This also shows why African nations' need for effective technical capacity building focuses mainly on the RAC servicing sector.

More information needed for HFC and energy efficiency cost guidelines, safety standards, and HAT exemptions

Overall, **African countries seem to be less prepared for a fast KA ratification** than other world regions surveyed. The follow-up interviews therefore intended to find out where exactly African NOUs needed more information. Results show that the selected NOUs have considerable knowledge of the overall **freeze and phase down schedule**, and are also well-informed on both the **countries' flexibility to select their own HFC phase down strategy** and the need to conduct **ODS alternatives surveys**. However, **ExCom cost guidelines** on energy efficiency incremental costs and the HFC phase down, as well as the **consultation on safety standards** only reached levels of "not well-informed" (see Fig. 3). These results suggest that especially the latter two consultation processes and guidelines, which are due in 2018, should be strongly addressed in communication efforts by implementing agencies or bilateral partners to prepare African nations for the upcoming ExCom negotiation meetings.

Fig. 3: How well-informed are NOUs about the KA implementation process?

How well-informed do you feel about the following components in the Kigali implementation process?



Legend: 1 = Not informed at all 5 = Very informed

For an overview of KA targets, the HFC phase down schedule, and the list of controlled substances, please see page 27.

Every third respondent expects difficulties in the KA ratification

Asked if they expected any **difficulties in the KA ratification** process, 67 per cent said they did not, but rather foresaw a smooth ratification for their country. However, every third African respondent could foresee difficulties due to **slow or complex administrative processes, strong hierarchical structures and changes in leadership, political instability**, or the **non-availability of financial support**. African representatives in particular mentioned a basic lack of incentives to ratify the KA at all, citing again the **unknown effect an HFC phase down would have on their socioeconomic development**.

Referring to the African Group's crucial role in reaching the final agreement in October 2016, one African country that has already ratified the KA called upon its fellow NOUs to actively drive their own ratification of the KA. However, this country has notably met several obstacles during the process that would also be relevant to other African nations. These obstacles include the **non-existence of domestic environmental legislation, the incoherence between existing legal texts, the lack of clarity on the competence of each governmental area**, as well as the **lack of enforcement** after signing a treaty.

A second African country, having already ratified the KA, suggested that although each African country would have a different approach, **common guidelines for the ratification and implementation process** should be issued with **best practice procedures** to maximize future benefits from the KA.

> "First things first we should try to ratify the Amendment. This will set us on the run to start thinking about how to implement it, learn from past experience, put our heads together and see the best ways to accomplish what we wish to accomplish in the Amendment."
> Juliet Kabera, Rwanda

IMPLEMENTATION, POLICY CAPACITY BUILDING & FINANCIAL SUPPORT

Priority area #1: Capacity building for policy makers

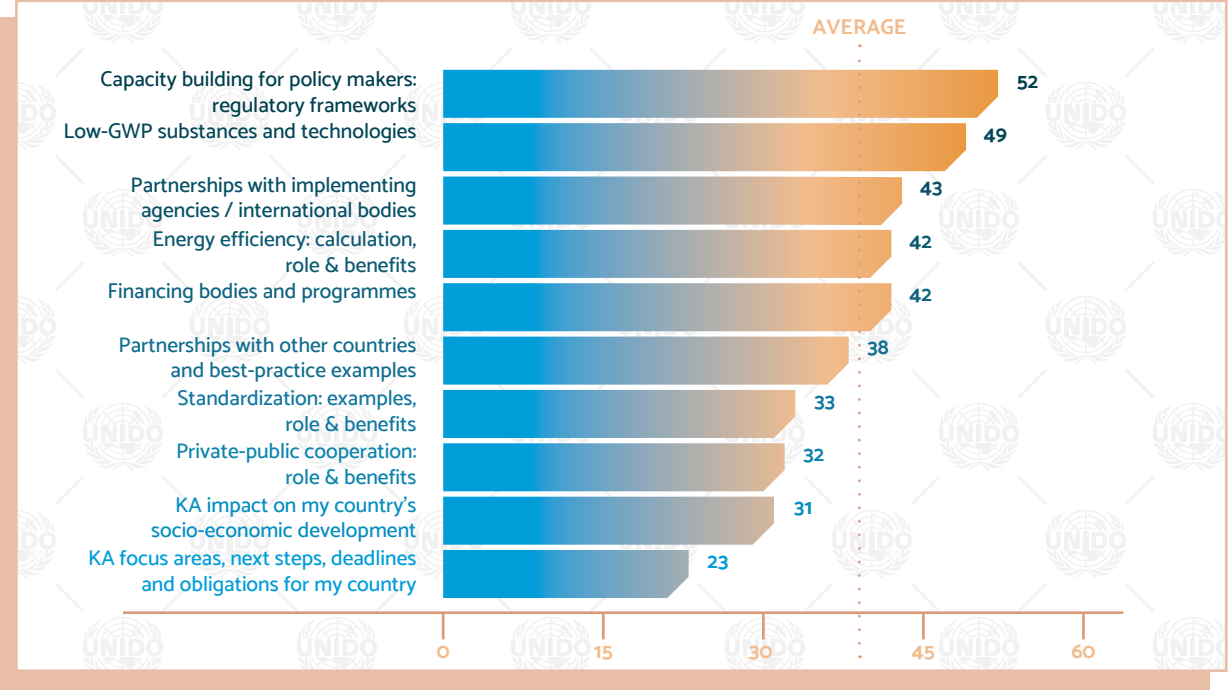
Selected African NOUs involved in the follow-up interviews were asked to evaluate the degree of urgency for receiving support for a list of items. Overall, the countries believe that **capacity building for policy makers** in drafting regulatory frameworks takes priority over all other activities. This is closely followed by the **availability and implementation of low-GWP substances and technologies. Partnerships with implementing agencies** are ranked above average, together with financing bodies and programmes (see Fig. 4).

> "We have to be competent on the policy framework and the technology transfer. In our policy we want to eliminate these HFCs and to do that we must be ready to have this in our law."
> Bafoday Sanyang, the Gambia

The complexity of the KA challenge ahead will require an entirely new set of skills, knowledge and cooperation. As well as creating the necessary regulatory frameworks and engaging in institutional strengthening, this task ranges from identifying all relevant stakeholders in one's country, to closing gaps in technological and non-technological areas, to establishing effective awareness-raising campaigns. One Northern African country reiterates the importance of capacity building for policy makers, stating that for the KA's future success it would be imperative to **reinforce organizational structures for the National Ozone Unit**, as well as providing **support on the logistics and personnel level**. Overall, the work burden put on NOUs in A5 countries could be a major roadblock for succeeding in the implementation.

Fig. 4: Priority areas for support

In which areas do you need support first? Please rank the items according to their importance.

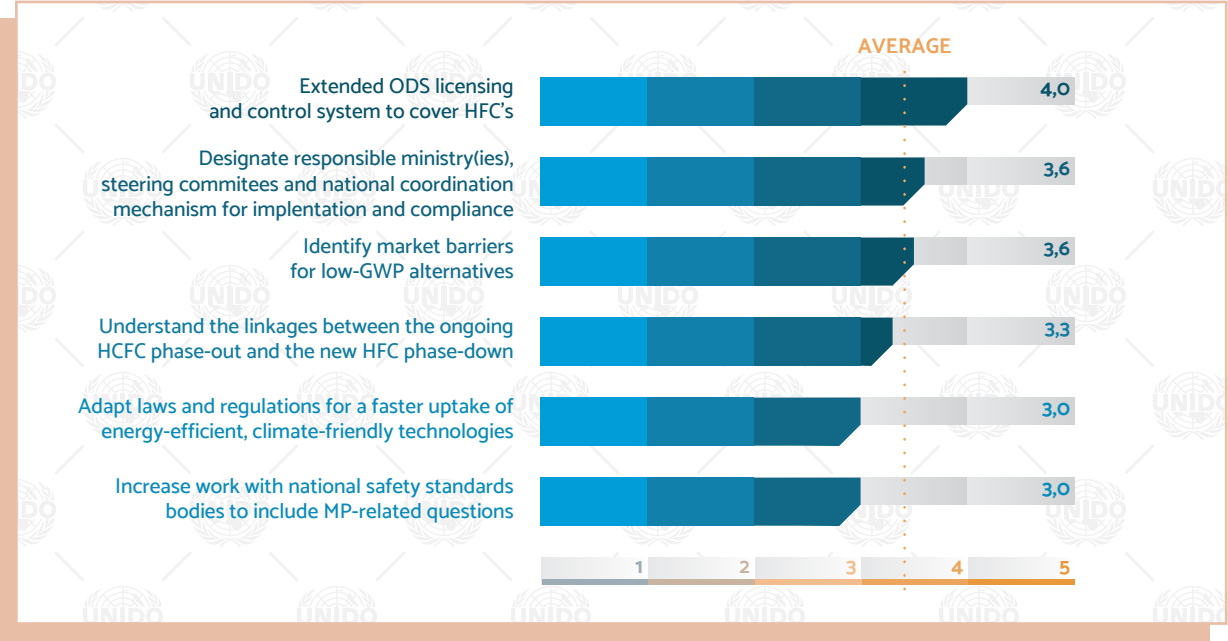


Legend: Ranked in order of importance, most important on top

Selected African NOUs were asked to identify what would be the most difficult part of setting up the **institutional framework for an effective compliance with the KA** in their country. The NOUs believed that **work with national safety standards bodies**, and the **adaptation of laws and regulations** for a faster uptake of energy efficient and climate friendly technologies were the most difficult (see Fig. 5).

Fig. 5: Challenges to setting up the institutional framework

How difficult are the following items for setting up the institutional framework for an effective compliance with the KA in your country?



Legend: 1 = Very difficult 5 = Very easy

Cost guidelines & financial support keys to success

For the first time, there is potential for the **Multilateral Fund (MLF) to widen its scope to support** to the extent possible research and development activities in the future, in addition to or through continued financing of demonstration projects. However, the overall level of incremental operation costs (IOCs) and incremental capital costs (ICCs); the incremental costs for patents, the safety of flammable and toxic substances, and R&D; and the support for energy efficiency, HFC disposal or exemptions for high ambient temperature (HAT) countries, are still to be further negotiated.

Finally, because of its direct impact on climate change and energy efficiency, the KA will also open the door to entirely **new funding sources outside the MLF scheme**, such as the **Kigali Cooling Efficiency Program (K-CEP)**, the **Global Environment Facility (GEF)**, the **Green Climate Fund (GCF), European Commission funding programmes, regional banks**, non-A5 countries' **regional climate funds** or **bilateral agreements for country-specific actions**. For Africa in particular, the Third Industrial Development Decade for Africa (IDDA III), as well as the bilateral cooperation programmes, such as some ad hoc initiatives between the government of Italy and a number of African states, on environmental issues could provide potential additional support options. As in follow-up interviews with selected African NOUs, the familiarity level with those additional funding sources was still relatively low. It can be concluded that much greater communication efforts will be needed in the coming years to fully utilise the support options offered by non-MLF bodies and programmes.

As a summary from this chapter and based on the received input from African countries, building an effective **list of measures for a smooth ratification, implementation, and enforcement of the KA** takes precedence (see Toolbox). The proposed set of actions must consider the reduction of both **DIRECT emissions** and **INDIRECT emissions**.

EFFECTIVE KA IMPLEMENTATION

- ★ **Carry out ODS alternatives surveys** for data collection, monitoring and reporting requirements for HFCs
- ★ **Designate ministries**, steering committees and national coordination mechanisms for implementation and compliance
- ★ **Increase synergies with energy and climate change policies and actors, cooperate with custom officials**
- ★ **Assess current regulatory framework**; adapt laws and regulations
- ★ **Extend ODS licensing and control system** to cover HFCs
- ★ **Prioritize sectors and technologies** for the HFC phase down
- ★ **Identify market barriers** for low-GWP alternatives and foster dialogue with industry
- ★ **Increase work with national safety standards bodies** to include MP-related questions

Voices from Africa

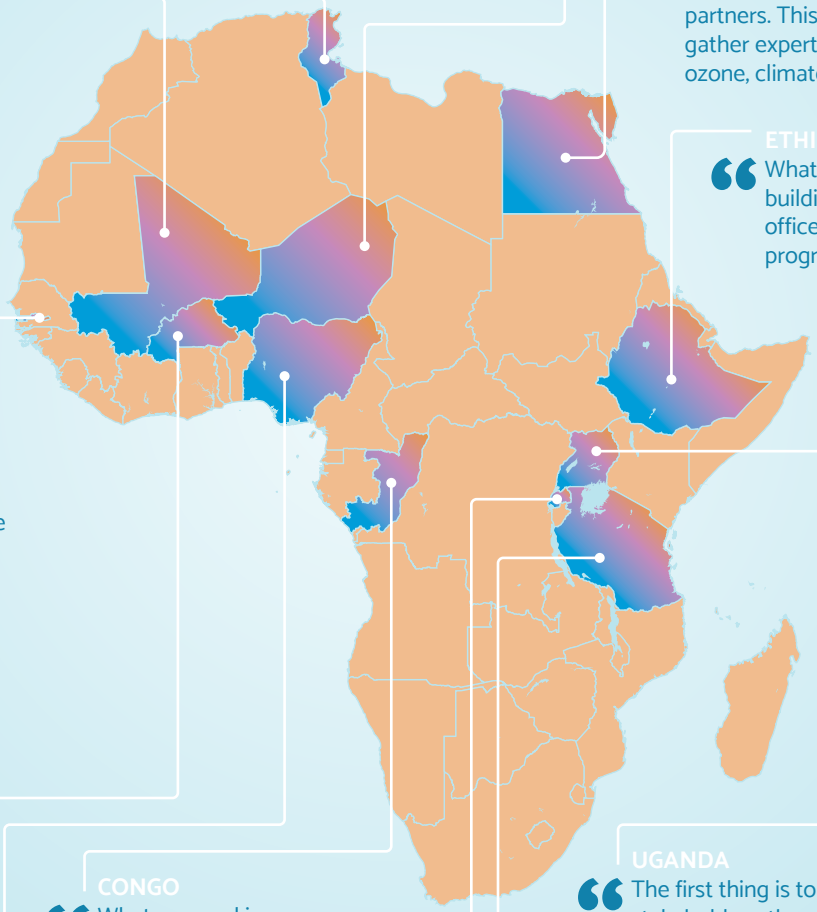
MALI
We need a forum at a national and international level. Also with the private sector, and the civil society organizations which one always tends to forget in this process. We need all those actors to put the work on track."

TUNISIA
Put in place a national system of certification. This needs to be efficient and autonomous."

NIGER
Our highest priority: Train the trainers, and have the appropriate equipment."

EGYPT
It's one word only: twinning. Between ozone and climate officers, between countries, between implementing agencies and bilateral partners. This means setting up a forum to gather experts, officials, NGOs to talk about ozone, climate change, energy efficiency."

ETHIOPIA
What is most important is capacity building for technicians and customs officers, and sensitization programmes for policy makers."



GAMBIA
We need to reiterate and emphasize capacity building and strong partnerships. And creating synergies between the NOUs and the Energy Ministry to harmonize our efforts. But even before these concrete measures, we need public awareness, as we need to get everyone on board for the success of the Kigali Amendment."

BURKINA FASO
We need key information on how the cost of the new technologies is moving. We need key focal points in different sectors that will help the ozone officers. We need better mobility of trainees, and more information in different local languages. Finally, we need the private sector to tell us if they can provide new technologies."

CONGO
What we need is training and equipment."

NIGERIA
Immediate availability of funds for the implementation of enabling activities."

UGANDA
The first thing is to orientate the different stakeholders, the private sector and especially the policy makers. And then relate it to the enabling activities because if they don't know or understand at first, it's difficult to bring these interventions."

TANZANIA
We need to sensitize decision makers on matters related to the Kigali Amendment to facilitate the national ratification process. Financial and technical assistance is essential for the implementation towards phasing down HFCs."

RWANDA
We need to enforce the capacity of refrigeration technicians, and take the lead in raising awareness about the economic benefits of alternative refrigerants. Immediate stakeholders to address are the importers, including their associations."

Cold-fashioned:

HFC control & low-GWP technologies

The Kigali Amendment prescribes recording historical and predicted consumption trends for ODS alternatives in A5 countries. The ODS alternatives surveys will help define the individual country baseline of phase down steps and form the basis for developing national strategies around priority industry sectors and application areas. Only then can HFC control and reduction measures take full effect in Africa. As a final piece of the puzzle, the selection of sustainable low-GWP technologies according to a country's priority needs is the ultimate goal to ensure that the transition is informed, structured and effective.

HFC REDUCTION & CONTROL

To better understand the preconditions of African countries for better HFC reduction and control, follow-up interviews investigated the **availability of RAC associations, training facilities, standardization bodies**, as well as a **refrigerant and equipment manufacturing sector.** As expected, both **RAC associations** and **training facilities** provide a stable basis – built in the last decades in most African countries – for a smoother implementation of the KA. They are especially important not only to **raise the skill level of the RAC sector and policy makers**, but also to significantly **influence the levels of cooperation** between policy and the RAC industry, in most cases the servicing sector. For the remaining factors, their adoption varies among African states and would therefore need specific attention by implementing agencies and bilateral partners. As one example, not all African states count on a **national standardization body**, which is something that needs to be urgently worked on to effectively implement one of the three key KA pillars, the role of safety standards in effective implementation (decision XXVIII/4).[3] Finally, a **product database for refrigeration and air conditioning equipment** for the systematic collection of annual sales numbers, energy consumption or refrigerant charge is only available in very few African countries (as is the case even among industrialized countries). Such a database would significantly enhance the control and reduction of ODS and HFCs, while also creating the basis for effective energy efficiency programmes or economic interventions.

ODS alternatives surveys: getting the facts right

ODS alternatives surveys will be a guideline and measurement tool for finding a sustainable replacement for HCFCs and high-GWP HFCs. As a result of ODS alternatives pre-surveys conducted among 127 Article 5 countries, among them 48 countries in Africa, a total of 13 pure HFCs and 33 HFC blends have been identified. However, 78 per cent of the consumption of pure HFCs and HFC blends can be associated with just three substances: R134a, R410A, and R404A. The RAC sector is responsible for 92 per cent of this consumption in terms of CO_2-eq tons.

Across African nations, **different methodologies to estimate production and consumption** of HFCs are applied. Often a **top-down approach** is used, which leads to problems with availability and the ability to update data in official sources. Also the **forecasting of future HFC emissions** proves difficult for most countries, due to a lack of historical data points. As **Africa mostly relies on a strong RAC servicing sector**, this sector in particular requires special attention and better cooperation when tracking the use of ODS and HFCs.

One Central African country summarised the **main gaps from the ODS alternatives survey** conducted, referring to the **non-registration of service technicians in national RAC associations**, the **absence of proper bookkeeping on non-ODS** by importers and distributors, the **non-availability of survey documents in French**, or the non-availability of a column to **register refrigerant losses during manufacturing processes and assembly**. Also, the surveys did not make provisions for the **traceability of HFCs across the entire value chain**: from importers, to distributors, retailers and servicing workshops. Finally, the **lack of proper understanding of HFC substances led to a mix up of HFCs in customs officers' listings**. As regards the cooperation between the different parties, NOUs often encountered **suspicion on the importers' and distributor's part in fear of taxation**. Many of these barriers can be assumed to be applicable to other African nations.

3 The three main pillars of the Kigali Amendment are as follows: 1. The actual amendment of the Montreal Protocol to include HFCs (Decision XXVIII/1&2); 2. The energy efficiency component (XXVIII/3); 3. The role of safety standards in its effective implementation (XXVIII/4).

Fake refrigerants a major concern for Africa

The **illegal import of fake refrigerants** is a particular challenge in Africa where many countries border several others, making the control and enforcement of ODS and HFC regulations difficult, especially at **porous borders** outside official border crossings. **Mixed refrigerants, fake substances sold as refrigerants, improper drop-ins, or incorrectly labeled substances** can therefore enter the countries. The steeply growing price of high quality HFCs has further encouraged the illegal smuggle of impure substances worldwide.

> **"Those selling refrigerants will tell you: 'I have three qualities for R22: this is the cheapest one, this is the middle one, and this is the expensive one – up to you to decide which one you want.' Even if you pay for the most expensive one, it might not be the right quality."**
> Samuel Pare, Burkina Faso

ODS ALTERNATIVES REPORTING

- ★ **Establish a national registration system**, product databases and a legal obligation for equipment owners to submit periodic equipment records to competent authorities
- ★ **Update current ODS reporting** to include HFC consumption, to create an ODS alternatives bank and RAC inventory
- ★ **Provide technical assistance to HFC end users**, manufacturing and servicing sector, importers and distributors for data collection
- ★ **Ensure proper registration of service technicians** in national RAC associations
- ★ **Harmonise tariff codes** according to HFC commitments (pure substances, blends)
- ★ **Better control pre-charged equipment** at customs borders
- ★ **Train customs officers** in import trade control

In a significant UNIDO initiative, **Tanzania** was empowered to systematically check the quality of imported refrigerants with the help of **refrigerant identifiers**. In such a system, customs officers can check the purity and proper labeling in testing centers, and if the source of origin is evident penalize the importer. Other major success factors are the **training of trainers** for skilled customs authorities, **cross-border cooperation** for higher detection and enforcement rates, and increasing the **pressure on importers and distributors via stronger RAC associations.**

> **"We have put in place recovery and recycling centres, and equipped them with necessary tools and machines. Technicians utilize the facilities for good refrigeration practices."**
> Magdalena John Mtenga, Tanzania

LOW-GWP SUBSTANCES & TECHNOLOGIES

Low-GWP technologies already competitive

The **term low Global Warming Potential or low-GWP** is being used widely to define valid alternatives as compared to high-GWP substances such as HCFCs and commonly used HFCs such as R134a, R404A and R410A. However, one needs to remember that no official definition of the term exists yet. Given that the total environmental impact is a sum of **DIRECT** and **INDIRECT emissions**, choosing the right "low" GWP refrigerants will have a decisive effect on any country's long-term compliance under the KA.[4]

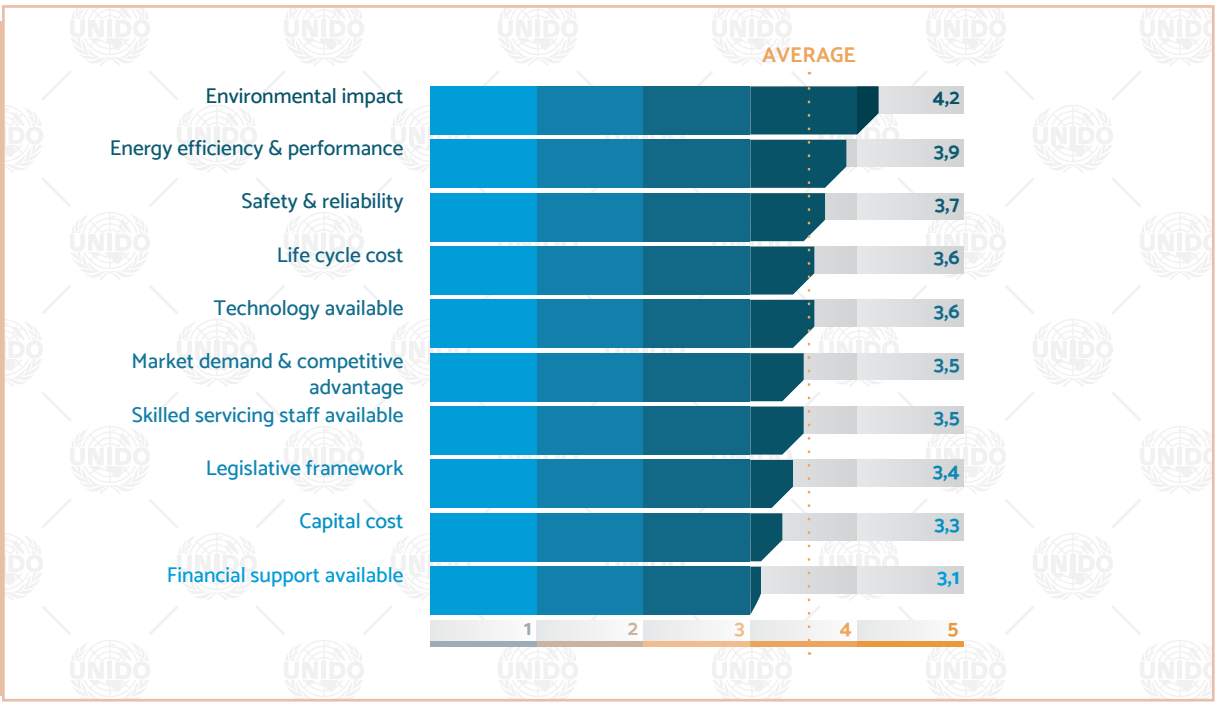
Natural zero- or low-GWP alternatives such as R600a, R290, R744 or R717 offer a superior **Life Cycle Climate Performance** (LCCP) and Total Equivalent Warming Impact (TEWI) as compared to HFCs in many applications. Taking a holistic perspective, both emission types need to be weighted in a cradle-to-cradle scheme to get to a refrigerant's **total environmental impact**. While this requires a **consideration of all emissions related to the production, distribution, use, leakage, recovery and reuse of the refrigerant** (see Fig. 1, introductory note), the result will be a better choice of truly sustainable substances. For more details, please refer to Tech Specs.

African countries were asked about the **competitiveness of low-GWP technologies**. Figure 6 shows that in terms of **environmental impact, energy efficiency and performance, safety and reliability**, and **life cycle cost**, low-GWP alternatives would be more competitive than existing technologies. For the last three items, the ozone officers' answers perfectly matched with their countries' overall priorities in selecting substances and technologies for RAC equipment, pointing to positive expectations regarding the new solutions to replace ODS. In fact, African NOUs showed significantly **higher confidence levels in low-GWP solutions** than their peers from other world regions. This is a positive basis to build on, if the right frameworks are set for a speedy uptake of non-HFC alternatives.

4 Please note that wherever the term "low-GWP" is used throughout this report, for reasons of simplicity it also includes "zero-GWP" substances with a GWP = 0 (like ammonia R717, water R718, or air R729 as a refrigerant)

Fig.6: Competitiveness of low-GWP technologies

How competitive are today's low-GWP technologies for the following aspects?



Legend: 1 = Low-GWP alternatives are very weak 5 = Low-GWP alternatives are very strong

Use of low-GWP refrigerants and familiarity levels still at a low level

Selected African NOUs were asked about their and other stakeholders' level of **familiarity with the properties and application potential of commonly proposed low-GWP alternatives.** Among the natural refrigerants, **R600a has the highest familiarity levels,** followed by R290. Ammonia, water and CO_2 received significantly lower ratings. On the areas of low- to medium-GWP HFCs, "HFOs" received low familiarity ratings, whereas R32 was slightly more familiar to the African NOUs. Still, **most respondents were relatively familiar with high-GWP HFCs** such as R134a, R410A and R404A. Results suggest that, even if a temporary move to high-GWP substances is to be avoided, more information about the use of natural and synthetic zero-, low- or medium-GWP substances is urgently needed.

Where low-GWP substances will gain market share quickly, and which information is still missing

Especially for **domestic refrigeration**, **African countries** expressed **high confidence in low-GWP solutions** as the only sector where it would be "rather easy" to find viable solutions. All other sectors – residential A/C, commercial refrigeration, transport refrigeration, commercial and industrial A/C, mobile A/C, residential heating, and industrial refrigeration – received a "neither easy nor difficult" rating. Finding solutions for commercial and industrial heat pumps was even perceived as "rather difficult". It can be noted that the first three **priority sectors are very closely related not only to the RAC manufacturing or servicing sector, but are also close to the consumer.** Effective involvement of the broader public and the commercial end users is therefore of utmost importance for swiftly implementing the KA in Africa.

> "It's very obvious we have a lot of alternatives. The use of carbon dioxide should be really common compared to what it is right now. In my country we have it as a byproduct from one big project of extracting methane gas and I was wondering why we have to always import instead of using what we already have."
>
> Juliet Kabera, Rwanda

Lack of technology availability still among the major roadblocks for a fast transition

The **lack of availability of low-GWP solutions** poses a strong challenge to African countries. In a project for **the Gambia** initiated by UNIDO, the refrigerant R290 had to be imported from Asia for training purposes. A plant in **Nigeria** producing high purity HCs is under way but has not yet started operation. Countries are therefore urged to explore existing sources of **propane**, CO_2 or **ammonia as byproducts from agricultural processes, petrochemical plants or methane gas extraction to then refine them as high purity refrigerants.** As a second challenge, global refrigerant suppliers are often unwilling to supply small refrigerant quantities to A5 countries with currently low consumption or still in the pilot testing phase. To become attractive markets for such suppliers, Africa could form **buyers' alliances with higher order quantities** and hence stronger purchasing power among neighbouring countries. As already highlighted, a third challenge is the **dependency of many African nations with no RAC manufacturing facilities on technology imports.** A possible solution is to **strengthen public procurement** so that bilateral agreements between the governments of the receiving country and the importer would clearly specify the refrigerant type or minimum energy efficiency, putting the A5 country on track for KA implementation.

Economic incentives and HFC control are most effective in driving technology change

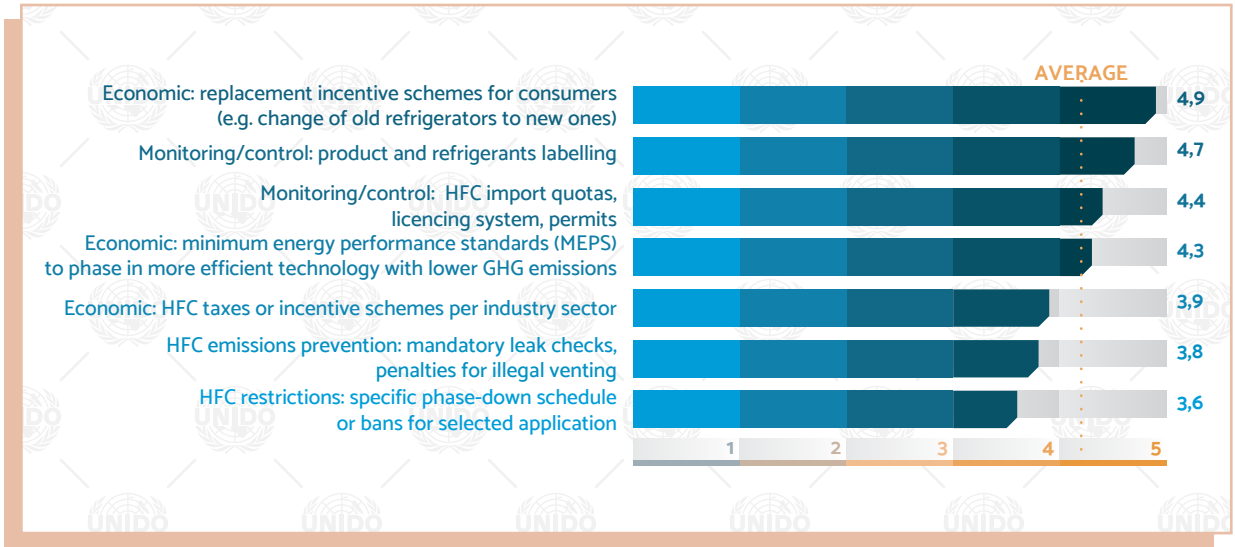
> "We have eight [RAC] original equipment manufacturers in Egypt and the competition between them is very high. We don't want everyone to go to one alternative and after they will all suffer. It is good to work with the manufacturers and to build confidence first."
>
> Ezzat Lewis Hannaalla Agaiby, Egypt

African participants agreed that their domestic private industry sector would be overall ready and willing to implement the KA, but that additional **incentives and support measures** from governments and the international community would be needed. Initiatives like a UNIDO project in **Egypt**, where eight air conditioning manufacturers participated in a capacity building activity to build confidence in new low-GWP technology, serve as a best practice example also because the scheme used funds for enabling activities under the HPMP Stage 1 instead of new MLF funds for demonstration projects.

Replacement schemes to exchange obsolete technology with state of the art equipment seem to be a popular measure among selected African NOUs. As Figure 7 shows, this is preferred over product and refrigerant labeling, and HFC import quotas and licensing systems. HFC restrictions, such as specific phase down schedules or bans in selected application sectors, are the least favoured option to drive a successful KA implementation.

Fig. 7: Tools to support low-GWP alternatives

How much do you believe the following legal and financial tools will help accelerate the transition to low-GWP alternatives in your country?



Legend: 1 = Not important at all 5 = Very important

Class act:

Training, capacity building & standards

Training and capacity building are mentioned by African countries as one of the highest priorities, along with securing financing for the transition, and an informed choice of next generation technologies. Given that low-GWP alternatives are often flammable, toxic or need to work under excess pressure, the proper training of customs officers, RAC technicians, but also of manufacturers and end users is an immediate necessity. National standards on the safety and energy efficiency of RAC equipment lie at the heart of any successful Kigali Amendment implementation.

RAC TRAINING & CERTIFICATION

Training of RAC servicing sector of highest concern

The **lack of appropriate technical skills among the RAC servicing sector** has strong implications for the KA implementation. First, it **endangers human health** when technicians work with refrigerants without proper instructions and standards. Second, one can expect **technicians' reluctance to service selected low-GWP technology** due to their ignorance of its thermodynamic or chemical properties will effectively result in **entire markets not adopting more sustainable refrigerants.** Finally, proper training has a decisive **impact on the energy efficient installation, operation and disposal of RAC equipment.** Hence, training influences **DIRECT emissions** of GHG into the atmosphere (through refrigerant GWP, refrigerant charge and recharge, leakage rates, recovery), and **INDIRECT emissions** (through electricity saved from equipment running efficiently).

Training: the cornerstone of scaling up technology change

> "We need to support RAC workshops with periodical publications, together with catalogues in the field."
> Yousef Hamami, Tunisia

In the follow-up interviews, African NOUs were asked about the **available training and capacity building activities on HFC alternatives.** Most countries stated that they have already initiated an **industry dialogue** or awareness-raising campaign among industry. **Theoretical training for RAC technicians, and practical hands-on training** using equipment, have also already started in most countries. The **change of university curricula to include HFC-related content**, however, is still not being implemented to a wide extent. Results indicate that training and capacity building efforts have indeed started in different fields across African nations, requiring a tailored approach by implementing agencies and bilateral partners.

> "From our own experience technicians are key in our fight against ozone depletion. Let them have a sense of belonging. If they are well-trained and you motivate them by providing the necessary equipment and empowering them with knowledge and skills, believe me, we will all succeed as a continent at large."
> Bafoday Sanyang, the Gambia

In a project for **the Gambia** supported by GEF and UNIDO, the NOU has given full responsibility for the establishment of a **country-wide training scheme** to the national training institute. Under this Refrigeration and Air-Conditioning Support Scheme, so-called "**super technicians,**" the country's best RAC technicians, ensure others are properly trained. The **issue of illiteracy**, common especially in rural areas in Africa, is addressed with a range of **stickers using pictograms on the refrigerant cylinders and the RAC equipment.** That way, technicians can easily understand if a refrigerant is flammable or otherwise requires caution, if a system contains a pure substance, or when the last equipment check was performed or is due next. The labels will be applied to both newly imported equipment and existing systems.

Only certification ensures high safety and replication potential

> "Our highest priority is: Train the trainers, and have the appropriate equipment."
> Sani Mahazou, Niger

As for the proper training on alternative working fluids, such as CO_2, hydrocarbons or ammonia, certain **minimum requirements** are recommended for any curriculum: basic thermodynamics and physics, including identifying the differences between low-GWP refrigerants and HFCs; good practice on selecting typical applications for low-GWP substances; health and safety requirements for installation, maintenance and in case of an incident; as well as knowledge of national and international regulations and standards. UNIDO has already conducted training on alternative refrigerants in **Eritrea**, the **Gambia**, and **Tunisia**.

Building national or regional **certification schemes** for the RAC manufacturing and servicing sectors is the next step to take. Especially the **compatibility of existing or emerging training concepts in African countries with international certification schemes and standards** is a subject of much concern. Training on one side and certification on the other need to be separate and independent. The **certification process needs to be standardized** to allow for easy replication, as well as mutual recognition internationally or at least between countries with the same certification schemes. The Toolbox at the end of this chapter provides a summary of actions on effective RAC training and certification.

For example, **Tunisia** is currently in the process of establishing a national certification programme for technicians and enterprises in the refrigeration sector. In 2016, a certification session was organised to determine the responsible vocational training centre. However, this session did not cover natural refrigerants, which indicates a clear need to reinforce efforts in this area. **Sudan** has already submitted a funding proposal on capacity building and training for HFC alternatives.

> "We do have some existing training centres but they need to be strengthened to take into account the new technologies coming with the phasing down of HFCs. We either need a better cooperation with existing centres or even to talk about a new one. We are more than interested to implement this with the support of UNIDO and our bilateral partners."
>
> Samuel Pare, Burkina Faso

> "Most important for us is to put in place a national system of certification. This needs to be efficient and autonomous."
>
> Khalid Mohieldein Ibrahim Hammad, Sudan

ODS ALTERNATIVES REPORTING

- ★ **Train-the-trainers** schemes to establish a cascading system of highest qualified senior technicians to train medium- and junior-level staff
- ★ **Universal RAC training kit** with pre- and post-assessment of training and checklists, minimum teacher qualification and equipment, venue requirements for theoretical and practical training, text books, manuals, etc.
- ★ **Smartphone applications** for technicians for onsite handling of flammable, toxic refrigerants
- ★ **Refrigerants driver's license**: globally recognised minimum qualification scheme for sound refrigerant management
- ★ **Refrigerant literacy course**: for non-technical people, such as NOUs, energy efficiency or climate change-related personnel to interact with technical staff
- ★ **Technology exhibitions & pilot conversions**: use policy and technology capacity for a faster adoption of alternative refrigerant technology in real-life applications
- ★ **Use of labels with pictograms** on RAC equipment and cylinders to involve illiterate technicians
- ★ **Study tours** to neighboring countries, case study sites, training institutes and exhibitions in other countries

STANDARDS ON SAFETY & ENERGY EFFICIENCY

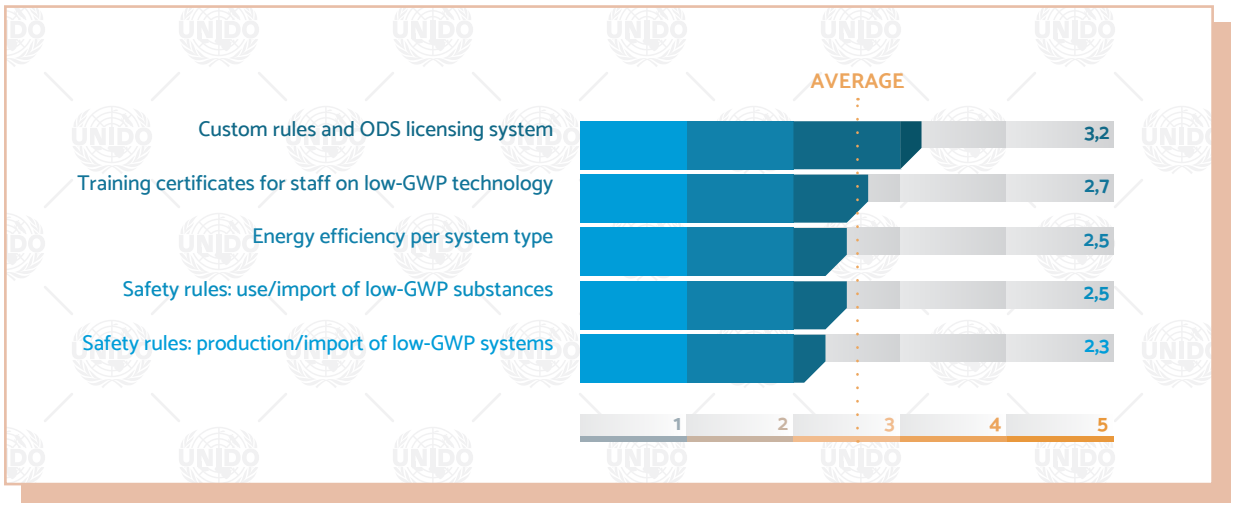
Standards important, but more progress needed

Safety standards for RAC equipment are crucial measures to effectively implement KA obligations. The standard setting process for defining refrigerant classifications, safety rules and charge limits for flammable or toxic low-GWP substances, however, is a laborious process. African nations therefore actively **need to work with their national standardization bodies** to have a say in international standard development. Otherwise, inappropriate standards could effectively hold back entire application sectors to move into more efficient and safe alternatives. As a case in point, **TEAP has established a standards task force.** All countries are urged to actively engage in this ongoing work and as a priority strengthen weak national standardization bodies. In fact, as mentioned previously, some African countries have not yet created a national standardization body. Such an entity is a prerequisite for the involvement in international standardization committees, where the creation of new and the revision of existing standards takes place. On the national level, it also serves as a strong supporting body, which advises on transposing standards into national industry rules or governmental laws.

African respondents rated standardization as a matter of urgency and high importance. All areas affected by standards got a "standardization will be important" mark (4.4 to 4.1, on a 1-5 scale). Those areas are customs rules and ODS licensing system; safety rules for the use and import of low-GWP substances and technologies; energy efficiency per system type; and training certificates for staff on low-GWP technology. However, asked about **how much progress had been made** in these areas, respondents admitted that **most areas still lacked sufficient progress** (see Fig. 8). The only exception was on implementing standards for customs rules and establishing an ODS licensing system which received higher than average progress rates.

Fig. 8: Progress on standardization

How much progress has your country made regarding standardization in the following areas related to the KA?

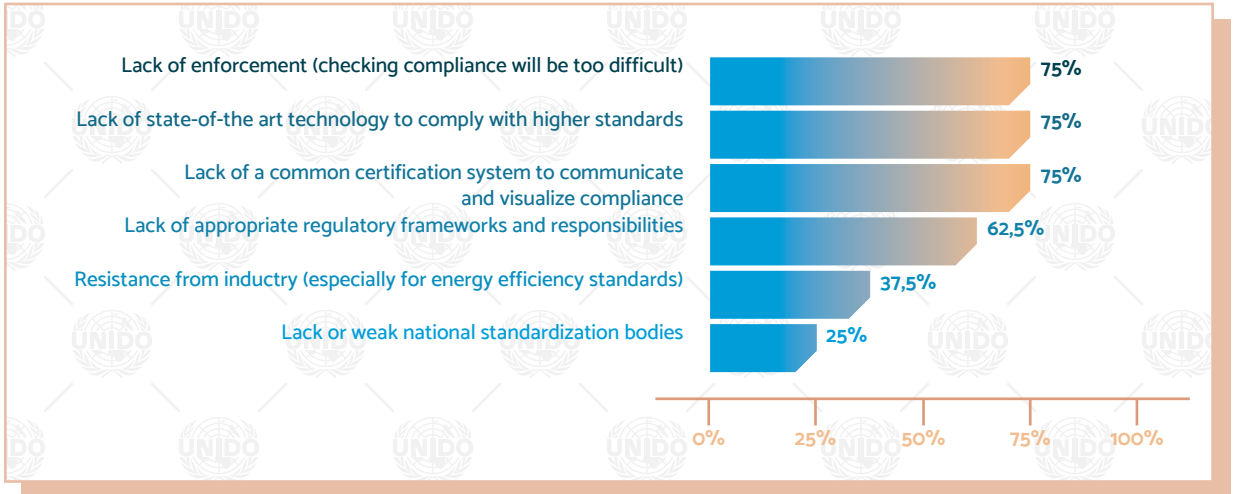


Legend: 1 = My country has not yet started standardization 5 = My country has fully completed standardization

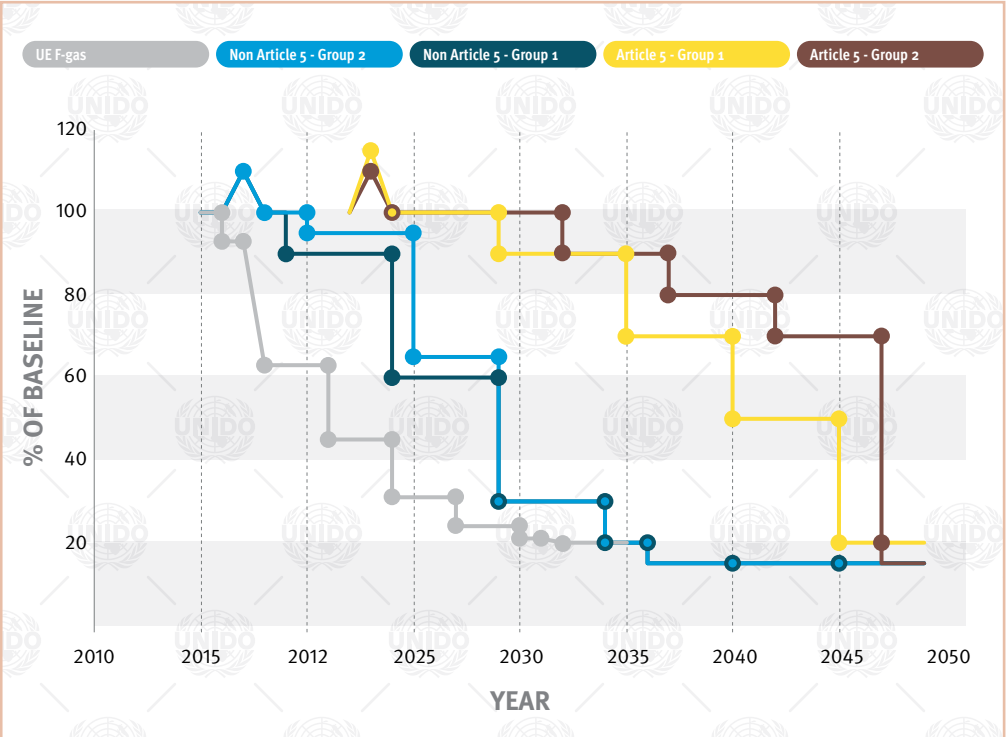
As a follow-up, selected NOUs were asked about the main barriers to developing energy efficiency and safety standards for low-GWP technologies. A majority saw the lack of enforcement, the **lack of state of the art technology to comply with higher standards, and the lack of a common certification system to communicate and visualize compliance as major barriers.** Figure 9 provides an overview of the situation.

Fig. 9: Barriers to energy efficiency and safety standards for low-GWP technologies

What are the barriers to develop energy efficiency and safety standards for low-GWP technologies? Please select all that apply.



HFC phase-down schedule for A5 and non-A5 Parties



Baseline formula for all country groups

Non-A5 Parties
Average HFC consumption for 2011-2013 + 15% of HCFC baseline

Non-A5 Parties Special Group*
Average HFC consumption for 2011-2013 + 25% HCFC component of baseline

A5 Parties Group 1
Average HFC consumption (or production) for 2020-2022 + 65% of HCFC baseline

A5 Parties Group 2
Average HFC consumption (or production) for 2024-2026 + 65% of HCFC baseline

Keep your cool:

Energy efficiency

Energy efficiency is a key component of the Kigali Amendment, to select technology solutions that not only have low Global Warming Potential, but also a low overall environmental impact. The RAC sector, as a major energy consumer, plays a strong role to enable every African country to reach climate change targets, integrate renewable energies and save money.

Energy efficiency a main pillar of Kigali Amendment

Selecting technologies that are more efficient than the technologies they replace is a key success factor for the KA. Given that energy efficiency accounts for 60 to 90 per cent of GHG emissions, only 20 per cent of total costs normally relate to the equipment investment cost, whereas the remaining **80 per cent of operating costs** hold the true potential for cost savings. A decision for or against a widespread RAC solution should therefore always be guided by the **Total Cost of Ownership (TCO)** principle, and ideally the **Life Cycle Climate Performance (LCCP)** model. Please see Tech Specs for a more detailed explanation of these concepts.

From an economic and social perspective, **energy efficiency is also at the heart of three Sustainable Development Goals**: SDG 7 dealing with affordable and clean energy; SDG 9 on industry, innovation and infrastructure; and SDG 13 on climate action. The **Technology and Economic Assessment Panel (TEAP)** advising on Montreal Protocol-related matters has established a working group to deal with and report on the request in Decision XXVIII/3 on energy efficiency.

Energy efficiency programmes in Africa build on existing basis

> "A few weeks ago a Director General was appointed to be in charge of energy efficiency. This is a golden opportunity to go home with sound arguments to convince him [that energy efficiency is a key element under the Kigali Amendment.]"
>
> Samuel Pare, Burkina Faso

As regards initiatives that could be used for better strategies to couple **DIRECT** and **INDIRECT emissions**, **Burkina Faso** has already **established a Directorate General on energy efficiency** which it plans to effectively use also for KA compliance. **Nigeria**'s NOU is already **collaborating with the Energy Commission of Nigeria and the Standard Organization of Nigeria** on energy efficiency programmes, whereas **Senegal** can build on its **established product database** to record energy efficiency levels. Finally, in **Tunisia** a **regulation on the energy efficiency of domestic refrigerators and residential air conditioners** exists, which is controlled by the state body CETIME.

How to save energy in RAC equipment

> "I think the most important thing for the government is to establish standards, and focus on education. The government has to control the overarching rules, the energy efficiency, the goals, the standards."
>
> Ezzat Lewis Hannaalla Agaiby, Egypt

With a hugely increasing stock of RAC appliances and industrial equipment expected over the next decades, the electricity demand is set to more than double. One of many ways to effectively save energy during the operation of RAC equipment is in **refrigerant selection**, because refrigerants lead to different efficiencies depending on their chemical and thermodynamic properties, as well as the applications and conditions in which they work. A second way to improve RAC efficiency is to **select either more efficient individual components and/or improve their coordination**, to ensure that each step of the refrigeration process and the entire system work under optimal conditions. A third option is to **select the right insulation** to prevent the loss of heat or cold depending on the system's primary function. Last but not least, the **selection of new system processes** has a decisive impact on energy efficiency. Systems using CO_2 (R744) operate at higher pressure, but the refrigerant's inherent properties can be used to obtain savings on direct and indirect emissions. One example is an MLF-funded UNIDO project in a supermarket in **Tunisia**, where energy savings from using CO_2 refrigerant and applying other improvements to the system could reach up to 25 per cent. In summary, there is a variety of options to directly improve the efficiency of the system and establish a framework in which such technology can proliferate (see Fig. 10).

Energy efficiency centres in Africa combine standards, labeling and renewable energies for integrated approach

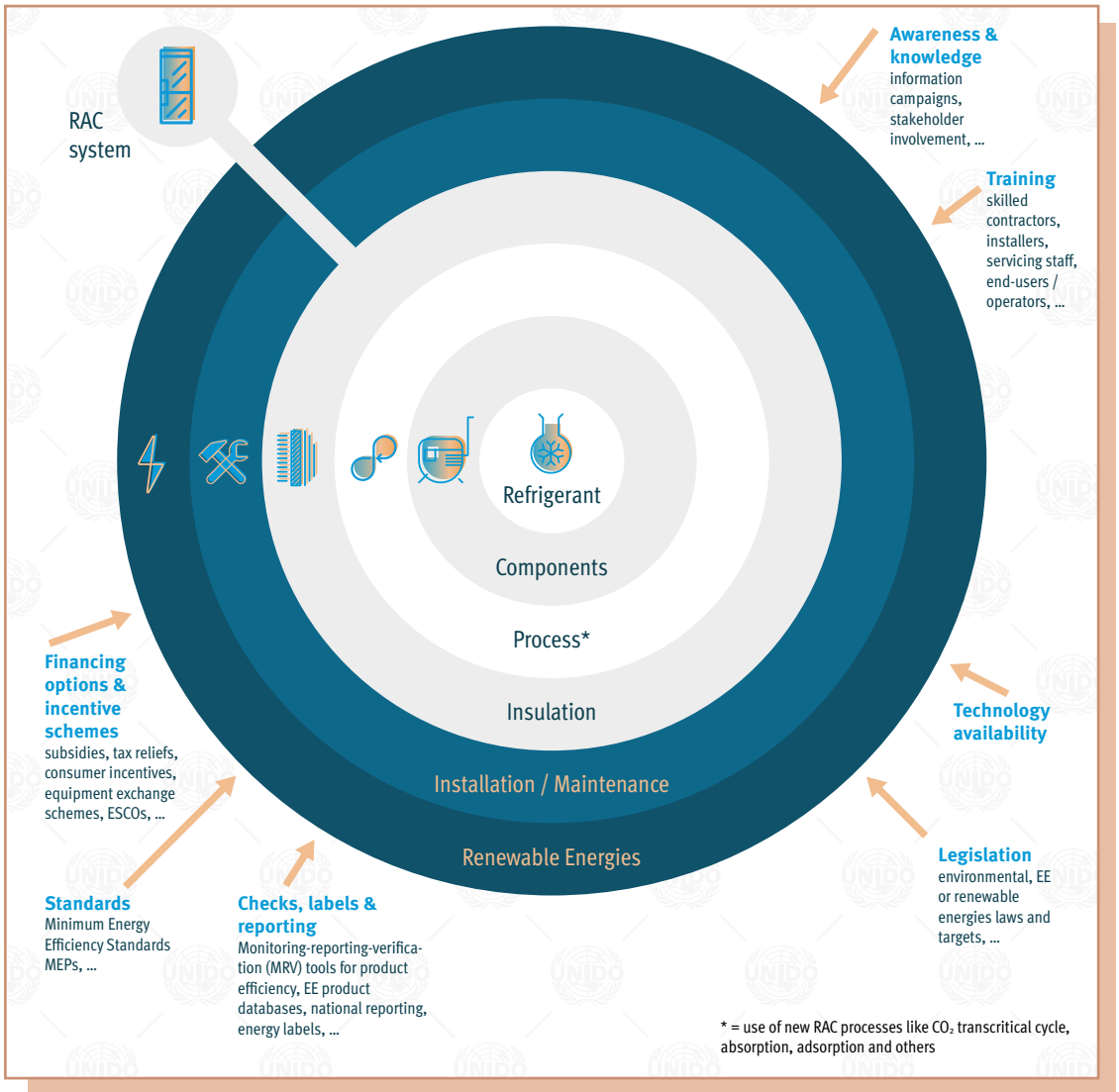
As a concrete example of how energy efficiency can be mainstreamed in Africa, UNIDO has established a **network of ECOWAS centres in the West and Southern Africa region.** The initiative developed **standards and labeling schemes on lighting and appliances**, and worked with the policy level to establish national strategies. The centres are operational to **build capacity** to both provide relevant equipment but also do the actual testing for the efficiency standards.

A significant initiative to outline the vast energy savings potential of **nearly 50 African states**, the "United for Efficiency" (U4E) country assessments have systematically calculated total **annual energy consumption for each country by 2030**, and in particular the energy use coming just from **room air conditioners and domestic refrigerators.** Figures differ widely: for **Somalia**, 24.5 per cent of the country's electricity use in 2030 is estimated to come from those two types of appliances alone, whereas for **Sudan** the figure could be 15.1 per cent, for **Chad** 12.1 per cent, **Niger** 6 per cent, **Ethiopia** 5.9 per cent, **Algeria** 3.1 per cent, **Tunisia** 2.4 per cent, **Egypt** 2.2 per cent, and **South Africa** just 0.6 per cent.[5]

More money available for efficiency projects

Today, **hardly any information on the energy efficiency of RAC equipment is available in African countries**, let alone consistent national standards on energy efficiency. For Africa to fully exploit opportunities for energy efficiency, UN agencies but also bilateral partners could help identify financing schemes and provide technology and knowledge transfer. One example of the successful use of energy efficiency financial support schemes is the **UNIDO-GEF financed project in the Gambia, which used funds for improving the energy efficiency of RAC equipment by means of proper training and capacity building.**

Fig. 10: RAC energy efficiency improvements



CHAPTER 4

Whatever the weather:

Partnerships

Partnerships between the government and private sector, South-South cooperation, and partnerships between countries and international agencies, touch on all of the areas mentioned in this report. Naturally, partnership is relevant whenever stakeholders are working together for a better result. African countries attach special significance to partnerships as a tool to collectively seize opportunities under the Kigali Amendment.

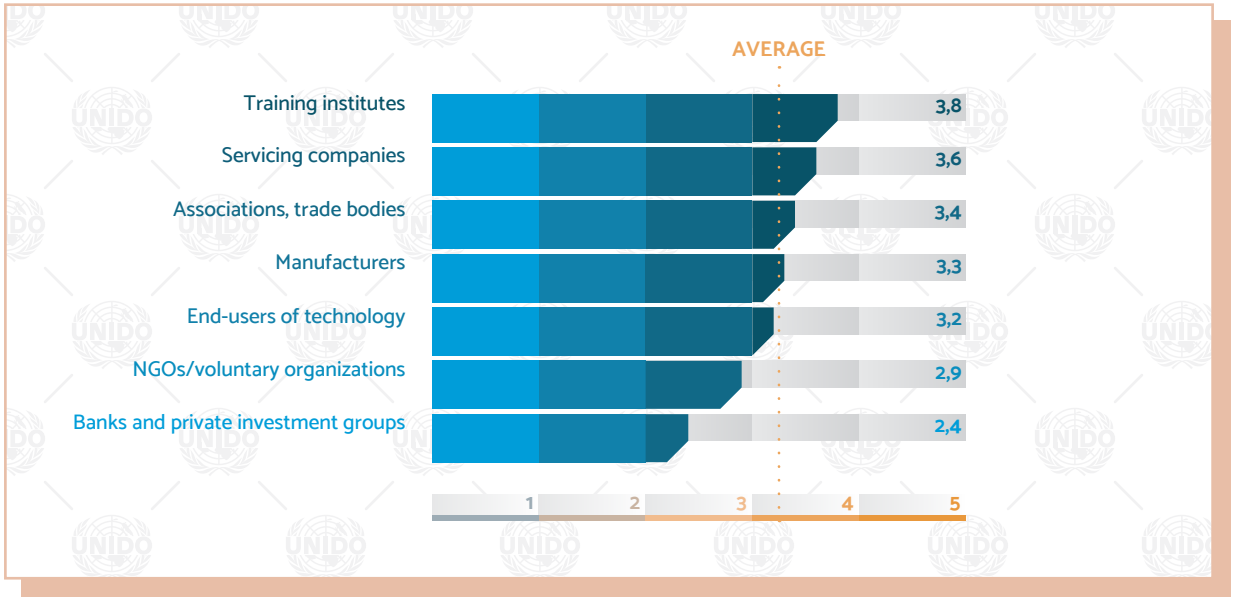
Private sector key to make KA work, but partnership with policy needs more efforts

The private business sector will continue to be one of the key partners in addressing Africa's development challenges under the SDGs while at the same time taking into account energy efficiency and climate change matters. A total of **14 African NOUs** agreed that **end users of RAC technology and training institutes, associations, servicing companies and manufacturers would all be "very important" or "important" for making the KA a success.** However, besides the cooperation with training institutes and servicing companies ("partnership rather strong"), all other partnerships still need more effort to become strong facilitators for the KA (see Fig. 11).

> "In my view the first thing is to orient the different stakeholders, the private sector and especially the policy makers, and then relating the Kigali Amendment to the enabling activities; because if they first don't know or understand, it is difficult to bring about these desired interventions."
>
> Margaret Aanyu, Uganda

Fig. 11: Partnership between government and KA actors

How strong is the cooperation between the government and the following actors from the private sector in your country, in the context of making the KA work?



Legend: 1 = Partnership does not yet exist 5 = Partnership is very strong

In follow-up interviews, selected African NOUs also believed that **end users in their own countries, as well as manufacturers in the region, would be best placed to influence the availability of low-GWP technology for their countries.** Overall, they saw political bodies in the country and the region being of slightly less importance than the private industry sector in their own countries and from neighbouring regions.

Public-private partnerships (PPP) are mentioned by several African countries as a key enabling factor. For example, **Nigeria** has worked on implementing a high-grade hydrocarbons refrigerant production plant that would benefit from bilateral agreements and other PPP programmes for its broader commercial exploitation.

> "It's very important to build confidence with especially the manufacturers. We try to do our best to facilitate the technology transition [...] and involve them in demo projects even outside of Egypt. And this is I think one of the main duties of the ozone unit in the country."
>
> Ezzat Lewis Hannaalla Agaiby, Egypt

South-South cooperation & regional twinning uses the power of a team

When **African participants** were asked about the impact of the KA on their countries, South-South cooperation featured prominently as an exchange of resources, technology and knowledge between A5 countries. Partnership with countries in the same region also featured highly (see Fig. 1, introductory note). **Study tours or exchange visits** are considered valid options to

foster dialogue, along with regular meetings of countries with similar climatic, political and economic conditions. **"Twinning" as a fixed legal, political, social or informal partnership between cities, regions or countries**, is another strong format to address the KA challenges and stay ahead of technology development.

> **"First of all we need to have a vision. Then we will create a strategy and after this we will start activities. We cannot do everything at the same time. So let's create a forum of experts, officials, NGOs to help us with ideas to create this vision."**
> Ezzat Lewis Hannaalla Agaiby, Egypt

This was also confirmed by selected African NOUs, suggesting that a **regular dialogue forum with policy, NGOs, manufacturers, end users and academia in the region would be a high priority** to build on for developing national strategies and for constantly monitoring achievements. This idea received even more positive reception than establishing regional energy efficiency centres and testing labs; creating buyers' alliances with neighboring countries or regions with similar climates for purchasing low-GWP technology; or establishing regional centres for training RAC technicians or policy makers.

Bilateral partners and UN agencies can drive fast technology change

With the KA addressing a variety of issues besides the priority phase down of HFCs, new approaches for financing mechanisms are also urgently needed (see also chapter 1). **UNIDO** has already worked in partnership with the GEF (Global Environment Facility) in **the Gambia** project on capacity building. In another example, **Italy** has signed a **Memorandum of Understanding (MoU) with 16 African countries** – with another seven being currently negotiated – on improving energy efficiency and the uptake of renewable energies on one side, and the reduction of greenhouse gases (GHG) on the other[6]. In a project for **Botswana**, the improvement of energy and water efficiency will be combined with best practices to replace the existing HCFC air conditioning system in compliance with the KA. In specific cases, **bilateral programmes** such as the one that Italy is promoting, can also **provide additional opportunities for Africa to promote complementary actions interlinking with an HFC phase down.**

ODS ALTERNATIVES REPORTING

- **Intragovernmental cooperation** to streamline available expertise on energy, climate, agriculture, urban development, health, etc.
- **Twinning** between cities, regions or nations to exchange knowledge and move forward faster
- **Partnerships with implementing agencies** as neutral brokers with expertise in maintaining cooperation and investment schemes in various industry sectors
- **Use of innovative financing** schemes to fully exploit available resources for industrial development, energy efficiency, climate change, etc.
- **Bilateral agreements** between importing and exporting countries on state of the art refrigerants and technology
- **SME innovation programmes** to increase the competitiveness of small enterprises especially in the RAC import, manufacturing and servicing sectors
- **Regional meetings, exhibitions, study tours, exchange forums** to gather policy makers, NGOs, academia, industry and civil society for KA matters

6 MOUs signed: Algeria, Botswana, Comoros, Democratic Republic of the Congo, Djibouti, Egypt, Ethiopia, Ghana, Kenya, Lesotho, Morocco, Rwanda, South Africa, Sudan, Swaziland, Tunisia. MOUs negotiated: Mali, Mauritius, Mozambique, Namibia, Senegal, Tanzania, Zambia.

CHAPTER 5

All aboard:

Socio-economic effects & gender balance

The Kigali Amendment requires the active participation of all civil society groups to achieve its full potential. Women, youth and disadvantaged groups are still significantly underrepresented in African countries' national strategies addressing sustainable development, economic growth and technology change. To ensure the rapidly growing RAC sector continues to work effectively in the future, countries now need to urgently turn their attention to stronger social inclusion.

Sustainable development agenda goes hand in hand with KA

Tackling both ozone depletion and climate change will require active participation from the entire civil society. This goes especially for **African countries attaching high expectations to the positive socioeconomic impulse coming from the KA**, in terms of higher economic growth or increased competitiveness (see Fig. 2). Although social factors such as gender balance and social inclusion, education or employment received lower rates than environmental, legal or economic factors, NOUs are increasingly aware of the benefits of integrating social aspects at the early stages of the KA enforcement.

> "I would like to launch a call here to everybody, that we cannot reach SDGs for 2030 as long as we do not put in place now the Paris Agreement or the Kigali Amendment. If we manage to have the same enthusiasm for the Amendment [...] I think we will be able maybe to save our planet."
> Modibo Sacko, Mali

Issues such as poverty reduction, food security, economic growth, health, quality education, gender equality, sustainable production and consumption, and the access to affordable and clean energy are among the opportunities African countries can benefit from. Especially in combination with the **Third Industrial Development Decade for Africa (IDDA III)**, the KA could unfold its full socioeconomic potential to provide support through partnerships, joint resource mobilization, technical cooperation, and the management of industrial policy instruments. In Africa, programmes need to address specific challenges, such as the **low 40 per cent rate of access to electricity** across the continent, as well as the **affordability of refrigeration for the food cold chain, pharmaceuticals and floriculture**, particularly in off-grid communities. **Integrated thinking on the KA to achieve the 2030 Agenda for Sustainable Development** should guide African states in their implementation strategies.

Future of RAC sector depends on active involvement of women and youth

Although women make enormous contributions to economies, they remain disproportionately affected by poverty, discrimination and exploitation. A field of immediate threat to the KA's success is the constantly decreasing **representation of women in the RAC sector**. This is counterintuitive, given that there are 3 billion RAC systems operating worldwide with a steeply increasing trend for cooling solutions for the decades to come. More importantly, the need for RAC engineering staff is growing faster than in other professions. However, women are first underrepresented in science (comprising only 30 to 40 per cent), then in engineering professions (10 to 20 per cent), and finally in the RAC sector (1 to 10 per cent).

Encouraging **young generations** to work in the RAC industry is a second issue. The **lack of specific degrees in refrigeration** is one reason why young people do not strive to take a course in thermodynamics at university. The **remuneration and social status of refrigeration technicians** is another reason. Successful **individuals in an RAC role** are hence needed **to serve as role models** to convince young people to follow this career path. As a general problem prevailing in several African nations, the **underrepresentation of women in higher education** is a further roadblock to achieving the specific aim of becoming a RAC technician.

African countries are hence urged to **establish early plans to create national strategies around education, involve minorities and attract the next generation** to take an active role in the use of green technologies. Interventions at the basic schooling level are crucial to encourage girls to continue their education at the same pace as boys. Finally, **supporting the illiterate with visual clues on RAC equipment**, as in a UNIDO project in **the Gambia**, is an effective means to involve the rural community in the handling of new substances and technologies.

by Dr. Fabio Polonara

CHAPTER 6

Tech specs

"Low-GWP" technology and substances for RAC

The most important applications of refrigeration and air conditioning (RAC) require the presence of a **working fluid within their components. This working fluid – also known as "refrigerant" – is chosen on the basis of its physical properties and its thermodynamic ability** to perform the task assigned to the specific application. Unfortunately, **no single refrigerant or refrigerant type fits all possible applications**, and therefore the industry has to cope with a number of them, with different properties and characteristics.

Some of the refrigerants that emerged from the restrictions imposed by the Montreal Protocol have a high Global Warming Potential (GWP) and contribute to climate change. From a technological point of view this poses a real challenge, because such **high-GWP fluids (most of which are hydrofluorocarbons or HFCs) have become the backbone of many RAC sectors** in the past two decades.

Zero-GWP or "low"-GWP refrigerants have been around for decades, while others have newly emerged. Since **no official definition of "low"-GWP exists**, some bodies have provided indications on what constitutes "low"; however, the chosen limits tend to contribute to the confusion rather than resolve it.[7]

The best way to analyse the current situation and opt for the best technology solutions is by dividing the applications by sectors, which use a common type of equipment and refrigerants. The main sectors of RAC applications are:

Refrigeration (cold chain for food)

Domestic refrigeration

The **number of domestic refrigerators operating around the globe is in the range of billions.** Even though they have a minimal refrigeration capacity and their refrigerant charge is in the order of tens of grams, such large figures make them an important part of the refrigeration industry. Luckily, **they do not represent a technological challenge:** due to their small refrigerant charge, domestic refrigerators equipped with R-600a (isobutane) are widely accepted and are not considered a safety threat. Trends indicate that **by 2020 around 75 per cent of the domestic refrigerators on the global market will be equipped with R-600a.** The same considerations made for domestic refrigerators apply also to small portable equipment used in rural areas, for example for storing vaccines.

7 Compare selected examples: European Commission sets GWP limit of 150 and 750 for different application areas in the F-gas regulation; preparatory study for the EC (F-Gas Regulation) sets 1-10 "ultra low" and 140-1,400 "moderate;" TEAP report for Montreal Protocol sets 30 as "ultra low," below 100 "very low" and 300-1,000 "medium."

Commercial refrigeration

Commercial refrigeration includes all equipment for the retail sector (shops, supermarkets, small cold stores, etc.). The **technology still relies heavily on high-GWP HFCs (such as HFC-404A)** to be phased down under the KA. At present, the **most promising alternative for the sector is carbon dioxide (CO_2, R-744)**. The physical characteristics of CO_2 make it an effective refrigerant in temperate environments, but it becomes less energy efficient when the equipment is installed in hot climates such as in Africa. However, **R&D efforts in the last decade now allow CO_2 equipped machines to be as energy efficient as the previous generation of HFC machines.** The addition of parallel compressors and ejectors in the working cycle has reduced the thermodynamic losses that originate from operating in hot climates. A drawback linked to the use of CO_2 refrigerant lies in the high operating pressures reached within the cycle (around 90 to 100 bars). This characteristic requires specifically designed components and equipment, and corresponding specific training for the maintenance personnel.

An important subsector for commercial refrigeration is represented by the display units and other self-contained units used, for example, as bottle coolers, food and drink dispensers, ice machines and ice-cream dispensers. This type of equipment, which carries the whole refrigerating unit onboard, used to rely heavily on HFC-134a, but that refrigerant is now being effectively substituted by hydrocarbons (such as HC-600a and HC-290) and also, in some applications, by CO_2.

Transport refrigeration

Terrestrial transport refrigeration for trucks, trailers and shipping containers – mostly used in the food cold chain, and primarily using R134a – still requires a new refrigerant for the future. R&D efforts are concentrated on some HFC/HFO blends, and the use of the natural refrigerants, hydrocarbons (HCs) and CO_2.

Industrial refrigeration

Refrigeration is used in many industries, even if the food industry and oil and gas represent the two sectors where the technology is used on a very large scale. In all cases where appropriate safety measures can be deployed, the **natural refrigerant ammonia (R-717) is the preferred choice.** It has very good thermodynamic characteristics but is toxic and flammable. One good solution in terms of energy efficiency and total environmental impact for those food industry applications requiring low temperatures (down to -40°C) is **cascade systems employing ammonia** for the high temperature segment of the cycle (to be confined in the machine room) and CO_2 for the low temperature segment, which usually is distributed around the factory and requires less stringent safety measures than ammonia.

Air conditioning

Room air conditioning (RAC)

RAC is the sector with the highest expected growth in the coming decades, because the most populated countries are situated in hot climates and increasing numbers of citizens are able to afford AC units in their homes. In the past, HCFC-22 was the refrigerant of choice and is still present in many developing countries. Although the industry in general seemed to be moving towards R410, several manufacturers and stakeholders are currently working on possible low-GWP alternatives for this sector: **HC-290 (propane, which has good thermodynamic properties), HFC-32 (a flammable substance with a medium-GWP), or one of the announced HFC/HFO blends (not yet ready for the market).**

Mobile air conditioning

The automotive industry today supplies cars equipped with mobile air conditioning (MAC) worldwide, making this sector a growing source of concern for environmental protection. The refrigerant used in past decades was HFC-134a, a high-GWP HFC to be phased out. At present the **most promising alternative is a flammable unsaturated HFC, HFO-1234yf.** Not all car manufacturers are happy with this solution, because **R1234yf is much more expensive than HFC-134a, and because there are concerns about whether it is safe** for human health and ecosystems. R&D efforts are devoted to finding **other alternatives, including HCs or CO_2.** The latter could be most suitable, especially in electric vehicles that need MAC not only in summer, but also in winter to supply heating, as the hot water from the engine is no longer available. CO_2 works very well in heat pumps.

Chillers for air conditioning

Chillers produce chilled water used in factories, in large air conditioning plants and in district cooling (DC) plants. The peculiarity of the equipment, and the fact that it can be installed where the general public is not allowed, calls for a number of potential solutions for the future, ranging from **ammonia, to propane, to HFC/HFO blends.** One interesting alternative for chillers, especially if waste heat is available, is the **absorption cycle**, considered one of the not-in-kind (NIK) technologies.

Heat pumps

Heat pumps are a **good alternative to tap water heating** in terms of energy efficiency. They can also **gain market shares as room heating devices**, especially when used in temperate climates, where the same equipment can cool in summer and heat in winter. They are expected to gain market shares also in connection with the **progressive electrification of modern societies. CO_2 and propane** can be a good solution for smaller heat pumps, whereas **ammonia** has been used in industrial-sized equipment.

Technological issues for the implementation of the KA

The widespread adoption of low-GWP alternative refrigerants throughout the different sectors and applications of RAC is dependent on the resolution of a series of technological issues, namely:

Natural refrigerant issues

Natural (or non-synthetic) refrigerants, namely **hydrocarbons (HCs), carbon dioxide (CO_2 or R-744), ammonia (NH_3 or R-717)**, water (H2O, or R-718), and air (R-729) have no or only negligible environmental impact when used as working fluids for RAC. In this sense their application should be promoted as much as possible. However, there are some technological issues linked to their use that are currently addressed in R&D efforts. As a result, natural refrigerants are the **most promising option for important applications such as domestic refrigeration (HC), commercial refrigeration (CO_2 and HC), industrial refrigeration (ammonia and CO_2) and small room air conditioning (HC).** No technological issues exist for their application in such sectors, apart from the safety issues dictated by the fact that **hydrocarbons are flammable, ammonia is toxic, and carbon dioxide needs to operate at high pressures.** In fact, some technological issue may exist for the application of CO_2, since it requires some plant modifications to achieve high energy efficiency. The use of high pressure resistant components makes CO_2 systems more expensive in some applications, whereas others have reached cost parity with HFC systems. This drawback can be overcome when mass production will help reduce costs.

Synthetic refrigerant issues

For those applications where R&D has not been able to overcome the technological issues posed by the use of natural refrigerants, the only possible solution is the use of synthetic refrigerants. However, **synthetic refrigerants with good applicative characteristics and low-GWP are scarce, and very few of them can be used as pure substances.** They must be combined to form blends, and this does not help the matter of simplifying their application. One synthetic pure fluid showing good thermodynamic properties is **HFC-32 (GWP=675).** Its use is proposed for the **room A/C sector but, being a flammable fluid with still a medium GWP, it remains to be seen if it can be more than a temporary solution.** Other synthetic fluids currently being proposed as HFC alternatives are the **unsaturated HFCs ("HFOs"), but no single substance seems to be good enough to be used as a pure fluid.** What can be foreseen is that one or two blends out of the currently high amount of announced substances will be used for those applications where no natural refrigerant or synthetic pure fluid have the right characteristics.

Safety issues

Most of the potential alternatives to currently used refrigerants raise safety issues because they are flammable, toxic or require high pressures to operate. With **flammable refrigerants** (hydrocarbons, some synthetic low-GWP refrigerants) the current charge limits introduced by safety standards prevent their widespread adoption for many application sectors. With mildly flammable refrigerants (HFOs and HFC-32) there is a lack of knowledge about their behaviour and a need for more studies and tests. The safety issues of ammonia and its **toxicity** are under control because they have been well known for many decades. The **high operating pressures** of CO_2 pose few problems and it is well known how to cope with them.

In summary, **flammability is the main concern, which is why all the main international safety standards are currently under review, to align their requirements with technology improvements.** The charge limits will be increased, and the refrigerating capacity of systems equipped with **flammable refrigerants will grow to cover a greater number of applications.** As a consequence, the need for well-trained maintenance personnel able to cope with the increased competence levels required by more demanding technologies will grow.

Fake or unsuitable refrigerants

While this is more of an economic and a social issue than a technological one, it becomes a technological issue when the **misuse of refrigerants undermines the performance of the equipment or introduces further safety issues.** Reference is made mostly to **LPG (Liquid Petroleum Gas)** as a mixture of propane and butane, sold in liquid state in metallic bottles, for cooking and heating purposes. From a pure thermodynamic point of view, LPG can be a suitable refrigerant for many sectors. **When used as a drop-in refrigerant for equipment originally designed for non-flammable refrigerants, it may become a real danger for maintenance people and final users.** Its use is therefore to be absolutely avoided and adequate measures should be taken to prevent this happening.

Energy-related issues

As already mentioned throughout this report, the impact from RAC equipment on climate change is twofold: there is a **direct impact**, due to the emission of GWP fluids into the atmosphere, and there is an **indirect impact**, due to the GHG emissions linked to the production of energy consumed by the RAC equipment to perform its task. The goal of any correct implementation of the KA should be the minimization of the total impact (direct plus indirect), rather than the simple elimination of high-GWP refrigerants.

This impact minimization can be measured using one of the several metrics available in the literature, among them the following described in more detail: **Total Equivalent Warming Impact (TEWI), or Life Cycle Climate Performance (LCCP).**

Total Equivalent Warming Impact (TEWI)

Relatively easy to calculate, TEWI gives first indications of the total environmental impact from RAC equipment. TEWI is defined as follows:

TEWI = GWP coming from direct emissions (refrigerant leakage and maintenance plus refrigerant emissions at end of life) + GWP coming from indirect emissions of CO_2 for the production of energy consumed by the RAC equipment.

It can be calculated adopting the following formula:

$$TEWI = (GWP_{refr} \cdot m \cdot L_{annual} \cdot n) + [GWP_{refr} \cdot m \cdot (1 - \alpha_{recovery})] + (E_{annual} \cdot \beta \cdot n)$$

GWP_{refr}	is the global warming potential of refrigerant, relative to CO_2 ($GWPCO_2$=1)
L_{annual}	leakage rate per annum as a fraction of charge
m	refrigerant charge [kg]
n	system operating years [years]
$\alpha_{recovery}$	recovery/recycling factor, from 0 to 1
E_{annual}	energy consumption per year [kWh]
β	national indirect emission factor [kg of CO_2 per kWh of produced electricity]

The mutual ratio among direct and indirect emissions substantially depends on:

» the GWP of the refrigerant

» the energy efficiency of the equipment (represented by its seasonal coefficient of performance or COP)

» the indirect emission factor, which represents the quantity of GHG emitted by the national power system per unity of electricity produced

The last parameter depends on the type of mix of energy sources (also known as generation mix) a country uses to produce its electricity. As a general conclusion, indirect emissions are always prevalent over direct emissions when fossil fuels are used to generate electricity. On the other hand, when renewables (and/or nuclear) are prevalent in the generation mix, then direct emissions gain a certain relevance and switching from high-GWP to low-GWP refrigerant becomes very important.

Life Cycle Climate Performance (LCCP)

LCCP is a more comprehensive and complete tool than TEWI. It considers GHG emissions (both direct and indirect) related to the whole life cycle of the equipment: not only those released during its operative life but also those related to the construction phase and the decommissioning phase. In other words, LCCP analyses the equipment behaviour "from cradle to grave."

It must be said that, from an observer's point of view, in general the difference between LCCP and TEWI indexes is quite small; the contribution to GHG emissions of the construction and the decommissioning phases is limited to a few per cent of the emissions released during the operative phase. Therefore, in a not especially detailed analysis, using one index or the other introduces only a very small error.

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna International Centre
P.O. Box 300, 1400 Vienna, Austria

Phone: +43 126026 3821
montrealprotocol@unido.org
www.unido.org

Facebook: www.facebook.com/EnvironmentDepartmentUNIDO/
YouTube: www.youtube.com/UNIDObeta

READY, STEADY, GO!

Africa and the Kigali Amendment