5. Lessons learned: best practices and challenges encountered

Armenia

Based on the experience gained, several areas for improvement were identified, particularly with regard to further clarifying the legal status and strengthening the governance model of the Centre. At the moment, the Centre continues to develop its operational capacity.

Burkina Faso

Best practices: the inclusive and participatory approach adopted enabled stronger stakeholder ownership and rapid progress in project implementation; the involvement of professional associations and technical experts facilitated discussions on the future certification system.

Challenges encountered: expenditures related to the construction or renovation of buildings for the centres of excellence are not eligible under the project framework; limited financial resources restrict the acquisition of sufficient maintenance equipment and tools required for the effective operation of the centres.

China

Best practices: integration of hardware and standards, combining cutting-edge laboratories, such as the liquid cooling laboratory for data centres, with immediate standard updates to ensure market relevance; and an anti-commercial-bribery mechanism, having established robust data traceability and integrity systems to ensure impartiality.

Challenges: rapid technology shift, as keeping pace with the transition to low-global-warming-potential refrigerants requires constant capital investment in facility upgrades; and global harmonization, as aligning diverse regional standards across North America, the European Union, and the Middle East remains complex.

Colombia

Among the principal challenges identified, several structural issues merit particular attention. First, ensuring financial sustainability remains a critical concern, as the demand for services provided by the centre is not constant, thereby requiring stable and permanent cash flow to guarantee continuity. Second, the retention of highly qualified personnel poses difficulties, given that professionals often encounter more competitive salary opportunities within the productive sector, which can undermine institutional stability. Third, the innovation component faces limitations, largely due to the characteristics of the region, which is predominantly composed of consumer countries with limited manufacturing capacity; this structural condition, coupled with the complexities associated with patent development, restricts the potential for advancing innovation at the desired scale. Addressing these challenges will be essential to strengthen the long-term viability and impact of the centre.

As a key lesson learned, the importance of establishing clear coordination mechanisms, roles, and responsibilities from the early stages, as well as effective communication channels among the various stakeholders involved, is highlighted. Likewise, coordination among training institutions, ozone units, and international partners will be a key element in strengthening the technical and operational sustainability of the centres, allowing for the optimization of resources, expansion of regional coverage, and a more effective response to the sector's needs.

Ecuador

Best practices: strong partnerships between government, academia, and international organizations have been essential for the successful establishment and operation of the centres, and collaboration among the National Ozone Unit, universities, industry stakeholders, and international partners has enabled the mobilization of technical expertise and resources. Institutionalization within universities has proven critical for long-term sustainability. By embedding training activities within the regular academic and extension programmes of the Escuela Politécnica Nacional (EPN) and the Escuela Superior Politécnica del Litoral (ESPOL), the centres are able to maintain operations beyond the duration of individual projects. Competency-based training approaches have improved the quality and consistency of technical education, and the development of nationally recognized occupational competency profiles for the refrigeration and air-conditioning sector has provided a clear framework for skills development and workforce qualification. Hands-on practical training has been particularly effective in building technician capacities, as access to real equipment, demonstration systems, and practical exercises has significantly improved learning outcomes and the adoption of best practices. Combining training with demonstration activities has facilitated the transfer of knowledge and technologies to technicians, service companies, students, and other stakeholders.

Challenges encountered: ensuring long-term financial sustainability remains a key challenge, as continuous operation, equipment maintenance, laboratory upgrades, and training activities require sustained financial and institutional support. Keeping pace with technological change requires ongoing investment in equipment, training materials, and instructor development, particularly as the sector transitions to low-global-warming-potential and alternative refrigerants. Expanding technical capacities nationwide remains challenging due to the geographical distribution of technicians and the need to reach professionals outside the main urban centres. Limited awareness of refrigerant recovery and regeneration practices among some market actors has highlighted the need for continued outreach and capacity-building efforts. Strengthening linkages between training and industry demand is an ongoing process to ensure that training programmes continue to respond to emerging technologies and market needs.

Jordan

These centres have supported the enforcement of the policy adopted by the Jordanian government, improved the quality of appliances in the market, and ensured fair competition among manufacturers. The establishment of the first accredited laboratories in Jordan and the Middle East has positioned Jordan as a regional leader in the successful enforcement of energy labelling regulations for household appliances, while the Royal Scientific Society's testing laboratories have helped resolve disputes between competing manufacturers and importers, improved product quality in the local market in line with Minimum Energy Performance Standards requirements, and delivered significant benefits to both consumers and the country.

Kenya

Challenges include high-technology equipment requirements, the high cost of energy-efficient equipment, and a limited number of trainers.

Liberia

Key lessons learned from establishing and operating centres of excellence for sustainable cooling and energy efficiency testing in Liberia, as in other developing countries across Africa, relate generally to governance and policy, technical and operational capacity, and financial sustainability.

Mali

Mali is the fourth country in the West Africa and Sahel region with an identified energy savings potential of 11,900 gigawatt-hours for the period 2024–2040, according to a 2024 study report of the African Energy Commission. Electricity distribution network losses average 23 per cent annually overall, compared with a contractual level of 14 per cent. Average annual growth in peak demand is 30 megawatts, driven in large part by the import of waste electrical and electronic equipment, particularly air conditioners and refrigerators. Between 85 and 90 per cent of electricity is consumed in buildings, including in the services, commerce, and residential sectors. The absence of minimum effective building standards, combined with a severe climate causing temperature peaks reaching 50 degrees Celsius, compounds these challenges. National institutional procedures for energy efficiency certification are inadequate, and relevant incentives and specialized national structures are insufficient. An initial project, PASEM (the Projet d'appui au secteur de l'énergie au Mali), was funded by the World Bank, and a process to establish a SUPER ESCO is under way.

Nigeria

Challenges include a lack of trained experts able to effectively operate the software programme for the testing chamber, owing to calibration issues, and a poor power supply to sustain testing operations.

Slovak Republic

The Slovak experience shows that a functioning system of training, examinations, and certification is essential for the effective implementation of obligations related to fluorinated greenhouse gases and the transition towards sustainable cooling. Key lessons learned include:

- Professional competence of technicians and companies is a critical condition for reducing refrigerant emissions and ensuring the safe operation of equipment;
- Regular updating of training content is necessary, especially in view of new European Union legislation, lower-global-warming-potential refrigerants, natural refrigerants, and related safety requirements;
- Cooperation between public authorities, professional associations, and the private sector is important for practical implementation;
- Certification and training systems can also serve as a useful channel for disseminating information on new legal and technical requirements; and
- The transition to alternative refrigerants requires not only legal obligations but also practical training, safety awareness, and sufficient technical capacity in the market.

The main challenges include ensuring that training and certification systems keep pace with rapidly developing European Union requirements, supporting sufficient capacity for technicians across the country, and strengthening expertise related to alternative refrigerants and energy-efficient technologies.

South Africa

Lessons learned: collaboration between government, universities, industry, and international partners; the establishment of demonstration projects accelerates adoption.

Best practice: establish formal partnerships including government (policy and funding), academia (research and training), and industry (deployment and commercialization).

Challenges encountered: duplication of research; weak implementation pathways.

Turkiye

Best practices and lessons learned:

- Existing public testing infrastructure is a strategic foundation. The Turkish Standards Institution's national laboratory infrastructure provides an important basis for standards implementation, product testing, conformity assessment, and certification, and this public infrastructure can support the future development of more structured sustainable cooling testing capacity;
- Distributed capacity provides a useful starting point. Although there is no single national centre of excellence, Türkiye has relevant distributed capacity across the Turkish Standards Institution, public institutions, sectoral organizations, universities, and private-sector laboratories, providing a useful basis for developing a more coordinated sustainable cooling testing ecosystem;
- Private-sector laboratories are important drivers of technical capacity. Export-oriented heating, ventilation, air-conditioning, and refrigeration manufacturers have developed in-house testing and verification facilities to meet product development, customer, certification, and international market requirements, contributing to practical testing know-how; and
- Integration of testing with research, development, and product development is effective. Laboratories are closely linked to research, development, prototype development, product validation, and quality improvement processes, enabling test results to be used directly for product optimization and energy efficiency improvement.

Challenges:

- Human resources and technical capacity. Advanced testing laboratories require qualified engineers, laboratory specialists, technicians, quality managers, and continuous training programmes, and personnel recruitment, retention, and capacity development are critical issues;
- Accreditation and international recognition. Strengthening accreditation, quality management, and international recognition remains important, particularly for testing activities intended to support market surveillance, conformity assessment, export competitiveness, and international certification;
- High investment and operational costs. Establishing and operating advanced testing infrastructure requires significant investment in equipment, calibration, safety systems, skilled personnel, maintenance, and quality management systems, making long-term financial sustainability a central design issue; and
- Coordination among institutions. Responsibilities related to energy efficiency, industry, climate policy, refrigerants, standards, accreditation, vocational education, and market surveillance are distributed across several institutions.

United Kingdom

From a donor perspective, drawing on delivery partner reporting, monitoring and site visits, key lessons include:

- Systems approach and engagement: Delivering sustainable cooling through centres of excellence requires a systems-based approach, addressing multiple interdependent barriers simultaneously (e.g. technical skills, equipment supply, policy frameworks and market demand). An early needs assessment shows that isolated interventions are less effective, and that aligning these components is critical to enabling sustained implementation of the Kigali Amendment. Since ACES has been designed to be a multi-sectoral regional Centre of Excellence, early and consistent engagement across sectoral stakeholders including Government, industry, service users and policy makers has been important to establish functions which can address the variety of actors required to deliver sustainable cold chains in the local context.
- Phased implementation: Establishing centres of excellence has required an initial phase focused on demonstration and validation of delivery models before scaling implementation. Experience shows that refining a reference model and testing approaches in-country is critical to support replicability and effective scale-up across different contexts.
- Replicability through standardised tools: Developing standardised tools, models and operational frameworks (e.g. training materials, SOPs, and system design tools) is critical to enabling replication of centres of excellence in new markets, reducing delivery time and improving consistency of implementation.
- Behavioural factors: Uptake of sustainable cooling solutions can be constrained by behavioural and cultural factors, including perceptions of cold chain technologies. Addressing these through targeted training and awareness-raising is important to support adoption and maximise the impact of centres of excellence.
- Context-appropriate training: Effective capacity building requires training approaches that are adapted to local skill levels and educational contexts. Experience shows that standardised training models may need to be tailored to ensure accessibility and effective knowledge transfer to technicians and end users.
- Community-level delivery models: Centres of excellence can improve effectiveness of sustainable solutions uptake when linked to community-level delivery and business models (e.g. cooperatives and demonstration pilots), which help de-risk adoption, build demand and enable access to finance for sustainable cooling solutions.
- Monitoring and evidence: Establishing robust monitoring, evaluation and learning systems early in programme delivery is essential to track outcomes, test assumptions and demonstrate impact, particularly for first-of-kind approaches.
- Realistic delivery timelines: It has taken over 5 years for the programme to move from early-stage design and development through to sustained roll out of activities. Timelines can be context specific, but are significantly influenced by procurement, contracting and governance arrangements. Experience to date shows that establishing centres in new contexts can be delayed by processes such as equipment procurement, infrastructure development and coordination across delivery partners. This underlines the importance

of delivery realism, supported practically by early-stage risk management, setting realistic timelines and streamlined operational arrangements to ensure delivery can proceed efficiently.

- Building capacity of local delivery teams: Strengthening the capacity of local operational teams to take forward centre activities has been critical to enabling transition towards locally led delivery models. This supports long-term sustainability beyond programme funding, strengthens in-country technical capability, and enables continued implementation of Kigali Amendment requirements through locally embedded expertise.
- Capacity constraints at country level represent a key challenge. Evidence shows that limited technical skills, particularly in installation, servicing and system management, can constrain uptake of cooling technologies. As a result, sustained investment in targeted training and workforce development is essential.
- At the policy level: U4E-led regional harmonisation and national implementation of regulatory frameworks are time-intensive processes requiring sustained engagement. Centres of Excellence could play a key role in bridging these processes, providing ongoing technical support and coordination to enable consistent implementation across countries.
- Host Government Support: Active engagement with Host Governments when designing, developing and deploying a Centre of Excellence has been important to maintain progress within the country context and to establish a centre which can service national needs, as well as those of the region.

Leveraging finance for sustained impact: The role of programme delivery partners in mobilising co-financing and partnerships has strengthened value for money of initial donor investments. Establishing financial self-sustaining approaches (such as blended finance models) to maintain equitable and effective delivery of the Centre of Excellence functions can support sustaining impact.

Zimbabwe

The only major challenge is a lack of financial and technical resources to set up and run centres of excellence and testing centres.