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WALK-IN COLD ROOMS

Solar Appliance Technology Brief

JULY 2021

EFFICIENCY FOR ACCESS COALITION

CONTEXT

This walk-in cold room technology brief is one in a series of insight briefs developed to synthesise the latest market intelligence and chart a pathway to commercialization for a set of off- and weak-grid appropriate appliance and productive use technologies most relevant to catalyzing energy access and achieving Sustainable Development Goals.

The first iteration of the LEIA Technology Summaries was published in 2017 to help the newly established Efficiency for Access Coalition navigate a nascent market. At the time there was limited data and research available on market trends and off/weak-grid appliance performance. This walk-in cold room brief updates and expands on these summaries, bringing together the latest insights on market and technology trends, consumer impacts, and pathways to scale for fans. You can access briefs on all technologies that are a part of this series here.

This brief was developed by CLASP and Energy Saving Trust as part of the Low Energy Inclusive Appliances programme, a flagship programme of the Efficiency for Access Coalition. It is a catalyst for change, accelerating the growth of off-grid appliance markets to boost incomes, reduce carbon emissions, improve quality of life and support sustainable development.

This brief was authored by Ruth Kimani and Nyamolo Abagi of CLASP. We thank Jenny Corry Smith, Yasemin Erboy Ruff and Joanie Coker (CLASP), Chris Beland and Leo Blyth (Energy Saving Trust), Nnaemeka Ikegwuonu (ColdHubs), Ravindra Dolares (Ecozen Solutions) and others for their review and input.

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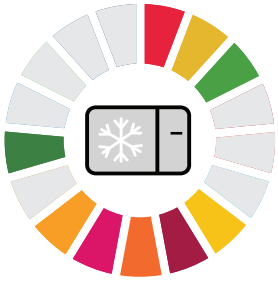
SDG INTERLINKAGES



WALK-IN COLD ROOMS

SDG 1: No Poverty
SDG 2: Zero Hunger
SDG 3: Good Health & Wellbeing
SDG 7: Affordable & Clean Energy
SDG 8: Decent Work & Economic Growth
SDG 9: Industry, Innovation & Infrastructure
SDG 10: Reduced Inequalities
SDG 11: Sustainable Cities & Communities
SDG 13: Climate Action

Introduction

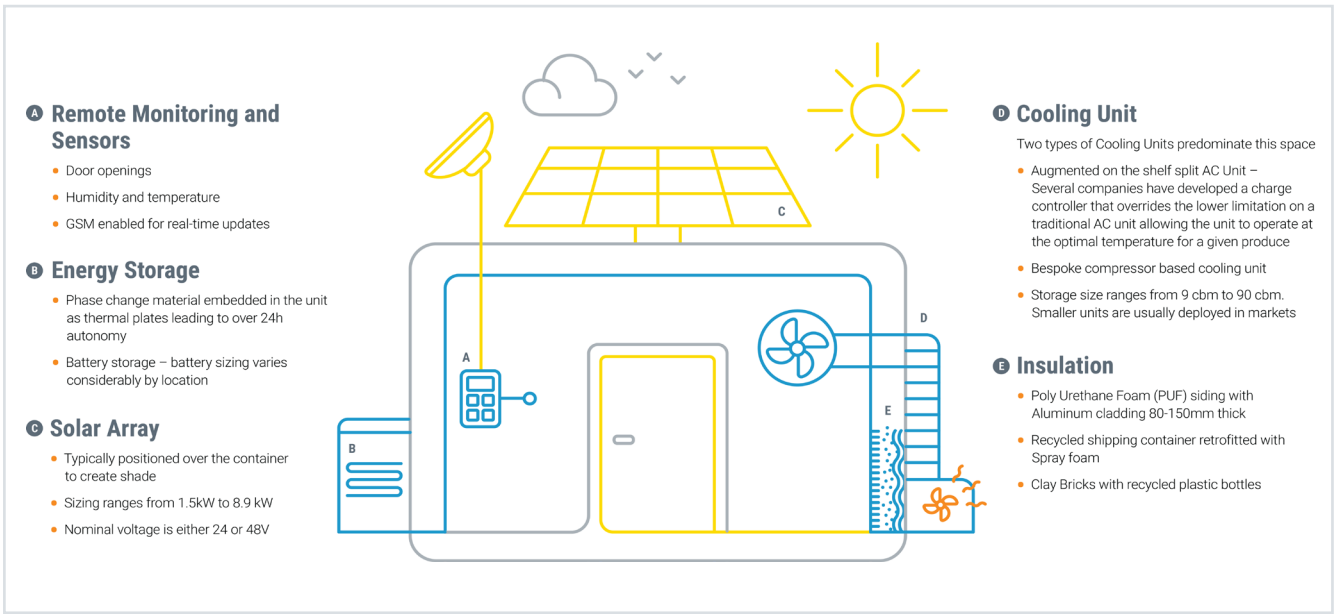
Walk-in cold rooms are a refrigerated space with controlled temperatures. They can be powered from multiple power sources across grid electricity, solar systems, diesel generators. A typical commercial off-grid walk in cold room consists of five components: a solar array, remote monitoring, a battery and/or thermal storage, a cooling unit and insulation materials (Figure 1).

Walk-in cold rooms are an important part of a "cold chain," a term most often used to describe a process of maintaining the temperature of stored produce or vaccines within a given range that maintains quality and safety from the point of origin through the supply/distribution chain to the final consumer. A complete cold chain involves multiple stakeholders, and in the agricultural context this would include farmers, aggregators, transportation companies, warehouses and processing centres. Different technologies are used across the cold chain from post-harvest pre-cooling, pack house technologies, cold storage (e.g., walk-in cold rooms), ripening chamber, refrigerated or 'reefer' vehicles and retail refrigeration (Figure 2).

The scope of this brief is limited to walk-in cold rooms designed for the first mile in agricultural cold chains. The majority of potential off-grid walk-in cold room beneficiaries live in emerging economies and rely heavily on agriculture. In these economies, food loss is estimated to reduce incomes by at least 15% for 470 million smallholder farmers and downstream value chain actors.[1] Establishing cold chains as extensive and reliable as those in industrialised countries would enable developing countries to raise food supply by 15% – about 250 million tonnes.[2]

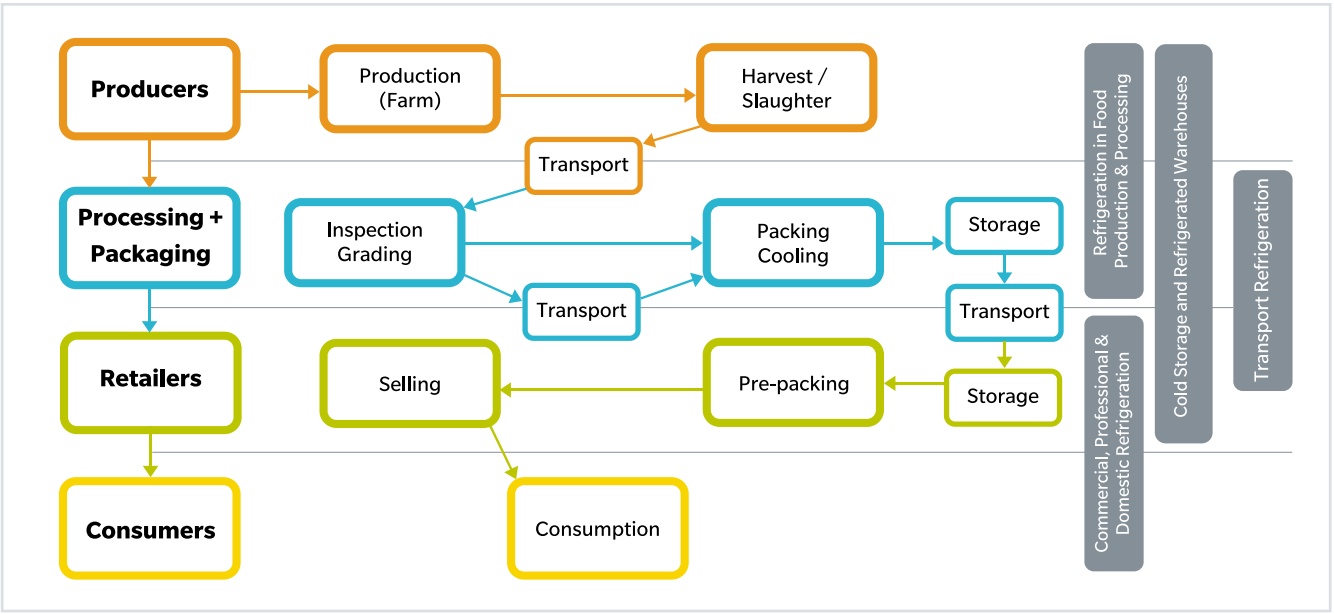
Modern cold room technology is crucial to developing agriculture-based markets and food security. Agricultural cold chains can improve livelihoods for smallholder farmers by reducing post-harvest losses of high-value crops, increasing profits through greater bargaining power at the marketplace, and enabling better commercialisation of agricultural produce in regional and international markets.

Figure 1. Components of Off-Grid Cold Rooms



1. Carbon Trust and Kigali Cooling Efficiency Program, Net Zero Cold Chains for Food. (2020), https://prod-drupal-files.storage.googleapis.com/documents/resource/public/Net_zero_cold_chains_for_food.pdf.
2. IIR, The role of Refrigerator in Worldwide Nutrition: 5th Informatory Note on Food and Refrigeration. (2009), http://www.iifir.org/userfiles/file/publications/notes/NoteFood_05_EN.pdf.

Figure 2. Example of an Agricultural Cold Chain



State of Play

Walk-in cold rooms are a very energy-intensive and expensive technology that requires reliable electricity supply. In emerging markets, this precondition is often not met, and capital and running costs for cooling solutions are generally too high for farmers. As such, the penetration rate of these technologies remains very low. Significant effort is still required to fully develop the market (Figure 3).

Vapour Compression Cycle (VCC) and Vapour Absorption Cycle (VAC) are the primary techniques walk-in cold rooms use to generate refrigeration.[3] VCC, which was invented after VAC, has become more popular due to its ease of operation, size of systems, use of electronic drivers and maintenance.[4] The average operational energy of a conventional VCC-based cooling system is about 2 kilowatt hour per ton-hour (kWh/TR) speaking to their higher efficiency compared to VAC- based system. Recent efforts indicate that continued research and development is needed in above mentioned areas. The use of more energy efficient DC brushless motors in appliances is already an emerging trend.[5]

In terms of insulation, Polyurethane (PUF) is the most common, and more expensive, choice of insulation material for walk-in cold rooms. It is available in varying prices depending on its level of thermal insulation (the lower the thermal transmittance value of PUF, the better-insulated the structure will be, and the higher the cost). To bring down the insulation cost, some innovators utilise PUF with a higher thermal transmittance value and envelope the structure with aluminum cladding to minimise cold losses. Others use more locally available materials like clay bricks and recycled plastics that offer less insulation but are more cost-effective. Vacuum Insulated Panels are another alternative suggested for application. However, our research has not uncovered a clear indicative trend regarding use of this alternative.

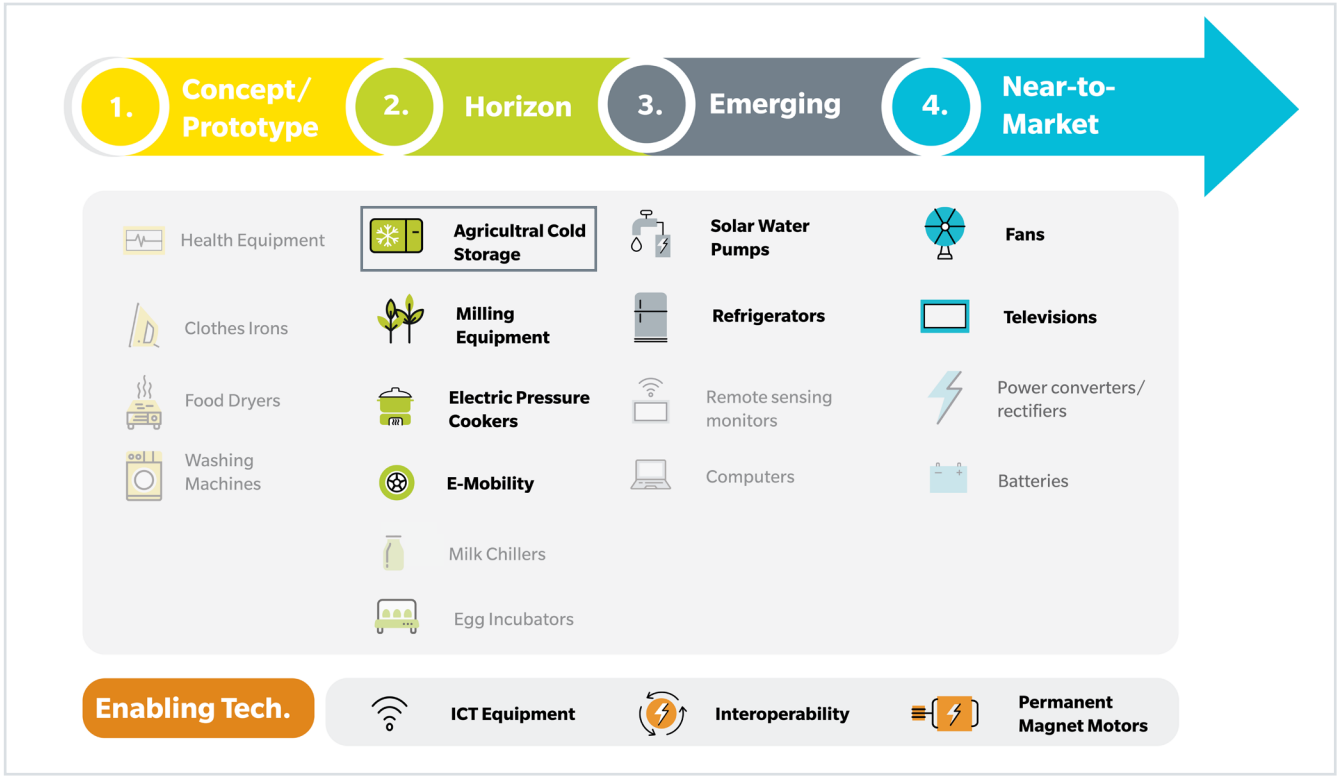
Innovation around energy storage is another focus area. In recent years, progress has been made towards use of the solar direct-drive (SDD) technology, which eliminates the use of the expensive and often problematic energy storage batteries. However, very few walk-in cold rooms using pure SDD technology exist. The use of solar photovoltaic panels in combination with batteries remains fairly common for off- and weak-grid applications, though we are seeing a shift to incorporate phase change materials to enhance system efficiency.

Other efforts to innovate new cold storage technologies focus on alternative sources of energy for cooling and increasing accessibility. For example, tapping into renewable energy sources and developing closed-loop systems such as waste heat recovery within the cold chain itself and adoption of use Internet of Things (IoT). Use of clean energy-efficient technologies in the cold chain holds potential to reduce the carbon impact across the supply chain directly by using cleaner refrigerants, and indirectly by using alternative technologies such as waste heat recovery, concentrated solar thermal, etc.[6]

When selecting a walk-in cold room, it is important to consider ambient temperatures, the level of reliability required and resources available – including skilled labor, capital, electricity and water supply, and drainage and waste disposal options.

3. Shakti Sustainable Energy Foundation and University of Birmingham, Promoting Clean and Energy Efficient Cold Chain in India. (2019), https://shaktifoundation.in/report/promoting-clean-and-energy-efficient-cold-chains-in-india-2/?psec=Mw==#MTEwNTU=.
4. Id.
5. Efficiency for Access, 2021 Appliance Data Trends: Insights on Energy Efficiency, Performance and Pricing for Off-Grid and Weak-Grid Appropriate Appliances. (2021), https://efficiencyforaccess.org/publications/2021-appliance-data-trends.
6. Shakti Sustainable Energy Foundation and University of Birmingham, Promoting Clean and Energy Efficient Cold Chain in India.

Figure 3. Relative Market Maturity of Select Appliances



Market Insights

In both Sub-Saharan Africa and South Asia, solar-powered walk-in cold rooms are a relatively new technology for farmers and other target groups. In Sub-Saharan Africa, farmers typically rely on basic non-mechanical cooling technologies such as charcoal coolers, night air ventilation and brick and mortar storage rooms. A few new companies have emerged in Sub-Saharan Africa that provide off-grid walk-in cold room solutions, including Eco-life, Fresh box (both Finalists in 2019 Global LEAP Off-grid Cold Chain Challenge) and InspiraFarms. InspiraFarms installed over 50 walk-in cold room units, representing 8,000sqm of cold storage and processing space in Kenya, Rwanda and other geographies.[7]

The cold storage market in India is more advanced than that in Sub-Saharan Africa, with a commercial sector most developed on-grid but of growing maturity for weak and off-grid.[8] India already has several commercial outfits locally fabricating walk-in cold room units (e.g., Shakti, Ecozen Solutions, Epack Prefab, Innocool Limited) and several of these companies have sophisticated business models, such as the cooling as a service (CaaS) model and leasing. Deployment of walk-in cold rooms is however, skewed towards single versus multi-commodities and wealthy states versus poor.[9] The majority (83%) of the cold chain market is focused on horticulture/agri-based products, and almost 70% is dedicated just to potato storage.[10]

Our research on the number of walk-in cold room sales and models available in India and Sub-Saharan Africa yielded limited data. Anecdotally, from our experience administering the Global LEAP Off- Grid Cold Chain Challenge, we estimate few product sales – less than 100 units in Sub-Saharan Africa – owing to the high CAPEX costs of these technologies i.e., starting prices from USD 6,000. While India has over 7000 walk-in cold room installations, the majority are on the grid.

Under India's Mission for Integrated Development for Horticulture (Agriculture Ministry) and Pradhan Mantri Krishi Sampada Yojana (Ministry of Food Processing Industries) - financing schemes to set up cold storage in the country - a total of 1,104 cold storage facilities with a 4.834 million ton (MT) capacity (2014-15) and about 208 cold chain and value addition infrastructure facilities with a 0.53 MT capacity (2019) have been created to date.

India's annual production of fruits and vegetables is about 300 million tonnes, which accounts for 18% of all agricultural output. According to estimates from the National Centre for Cold Chain Development (NCCD), there is a shortfall of 12.6 MT of cold storage capacity in India. The Indian cold chain market is projected to grow by 13-15% over the next 5 years.[11] This increase will likely be driven by some key shifts in the market: a) growth of organised food retail, b) increased consumer demand for processed foods, c) shift by farmers from cultivating grains to growing fruits and vegetables (latter requires less risk and investment) and an expected double-digit growth rate of India's vaccine and biopharmaceutical market.[12]

7. Shell Foundation, "The 'Cold Chain' Opportunity: Reducing Postharvest Losses and Increasing Market Access for Rural Farmers,"2019, https://shellfoundation.org/feature_posts/the-cold-chain-opportunity/.
8. Carbon Trust and Kigali Cooling Efficiency Program, Net Zero Cold Chains for Food.
9. Chakraborty, Cold Storage in India: Challenges and Prospects, Vol 2. (2020), https://www.researchgate.net/publication/344441289_Cold_Storage_in_India_Challenges_and_Prospects.
10. Id.
11. Id.
12. Id.

Consumer Impacts

Globally, 1.3 billion tons of food are wasted or lost per year.[13] Post-harvest food loss presents a threat to food security, farmers' livelihoods, and the environment. The CO_2 emissions from global food loss and wastage is estimated to be 4.4 billion tons each year, or between 6-10% of overall human generated greenhouse gas emissions.[14] Most of these emissions are from methane gas generated in landfills as wasted food decomposes.

Walk-in cold rooms offer many benefits that would help achieve a variety of sustainable development goals. Walk-in cold rooms have the potential to significantly improve livelihoods for smallholder farmers and small traders by reducing post-harvest loss of high-value crops, increasing profits through greater bargaining power at the marketplace, and enabling better commercialization of agricultural produce in regional and international markets. For example, 60% of mangos in Kenya are lost post-harvest, 45% of which occur at the farmer level, and 5% at the trader level.[15] No losses occur at the colsolidator level. Reduction in food waste would reduce hunger and improve economic development.

In the health context, cold storage solutions can enable the delivery and storage of vaccines and medicines to the furthest, most marginalised communities. However, off-grid walk-in cold rooms remain prohibitively expensive and inaccessible to a lot of consumers who would greatly benefit from its service, especially in the first mile.

COMPANY SPOTLIGHT

HARNESSING SOLAR FOR NIGERIAN FARMERS

A man of boundless drive and infectious enthusiasm, Nnaemeka Ikegwuonu spent years travelling through rural areas across Nigeria, talking to farmers about the challenges they faced. Now, through his cold storage company ColdHubs, Ikegwuonu helps Nigerian farmers, retailers and wholesalers reduce food spoilage, boost their incomes and ensure that fresh food is available across the country.

ColdHubs' units can store up to three tons of food at between 12 and 16 degrees Celcius, and with their 120mm-thick insulated walls, galvanised steel floors and gasket-sealed doors, they are built for efficiency. They run on a block refrigeration system that draws a kilowatt of energy every hour, but each cooler has enough solar panels and batteries to generate 5.5 kilowatts; the system is oversized, Ikegwuonu explains, to account for any number of cloudy days.

In 2019, ColdHubs was the first-place winner of the Global LEAP Off-Grid Cold Chain Challenge. "We are dreaming very big," says Ikegwuonu. "We want to deploy up to a million cold chain units all across Africa within the coming years, and we know we can achieve it. The need is there and the solution is here."

13. Food and Agriculture Organization of the United Nations, Food Loss and Wastage. (2019), http://www.fao.org/food-loss-and-food-waste/flw-data).
14. Chakraborty, Cold Storage in India: Challenges and Prospects, Vol 2.
15. The Rockefeller Foundation, Reducing Post-harvest Loss through Market-led Approach: Lessons from Smallholder Farmer Sourcing in Kenya's Mango Value Chain & Mozambique's Cassava Value Chain. (2015), https://www2.deloitte.com/content/dam/Deloitte/za/Documents/consumer-business/ZA_FL2_ReducingPHLThroughaMarket-LedApproach.pdf.

Current Success and Remaining Challenges

The off-grid cold chain market in most emerging economies is still in its infancy, with most of the players being small-startup companies facing a variety of challenges associated with introducing new technologies. Despite these challenges, there has been some uptake of of cold storage technologies in the value chain.

Successes

Domestic manufacturing and innovative startups: There is an emerging market of small-scale interventions targeting specific segments of the cold value chain. A new generation of innovative technology providers are actively designing and manufacturing cold storage systems for the distributed energy sector. The first round of the Global LEAP Off-Grid Cold Chain Challende in 2018 attracted submissions from over 27 manufacturing companies specializing in off- and weak-grid cold storage systems, including companies like FreshBox and ColdHubs based locally in Sub-Saharan Africa. India boasts a much larger domestic manufacturing market with products from companies like Ecozen, Shakti Limited and Innocool Limited to mention a few. However, most manufacturers are based in the western economies. Other projects, such as Clean Energy Storage implemented by Powering Agriculture, also provide support to walk-in cold room manufacturers.

Momentum in cold storage technological innovation: The application of modular, prefabricated and mobile components is bringing cost-effective solutions that are sparking growth among producers and agribusinesses. The Efficiency for Access Research and Development Fund is currently supporting four projects focused on developing walk-in cold rooms for the off- and weak-grid markets.[16] Also, cooling equipment is becoming more efficient and less energy intensive, with the possible integration of solar powered systems. Examples of these include InspiraFarms and Ecozen walk-in cold room systems. InspiraFarms also recently secured USD 500,000 loan investment.[17] This includes funding and partnership collaboration with pioneering off-grid solar financier SunFunder, which is introducing an innovative financing mechanism that provides a source of consumer financing to overcome the upfront investment hurdle to unlock latent demand.

Business model innovations: Progress has been made with innovative cold chain business models aimed at increasing affordability and access to more consumers, especially in the first mile. Most countries in Africa lack well-developed cold chain third-party logistics. As such, entrepreneurs and technology providers are starting to explore rental-based and on-demand business models to stabilise fresh produce at source and increase quality throughout the supply chain. Notable is the Cooling as a Service (CaaS) which is a business model whereby the customer pays for cooling on a usage basis rather than purchasing the cooling equipment directly.[18] The Efficiency for Access Research and Development Fund is supporting Equatorial Power on Idjwi Island in DRC to test an innovative business model.[19]

Healthy ecosystems and progressive government interventions: The Indian government is actively working to accelerate the growth of the cold chain market through implementation of several policy instruments and schemes. The National Centre for Cold-chain Development (NCCD), a government-established institute, is promoting and coordinating the cold chain initiatives across government organisations and private industry. The NCCD attracts participation from a wide variety of private and public stakeholders, ranging from research institutions, and regulatory authorities, to trade bodies, individual companies, and farmer associations.[20]

Recently, there has been a marked increase in engagement and discussions on cold chain from a variety of stakeholders who are becoming increasingly cognizant of its importance in agriculture, trade, environment, and health. Initiatives implemented include the green cooling initiative by GIZ, KCEP program, Cool coalition, Efficiency for Access R&D Fund and the Off-Grid Cold Chain Challenge. The African Centre of Excellence for sustainable cooling and cold chain based in Rwanda is the latest initiative reported by the United Nations Environment Programme (UNEP).

16. The four projects supported under Efficiency for Access Research & Development Fund: DGrid Energy, ColdHubs, Solar Cooling Engineering, SVRG.
17. Sunfunder, "New InspiraFarms investment supports agricultural cold chain," 2020, https://www.sunfunder.com/post/new-inspirafarms-investment-supports-agricultural-cold-chain.
18. Kigali Cooling Efficiency Program, Cooling as a Service. (2018), https://www.k-cep.org/wp-content/uploads/2018/07/Cooling-as-a-service-Knowledge-brief-6.7.2018_Final_online_v1.pdf.
19. The Efficiency for Access-funded project: Equatorial Power
20. Sustainable Energy for All, Cooling for All: Cooling solutions for Cold Chains. (2018), https://www.seforall.org/data-and-evidence/cooling-solutions-for-cold-chains.

Challenges

Despite the above successes, there remain many technical, logistical and investment challenges that are hindering mainstream access to this technology:

There is limited data available on the agricultural cold room market potential in Sub-Saharan Africa. Research is needed to get a clear reading on the existing and potential market size for cold storage solutions and their potential impact in emerging economies.

Affordability remains a barrier to adoption in off- and weak-grid markets. Anecdotal evidence from market research in Kenya indicates a) almost zero commercial sales of walk-in cold rooms among first-mile farmers, b) that the majority of walk-in cold rooms distributed at the farmer level are paid for by donor funds (units are currently too expensive for the majority of farmers and farmer groups and, c) larger scale farmers may be a market and could pay for off-grid walk in cold rooms if it was affordable and there were financing options. On the part of innovators, there is need for them to continue experimenting with different materials to find a good balance between efficiency and cost of their technologies.

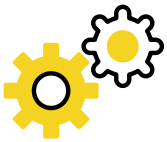
Walk-in cold room solutions are difficult to incorporate into product supply chains. Actors along the supply chain, including farmers, aggregators, transporters, wholesalers, or retailers, have little control over the temperature to which produce is exposed before or after their involvement.[21] To increase cold storage technology usage and penetration, manufacturers in emerging markets need to find creative ways to deliver attractive technology and business solutions that will lead to identifying customers. However, access to finance and support from banking sector is always a challenge to provide consumer financing. Further, even in the face of attractive business models, such as CaaS and leasing, there remains a low level of consumer awareness and the challenge of making these models viable for all commodities.

Walk-in cold room solutions in emerging economies have followed patterns developed with different food system structures, and they tend to be large-scale and built-in bricks-and-mortar.[22] Besides the cost, these facilities are hard to finance due to their depreciation factor and require important energy and transportation infrastructures to be built, making it prohibitively expensive and not often possible in rural areas.

On the other hand, even where walk-in cold rooms are designed for off-grid use, challenges still exist that need to be addressed. For example, limitation to pre-cooling capacity due to solar capacity. While solar capacity can be increased, this also means a corresponding increase in the cost of the technology. There is urgent need for solutions that can effectively reach and serve large numbers of small farmers and agribusiness in the first-mile of distribution, especially in terms of physical access and affordability, by boosting innovation in the sector.

There is a lack of an organised and enabling environment including absence of system wide collaboration, political alignment, enabling policies, as well as viable business and financial models. Although there is growing proliferation of available technologies, more research and value chain support is required to find answers to questions such as how to reach people in more challenging locations and/or with limited access to information, what solutions suit different segments of the population best, most efficient way to aggregate demand, and how to access financing, as well as to make solutions financially within people's reach, the level and type of training, pre-and after-sales services required to name a few.

21. Powering Agriculture, Technology Case Study -Clean Energy Cold Storage. (2016), https://pdf.usaid.gov/pdf_docs/PA00WHC6.pdf.
22. Inspira Health, 2019 Annual Report. (2019), https://www.inspirahealthnetwork.org/sites/default/files/Annual%20Report%202019.pdf.



Scale cold chain technology and business model research

To scale the cold chain market, there is need for sustained support and investment to identify viable walk-in cold room deployment models for both public and private sector approaches across regions. More proofs of concept are needed to identify different technology and business models suitable for diverse crop, culture, financial, geographical, and demographic variables. For example, there is scope to develop multi chamber off grid walk-in cold rooms to have various temperature range and thus store different commodities. On-the-go cooling of commodities using walk-in cold rooms is also another attractive solution.

Foster stakeholder collaboration

For example, creation of a dedicated body to bring together and coordinate activities between the different players in the supply chain which will greatly enhance the efficiency and responsiveness of local cold chains.

Increase financial support for R&D and innovation

More financial investment and support should be directed towards product R&D and enabling technologies e.g., digital platforms and quality monitoring equipment, providing funding for innovative business models that enhance affordability and access especially to producers and end-users in the first mile. Remote diagnostics will be a next level of technological advancement as many walk-in cold room parameters can be controlled remotely.

Build a strong enabling environment

The creation and implementation of policy instruments and schemes among governments could facilitate the uptake of nascent, productive use technologies like cold rooms. This could include: a) organizing capacity building activities to raise awareness among farmers about alternative, affordable and sustainable low-to-no energy cooling options for their fresh produce, b) capacity building programs to create necessary pools of technicians to provide after-sales services for solutions that may require regular maintenance, or which cannot easily be repaired without the right skills and, c) encourage financial institutions to provide financing packages attractive for small businesses and enterprises dedicated to walk- in cold rooms solutions.

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