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ASSESSMENT OF THE COLD CHAIN MARKET IN KENYA

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ACKNOWLEDGEMENTS

Efficiency for Access (EforA) is a global coalition working to promote high-performing appliances that contribute to clean energy access for the world's poorest people; its members have programmes and initiatives spanning 62 countries and 34 key technologies.[i] This report seeks to provide EforA stakeholders with an understanding of the role and potential of the cold chain in enhancing food security, unlocking sustainability, and tackling climate change. It aims to generate awareness and provide information on the cold chain technologies applicable in Kenya across key market segments (fresh fruits & vegetables, dairy, meat, and fish). It also maps the existing ecosystem of cold chain solutions and provides recommendations on how to support the market development of this sector over the next ten years.

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ABBREVIATIONS

3PL	Third-party Logistics
BAU	Business as Usual
BMC	Bulk Milk Coolers
BYD	Build Your Dreams
CaaS	Cooling as a Service
CAGR	Compounded Annual Growth Rate
CAPEX	Capital Expenditure
CCI	Cold Chain Infrastructure
COMESA	Common Market for Eastern and Southern Africa
EPRA	Energy and Petroleum Regulatory Authority
EU	European Union
FAO	Food and Agriculture Organization
FFV	Fresh Fruits and Vegetables
FPEAK	Fresh Produce Exporters Association of Kenya
GAP	Global Agricultural Practices
GCI	Green Cooling Initiative
GDP	Gross Domestic Product
GIZ	Germany Agency for International Cooperation
HFCs	Hydrofluorocarbons
JKIA	Jomo Kenyatta International Airport
KAM	Kenya Association of Manufacturers
KCC	Kenya Creameries Cooperation
KEBS	Kenya Bureau of Standards
KES	Kenyan Shillings
KIRDI	Kenyan Industrial Research and Development Institute
KMC	Kenya Meat Commission
KNBS	Kenya National Bureau of Statistics
KPLC	Kenya Power and Lighting Company
KRA	Kenya Revenue Authority
MEPS	Minimum Energy Performance Standards
MFIs	Microfinance Institutions
NCAP	National Cooling Action Plan
NPAs	Non-Performing Assets
PCM	Phase Change Material
PPP	Public Private Partnership
ROI	Return on Investment
TAM	Total Addressable Market
TM	Total Market
UAE	United Arab Emirates
USD/US$	United States Dollar
VAT	Value Added Tax

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GLOSSARY

Capital Expenditure (CAPEX)	Asset acquisition or asset investment
Cooling as a Service (CaaS)	Payment for cold chain services on a per-use basis depending on the quantity of produce and the number of days stored in a cold chain facility
Total Market (TM)	The total market demand for CCI solutions across different value chains, calculated either from a CAPEX perspective or from a CaaS perspective
Total Addressable Market (TAM)	The segment of the TM that could be realistically serviceable by CCI solutions (based on adoption rate)
Total Obtainable Market (TOM)	The segment of the TAM that could be realistically obtainable by CCI solutions
Business as Usual (BAU)	Estimation of the baseline figures assuming the normal or typical operation of a particular value chain
"As is" market size	Cold chain infrastructure (CCI) market size for 2019, which is the latest historical data available based on FAO's data sets
CCI projected 2030	Projected market size of the CCI by 2030
First mile level	Stage between production at farmgate and the point of aggregation or collection of produce
Hot meat value chain	Meat that is sold and consumed within one to two days post-slaughter and has not gone through any form of cold chain
Third Party Logistics (3PL)	An organisation (a third party) provides logistical services, such as warehousing & storage or transportation, to farmers' collectives or companies in need of cold chain inventory management and distribution
Thermization	Using heat-treatment to destroy pathogenic microorganisms in foods in order to increase their shelf life
Phase Change Material (PCM) /Thermal ice batteries	PCM can absorb or release sufficient energy at phase transition (solid to liquid) to provide cooling. Thermal ice batteries then store this energy, enabling them to operate at normal range for a long time without the need for external power
Build Your Dreams (BYD)	BYD is a Chinese manufacturing company that manufactures batteries, including the lithium-ion batteries that can be used as components of a cold room
Hydrofluorocarbons (HFCs)	HFCs are powerful greenhouse gases that contain fluorine and hydrogen atoms. They are specifically manufactured, unlike other greenhouse gases which are mostly waste or by-products

Kenya's domestic market is more than 56 million people and is considered one of East Africa's core business and logistics hubs. Agriculture is the backbone of Kenya's economy and central to the country's development strategy. It accounts for 31.5% of Kenya's GDP and employs 38% of the population. The World Bank's Kenya Agriculture Sector Risk Assessment report shows that over 75% of the total agricultural production is from smallholder farmers, those with an average farm size of 0.47Ha or approximately 1 acre of land, who account for 70% of maize, 50% of tea, 65% of coffee, and more than 70% of dairy production in the country. Despite this, Kenya remains food insecure. During the 2022 drought, approximately 4 million people faced extreme food shortages. About 40% of food produced in Kenya is wasted from the farm gate to the family table, primarily due to poor post-harvest practices and limited access to ready markets for farm produce. With the growing population and rising demand for food, increased disruptions in global food supply chains and the challenges posed by climate change, Kenya may face extreme food shortage, especially among low-income households and drought-prone areas. Effective Cold Chain Infrastructure (CCI) is a critical intervention that could mitigate many of these challenges.

A cold chain is an environmentally controlled chain of logistics activities that cools and preserves goods (produce or products) within stipulated parameters, including temperature, humidity, atmosphere, and packaging. A well-designed and developed cold chain can prevent food losses and reduce greenhouse gas (GHG) emissions related to food waste. Cold chains also ensure food security by reducing food price inflation, buffering the food supply, and overcoming seasonal shortfalls. This buffering mechanism dampens the price fluctuations that typically put vulnerable communities at risk of poverty and hunger and better supports the growth of farmers' incomes.

This report uses secondary research, modelling and stakeholder consultations to study the fruits and vegetables (FFV), dairy, fish and meat value chains in Kenya and the Cold Chain Infrastructure required. It assesses the gap between the CCI deployed and what is necessary to meet these value chains' CCI needs by 2030. In modelling the market size, a capital expenditure (CAPEX) method was considered, whereby users of CCI technologies purchase the asset upfront.

Agricultural cold chain systems from farm to fork are only in place for a limited number of high-value export crops. Cold chain infrastructure (CCI) in Kenya is vastly underdeveloped; where it exists, it is mostly fractured. Some companies are piloting systems for domestic markets, focusing on fresh fruit and vegetable (FFV) and meat value chains. Still, margins are slim for domestic produce, making financial viability uncertain.

Both on and off-grid storage technologies for agricultural cold chains exist, with the sophistication of the cooling technology increasing further up the value and supply chains. First-mile cooling technologies tend to be more affordable, low-tech technologies such as cold baths and evaporating cooling solutions. Export products use more sophisticated cooling solutions since higher margins mean exporters can afford solutions that provide stable temperature controls, and cold storage is often necessary to meet quality requirements.

Cold storage business models have diversified significantly in the past three to five years; more cold storage product distributors now offer some form of credit and are deploying cold rooms in a broader range of locations (e.g., farm gates, urban markets, safari lodges).

Regulations and policies governing the cold chain sector are limited. In cases where regulation exists, it does not cover all value chains. Additionally, enforcement of these policies remains challenging due to the limited number of certified inspectors/regulators supporting these value chains and the widespread informal markets incentivising disaggregation. Policies governing other sectors, such as renewable energy, also influence the cold chain sector, which can have either positive or negative impacts. For instance, the 2021 reinstatement of VAT exemptions for renewable energy components provided a reprieve to off-grid solar companies. However, there is no assurance that the government will not reimpose VAT at a future date.

The total market opportunity for CCI deployment is estimated at US$2.1 billion in 2030, considering the FFV, Dairy and Fish value chains under a CAPEX market sizing model. The meat value chain is projected to have the most significant deployment opportunity, estimated at US$34 billion by 2030, considering there is currently very limited CCI deployed for this value chain. However, it will require a significant shift in consumer behaviour, attitude and perceptions towards meat consumption.

Cold chain development requires systemic thinking to avoid possible climate-related negative externalities. Renewable energy infrastructure is essential for millions of smallholder farmers who lack access to the reliable grid electricity needed to power CCI technologies. Further, renewable energy supports climate mitigation and adaptation. Climate should be a consideration in CCI in the choice of power, technology choice, refrigerants and their handling. Poor disposal and displacement of refrigerants chemicals are estimated to be the most significant contributor to greenhouse gas emissions in the global food sector, at 89.74 gigatons. Given the high Global Warming Potential (GWP) of refrigerants (often thousands of times more polluting than carbon dioxide (CO^2)), cold chain development must consider and emphasise climate-neutral solutions.

Kenya faces several challenges in growing CCI:

- **Limited technical skills to provide after-sales services.**
- **Affordability**: Cooling interventions add costs for farmers already operating on thin margins. The product must be affordable and add value through its use to make it profitable for the end user. Financial innovation around usage-based payment models such as CaaS, group ownership models, and lease-to-own approaches such as PAYGO can reduce the adoption barrier over time.
- **Consumer awareness**: There is limited awareness, especially among rural smallholder farmers, of the benefits of using cold chain solutions.
- **Market dynamics and maturity**: Most of the food produced in Kenya is consumed domestically, with a significant portion sold through informal channels. For example, over 99% of the meat produced is consumed domestically, while 96% of fruits and vegetables are grown for local consumption (purchased at farmgate or through domestic markets). Unlike export markets, domestic markets generally lack regulations and standards that would necessitate the use of cold chain. Although some players may use cold chain to increase the shelf life of produce, cooling is not mandatory.
- **Lack of investment**: Access to affordable debt and equity for service providers is needed, but the sector is still relatively young, and the financial needs are diverse. More established companies are ready for long-term patient capital and concessional loans. However, there is still a need for grants and programme support for market development activities (e.g., awareness raising, skills training, capacity building, etc.).
- **Weak transportation infrastructure**: Poor road conditions and traffic congestion increase travel time and increase the risk of perishable products becoming damaged and spoiled. In addition, poor roads and infrastructure can damage refrigerated trucks/vehicles, resulting in the leakage of high GWP refrigerants.
- **Inconsistent policies**: Tariff regimes are inconsistent, and agro-based products have a favourable import duty, but it's unclear if this is applicable to all value chains (e.g., meat and fish) and for components. The lack of national standards for energy performance and food quality also inhibits market growth.
- **Availability of equipment and suppliers**: The development of a clean cold chain will have to be preceded by policies that encourage the import of cold-chain equipment in the country by local firms or even incentivise foreign firms to set up subsidiaries. That means that an entire industry will have to be developed or at least nurtured, including local manufacturers being encouraged/incentivised to undertake production.

Kenya's policymakers and entrepreneurs must collaborate to ensure appropriate cold chain development. This report recommends emphasising mainstreaming decentralised first mile CCI, educating farmers to use cold chain technologies, and providing incentives to develop a demand and supply side ecosystem. Some of the other key recommendations of this report are as follows:

Table 1: Recommendations for Various Stakeholder Groups in Kenya's CCI Sector

Stakeholder Group	Recommendations
OEMs CCI Owners Operators	• Strengthen product development, making them low-cost sustainable and farmer-centric • Develop financing and servicing model as value-added services
Government Donors	• Mainstream decentralised CCI at first mile (near farm-gate) • Promote the use of renewable and alternate energy-based CCI solutions • Develop Standards and Labelling programmes for cold chain constituents • Develop the right demand aggregation model for the deployment and utilisation of CCI • Create behavioural change for farmers • Provide incentives for growth of demand and supply side CCI ecosystem • Build capacity and raise awareness of key stakeholders • Drive energy efficiency in new and existing CCI
Financial Institutions	• Develop a long-term warehouse financing product that de-risks the farmer's produce, de-risks the CCI business for operators and helps benefit the small-holder farmers without owning the asset

*OEMs - original equipment manufacturers

Report Overview

1.1. Background and Overview

CLASP engaged PManifold and Intellecap to evaluate and segment the market for cold chain technologies across four value chains (fish, dairy, meat, and fresh fruits & vegetables) in Kenya, India and Nigeria. The term "Cold chain" refers to managing the temperature of perishable products to maintain quality and safety from origination to destination, thereby preventing textual degradation, discolouration, bruising and microbial growth.

This research aimed to identify current trends, barriers, and opportunities for market transformation, as well as strategies to accelerate the adoption of cold chain technologies at scale. The goal was to identify existing cold chain technologies, business models and technical challenges and to quantify the existing cold chain infrastructure and opportunities for improvement. The research consisted of the following:

- Undertaking a value chain analysis of the cold chain ecosystem, with a focus on dairy, meat, fish and fruits & vegetables
- Conducting a feasibility and technology assessment of cold chain solutions, taking into account costs, improvement opportunities, etc.
- Evaluating the existing business models of cold chain innovations and approaches by conducting primary research with off-grid solar refrigeration enterprises
- Examining cold chain policy and regulatory assessment at national and county government levels
- Estimating the market size of off-grid solar refrigeration technologies across the four CCI value chains
- Developing case studies on innovative business and financial models deployed by off-grid solar refrigeration enterprises in Kenya

1.2. Methodology Used to Estimate Cold Chain Infrastructure (CCI) Market Size in Kenya

Data were collected through primary and secondary sources to answer the research questions. The key components of this research were as follows:

- **Secondary research**: An extensive literature review was conducted to understand the state of Kenya's CCI market in Kenya. Based on the findings, a framework was developed for assessing the "as is" market size for CCI in Kenya and the projected 2030 market size. Key stakeholders in the CCI ecosystem were mapped, as was the potential size of the overall market, challenges, and opportunities, among other things.
- **Stakeholder consultations**: Key informant interviews were conducted with stakeholders, and data, insights, and information were collated into a qualitative and quantitative analysis of the challenges, opportunities, and market size of CCI for various value chains. Stakeholder consultations also helped fill data gaps and validate the secondary research findings. The stakeholder groups consulted include investors and development partners who have deployed capital in the sector; enterprises that have developed innovations; consultants who have published research on similar topics; and government agencies that directly or indirectly support the industry. The stakeholder list has been provided in the Annex.
- **Calculate the market size of CCI in Kenya**: The overall market size was triangulated based on quantitative and qualitative data analysis. This allowed the researchers to determine the CCI growth drivers for each value chain and the region's projected 2030 market size potential.

Various market models were developed and analysed to estimate both the current CCI market size and the projected CCI market size by 2030. The framework sought to estimate the dollar value of the CCI market size from a Capital Expenditure (CAPEX) perspective, whereby users of CCI technologies purchase the asset upfront.

The CCI market size was arrived at as described in Figure 1.

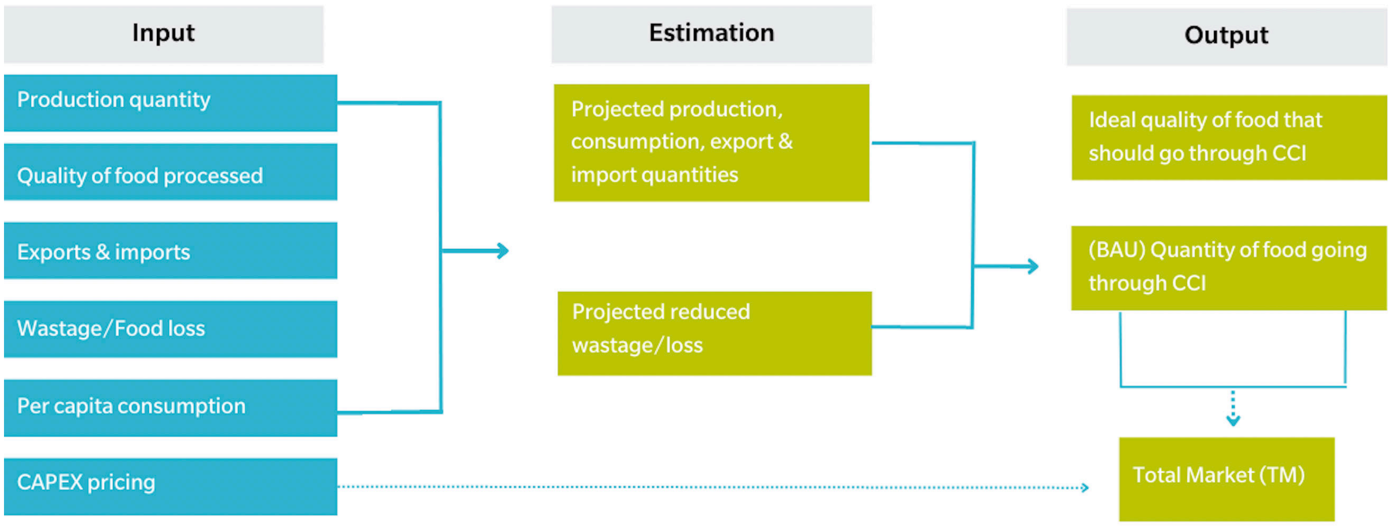
Every value chain is unique, which has been factored into preparing the market models. Some of the key considerations are highlighted below:

• Some of the milk coolers are underutilised at the cooperative level of the dairy value chain. This has been factored into the calculation of the market size.

• Consumption in the dairy value chain includes both human and calf consumption. Calf consumption has been deducted from the total milk produced to estimate the milk eligible for human consumption (and thus cold chain storage).

Please note that assumptions on addressable geographic reach and affordability were not factored in the model, partly informed by a lack of reliable data.

Figure 1. Framework Adopted for Estimating Current and Projected Market Size



1.3. Limitations of the Study in Kenya

The following were some of the limitations identified during project delivery:

- **The absence of a central database for government and private sector agencies**: Kenya, unlike other regions such as India, needs a central repository of data on losses that can be attributed to a lack of CCI across various levels of the value chain. A central database would have helped calculate the CCI market size. To overcome this challenge, data gaps were filled through stakeholder consultations.
- **A limited number of CCI stakeholders in the region**: There are very few CCI stakeholders, and those that exist are primarily in the early stage of operations. Researchers, therefore, adopted a bottom-up approach, spoke to multiple beneficiaries and triangulated data into a framework for assessment.
- **Inconsistency of data across various published sources**: Published reports and data sources differ in their estimations, primarily due to different baseline (year) data points for production, wastage, export quantities, etc. For instance, the KNBS economic survey data, FPEAK, differs from FAO reports. For this reason, only the FAO database was used, which is available across multiple value chains. This ensured consistency across value chains with similar baseline data.

Market Assessment

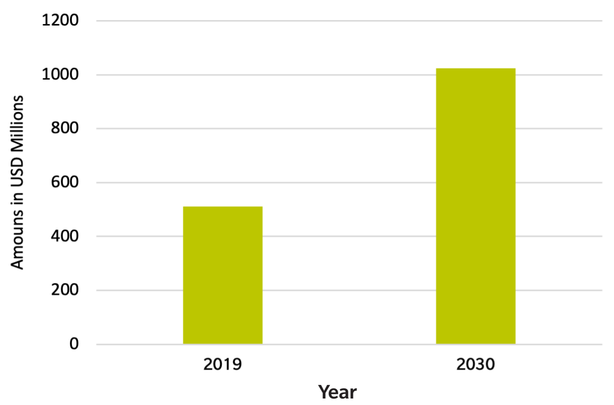
2.1. Cold Chain Infrastructure Market Summary

This report focuses on four value chains for cold chain solutions: fresh fruits & vegetables, dairy, meat, and fish.

For each value chain, the Total Market (TM) is estimated for 2019 and 2030 based on CAPEX market sizing. Assumptions of the portion of the addressable geographic reach and affordability were not considered in this model. This study finds that there will be a total opportunity for CCI deployment worth US$2.1 billion in 2030, considering the FFV, Dairy and Fish value chains. For the meat value chain, CCI deployment has been valued at an estimated US$34 billion by 2030.

Fresh Fruits and Vegetables

Figure 2: Estimated Total Market Size for Fresh Fruit and Vegetables Value Chain

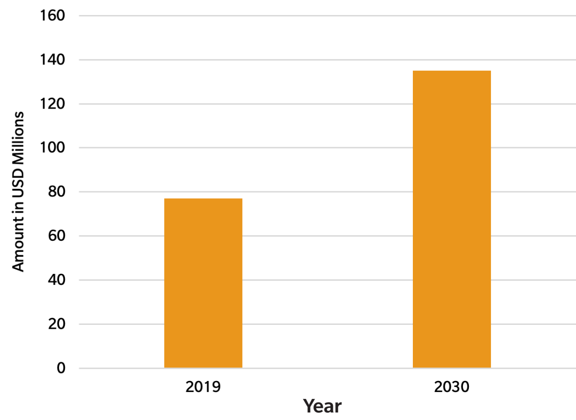


The current CCI market for FFV is estimated at US$511 million and expected to reach approximately US$1 billion by 2030. The CCI market size for FFV at production level assumes that the total production, minus what is wasted at the farm gate, requires cold chain. At the packhouse level, imported produce would be stored along with whatever produce is left after wastage, consumption, and processing. The assumption is that the produce would stay at the packhouse for a day before being exported.

Cold chain infrastructure in the FFV value chain is relatively fragmented. However, it is more elaborate for horticulture, for example, given the need to adhere to the strict quality requirements of target export markets. CCI tends to be concentrated in urban centres nearer to exit ports like airports and shipping ports. Jomo Kenyatta International Airport (JKIA) provides cold chain facilities with temperature controls (-18°C to 2°C), which exporters can use on a pay-per-use basis. Most CCI in the FFV value chain consists of large packhouses with cold storage rooms. In the first mile, rudimentary solutions are used in place of more sophisticated ones, but donor partners have begun piloting CCI solutions that will benefit this segment.

Dairy

Figure 3: Estimated Total Market Size for Dairy Value Chain



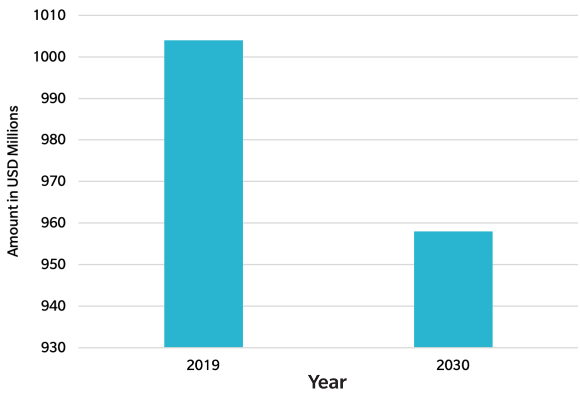
Cold chain in the dairy value chain is relatively more advanced than in other agricultural value chains, as there is more awareness of its benefits. The current CCI market for dairy is estimated at US$77 million and is expected to grow to US$135 million by 2030. In Kenya, the CAGR over the year is only 1%, hence the slow growth.

CCI solutions in the dairy value chain are used mostly at the processing and cooperative levels, where the central and county governments have supported the installation of milk coolers and chillers. Still, some of these assets are underutilised due to (a) a lack of supporting infrastructure and (b) the large informal market. Most of the milk (80%) is sold through informal channels where there are negligible price incentives for chilled milk. The Dairy Industry Act (2021) tried to solve this problem by recommending that chilled milk be sold for KES 2 (~US$0.02) more per litre than un-chilled milk; however, this price difference is negligible for smallholder farmers who produce only seven to nine litres of milk per day, and it has had little impact in the informal market. Institutionalising these prices has the potential to increase the uptake and utilisation of CCI technologies as farmers may try to take advantage of the price incentive.

In the dairy value chain, the production level relies primarily on milk chillers. This technology has the potential to scale since chillers come in portable versions of 50-litre capacity, ideal for smallholder farmers. At the processing level, chillers are much larger (2,500 litres) and are mostly grid reliant. At the transport level, cooling tanks of 200-litre capacity are often used. This allows for aggregation to take place between the farmer and the cooperative and/or processor.

Fish

Figure 4: Estimated Total Market Size for Fish Value Chain

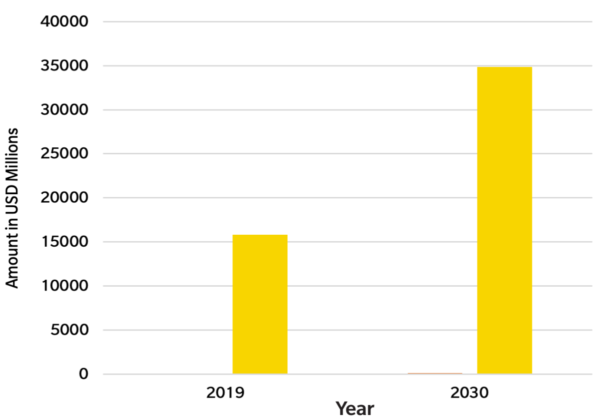


The CCI market size at the production level for the fish value chain presents a considerable opportunity as immediate preservation of fish retains their nutritional value and freshness. The current overall CCI market for fish is estimated at US$1 billion and is expected to decline gradually over time to US$ 958 million by 2030. This is because total fish production has been reducing in Kenya over the years, per the Kenya Economics Survey report.[ii] It is why CAGR projections are negative, leading to negative TM for cold chain in the fish segment.

Different technologies on different levels will likely impact the fish value chain. The CCI solution most used in the fish value chain is simple water-ice storage boxes. The disadvantage of this technology is that it may increase losses when the ice melts inside the box. More sophisticated innovations are being adopted as the fish value chain matures. Ice plants and coolers, for instance, are more likely to penetrate the production and aggregator/trader/transport levels. In contrast, players at the export level would be expected to rely primarily on cold rooms, given the level of sophistication required. However, the market share of these solutions still needs to grow.

Meat

Figure 5: Estimated Total Market Size for Meat Value Chain



The CCI meat market sizing considers beef, camel, pig, chicken, sheep, and rabbit meat, among others. The current CCI market opportunity is estimated at US$15.8 billion and is expected to double by 2030. This is because CCI in the meat value chain is nearly non-existent, with cold chains mainly limited to government abattoirs and premium retail shops (premium butcheries and supermarkets) that distribute meat. This is primarily due to the requirement that a slaughterhouse has freezing and chilling facilities before registration.

The almost non-existent CCI can be attributed to a combination of factors, including; a) Chilling may be delayed in the value chain, a producer can bypass the need for CCI technology if the animal is brought to the slaughterhouse alive, b) the meat value chain in Kenya is mostly a hot meat retail value chain – meat is consumed within two days of slaughter – due in large part to consumer preferences and perceptions.

With observed and expected changes in customer preferences, there is a shift towards embracing cold meat. This is expected to unlock the massive market opportunity that currently remains largely unexplored.

2.2 Drivers for the Uptake of CCI Solutions

Multiple drivers can increase the uptake of cold chain solutions across Kenya's FFV, dairy, meat and fish value chains. These include incentivising users of CCI technologies (farmers, for example) to encourage their utilisation across value chains, increasing stakeholders' interest and participation, and changing buyers' perceptions. The following is a breakdown of the key factors affecting the uptake of CCI solutions:

- **Affordability of solutions**: The first-mile segment is price sensitive, with farmers making buying decisions in the context of limited budgets. Here, financial innovation around usage-based payment models such as CaaS, group ownership models, and lease-to-own approaches such as PAYGO can reduce the adoption barrier over time.
- **Availability/existence of technology and business model solutions**: Availability of the right type of technology is a critical driver of change. The business model on offer should make the trade-offs between one technology and another clear to users, especially when it comes to farm yields, loss reduction and product pricing to the next segment of the value chain.
- **Access to technology and business models**: Technology and business models should not only be available to users but also easily accessible. Accessibility should be coupled with a clear route to market that can extend the reach of a product to various parts of the value chain, based, for example, on partnerships with third-party distributors. Often, ease of access is closely linked to technology adoption, as it reduces customer friction.

- **Enabling policy ecosystems**: Policy can play a role in driving both supply and demand. On the supply side, for instance, an enabling policy could be one that incentivises the import or manufacture of high-quality cold chain products over low-quality ones. Quality factors to be considered include minimum energy performance standards, robustness, optimum temperatures for the respective value chain, minimum warranty, and product lifetime; incentives could take the form of tax breaks or exemptions. On the demand side, technology awareness drives led by county governments, extension officers or other public sector workers can also be a lever of change.
- **Increased familiarity with CCI and awareness of its benefits**: Awareness of the benefits and overall use case of the technology is also a key driver. A well-informed customer can make more grounded, strategic buying decisions. Informed purchases of CCI assets may lead to better utilisation rates. It is more likely to correspond to the user's requirement, thus leading to long-term positive behaviour change. Limited awareness of an asset's benefits may lead to customers slipping back into old habits, underutilising it or using it incorrectly (for example, switching production and using the asset for a different value chain with different temperature requirements).

Specific drivers of technology adoption must also be considered for every stage of the agricultural value chain. The following is a breakdown of the factors that could boost CCI uptake at each of these five stages:

First Mile Level

Increased donor programmes and support: Recently, there has been a push by donor agencies to design and support programmes that raise awareness of CCI technologies at the first mile, as well as improve CCI market intelligence. For instance, GIZ has set up cold rooms near Lake Victoria for fish farmers; the Rockefeller Foundation, through the YieldWise Initiative, provides investment and technical assistance to a few companies; SNV is supporting the market adaptation of various CCI solutions; and USAID's Power Africa (which ended in 2019) supported off-grid technologies in the agricultural sector as part of its Powering Agriculture initiative. Increased funding for this sector should raise awareness of cold chain solutions, which could help to scale up CCI.

High production: Agriculture contributes about 26% of Kenya's GDP, [iv] with the total land available for agriculture estimated at ~27.6 million hectares.[v] The country produced around 6.7 million tonnes of fruits and vegetables, 5.53 million tonnes of milk, 810,000 tonnes of meat and 147,000 tonnes of fish in 2019.[vi] This high level of production provides a huge market opportunity for CCI solutions to increase the shelf life and reduce losses of post-harvest produce.

High post-harvest losses: Post-harvest management has been a major challenge in Kenya's agricultural sector, with estimated losses of 50% of fruits and vegetables at the farmgate level;[vii] 2% of milk annually, post milking; [viii] and 50% of meat post-slaughter.[ix] There is, therefore, a tremendous opportunity for CCI solutions to help reduce such losses.

Aggregation Level

Donor support for farmers at the aggregation level: There are relatively few commercial financiers deploying capital into the CCI sector. They tend to be discouraged by a few factors, including long payback periods for high-CAPEX assets, a low return on investment in an industry with low-profit margins, and forex variability. To fill this gap, donor programmes have emerged to provide the patient capital – such as grants and technical assistance – needed to ensure the growth and sustainability of the sector. The Rockefeller Foundation and GIZ, for example, provide capital support to cooperatives and farmers' collectives to acquire and install CCI assets. Farmers then pay to use these assets or pay for their operating costs. These donor programmes have also been promoting consumer awareness of the benefits of CCI solutions, thanks to which their usage has increased.

Emergence of business models such as Cooling as a Service (CaaS): Due to financing challenges and a lack of credit facilities, many CCI users have been unable to afford the assets themselves. But through innovative payment models like CaaS, they can pay per use or pay based on the quantities of produce they are storing. This is a more affordable option for most users, significantly reducing the burden of acquiring the asset and driving the uptake of cold chain solutions in Kenya.

Retail Level

Urbanisation and consumer patterns: Currently, most Kenyan consumers prefer to purchase perishable produce at farmgate or from nearby markets, considering it to be more "fresh." However, as urbanisation increases and household incomes rise, purchase patterns are shifting; many people unable to buy directly at farmgate now shop in retail stores or supermarkets, where the produce is refrigerated. These changing purchase patterns mean that more retailers are investing in refrigerated display counters to keep their produce fresh, thus driving the uptake of CCI solutions.

Emergence of fast-food chain restaurants:[x] Fast food chains such as Subway, Domino's Pizza and KFC have opened restaurants across Kenya, all using CCI solutions to preserve their food. The growth of such chains, therefore, has the potential to boost the uptake of CCI in the country.

Packhouse and Processing Level

Increased agricultural export demand: Kenya has seen a steady rise in the value of its exports since 2016 (except for a slight decline in 2019), with a total valued at US$11.5 billion in 2019.[xi] The country's primary exports include tea and flowers.[xii] Flowers require cold chain solutions from farmgate to destination country, and a vibrant demand for them has led to advanced cold chain solutions throughout the supply chain. CCI investment in the flower industry may experience a quicker breakeven since fresh flowers enjoy a price premium in European markets, thus incentivising players to purchase cold chain solutions.

Increased food processing: Food processing in Kenya is currently very limited, with over 80% of fruits and vegetables consumed locally and 80% of milk consumed in raw form. But recently, the Kenyan government, as part of its "big four" agenda, has been encouraging manufacturing and the local processing of food. [xiii] It is establishing six agro-processing zones and has identified value addition via processing as a key driver of growth in its ten-year agricultural sector transformation and growth strategy (2019-2029).[xiv] An increase in local food processing and value addition has the potential to boost the use of CCI technologies, as produce will need to be stored at processing centres that will require CCI solutions.

Market Level

Regulation: Although there are limited government policies regulating the CCI sector in Kenya, various stakeholders are supporting the development of a comprehensive guide to increasing the provision of and access to sustainable cooling through the National Cooling Action Plan (NCAP). The Kenya Bureau of Standards (KEBS) has also developed Minimum Energy Performance Standards (MEPS) to which all manufacturers need to adhere, including manufacturers of commercial display refrigerators. There are value-chain-specific cooling regulations, such as requirements for chilling giblets post-slaughter and pricing chilled versus un-chilled milk. However, the enforcement of these policies has been a challenge due to large informal markets and a limited number of certified veterinarians who can perform inspections. If these policies were well-enforced and a comprehensive guide through the NCAP was adopted, this would both improve governance in the sector and increase the uptake of CCI solutions across the country.

Emergence of innovative start-ups: Kenya is home to a few start-ups aiming to address the challenge of post-harvest losses, many of which have adopted innovative pricing and business models. CaaS is one such innovation intended to increase the uptake of CCI solutions, while another involves the use of solar and/or biogas as a power source (particularly for walk-in cold rooms) to make CCI more practical in off-grid areas. Other options under trial include using dry ice to increase the efficiency of cooling boxes and the development of zero-energy cooling chambers. Support for these start-ups would help to boost CCI usage.

2.3 CCI Technology Assessment

Kenya's cold chain infrastructure is still nascent, but the market is growing. Both off-grid and on-grid cold storage technologies are being used in the country, with the sophistication of the cooling technology increasing further up the value and supply chains. At the first mile level, cooling technologies tend to be low-tech solutions such as cold baths or evaporating cooling methods, which keep the price low and address affordability concerns. However, sophisticated cooling technologies are used at the export level since higher margins mean exporters can afford solutions that provide stable temperature controls.

Table 1 outlines the technologies involved in the different CCI solutions.

Table 2: Overview of Cooling Technologies in Kenya

Cooling Technology	Description
Evaporating cooling technologies	**Design**: Evaporating cooling technologies convert liquid water to gas and store heat. When dry air moves across a saturated surface, such as a container full of water, the water molecules absorb heat and change from liquid to gas, cooling the surrounding air and providing a stable storage environment with low temperatures. These technologies are suitable in hot and dry areas with access to water, such as Kenya's coastal, eastern, and northern regions.[xv] **Temperature Range**: Temperature ranges vary; a disadvantage of this technology is the lack of temperature control. However, a study on a specific evaporator cooler in an arid area in Kenya found inside temperatures of the cooler ranged from 1°C -11°C.[xvi] **Advantages**: • Utility in off-grid areas • Cost effective as it is cheaper to assemble **Use Cases**: Charcoal coolers, zero-energy pre-coolers, brick coolers, evaporating coolers
Ice-making	**Design**: Ice can be made based on any cooling technology suitable for freezing. Most applied are either vapour compression systems or absorption cooling, with ammonia-water or lithium bromide-water working pairs.

Cooling Technology	Description
Ice-making	**Water Ice:** Refrigeration through water ice is done by freezing water to lower temperatures to form ice. Water ice is mainly used in cooler boxes. Farmers can access ice through cooperatives with ice makers, using it to cool their produce. Although water ice is cheaper than dry ice, its cooling efficiency reduces when it melts. **Temperature Range:** Below 10°C **Advantages:** • Very cheap (cheaper than dry ice) • Readily available if an ice maker is installed **Dry Ice:** Dry ice technology works through the process of sublimation. Dry ice is manufactured from liquid CO2, and once the dry ice breaks (sublimation), it turns into its gaseous form (CO^2) rather than a liquid, thereby maintaining low temperatures.[xvii] **Temperature Range:** Adjustable temperatures between 8°C to -20°C **Advantages:** • Works without any external power source[xviii] • Provides much lower temperatures than water ice **Use Cases:** Ice boxes
Vapour compression cycle (VCC)	**Design:** Vapour compression technology is Kenya's most widely used cooling technology, using phase change material to provide cooling. It works by circulating the refrigerant through the system, which is alternately compressed and expanded, enabling the state to change from a liquid to a vapour. As the refrigerant changes state, heat is absorbed and expelled by the system, lowering the temperature of the conditioned space. This cooling system can achieve large temperature differentials. **Advantages:** • The temperature at the evaporator can be easily controlled by regulating an expansion valve • Size is small compared to an air refrigeration system for a given refrigeration capacity • The volume of refrigerant circulated is low, so the running cost is low **Use Cases:** cold displays, cold rooms, fridges
Peltier cooling	**Design:** Peltier cooling technology uses DC voltage transfer between two junctions joined by thermocouples. One disadvantage of this technology is that it is difficult to maintain low temperatures (below 10°C), which is problematic for the agriculture sector which requires sub-zero temperatures. One company in Kenya testing Peltier technology is Fosera, who has deployed it for the milk and FFV value chains. However, it has not been used in the meat and fish value chains.[xix] **Temperature Range:** Differential temperatures of up to 28°C with ambient temperatures.[xx] **Advantages:** • Longer shelf life compared to vapour compression as it is less mechanical. • Cooling can be more accurately measured than with a compressor, so these systems can be energy-efficient for small temperature gradients **Use Cases:** Fridges

These technologies have been coupled with various storage methods to ensure more reliable cooling. This is because, since the sun is intermittent, there is a need to store solar energy to power the device at peak hours of usage, especially evenings. Thermal storage, for instance, is used to increase energy storage capacity when the sun is unavailable. Some of these innovations are incorporated into portable devices, with appropriate modifications, to ensure cooling during transportation.

The applicability of these technologies to various value chains has been summarised below:

Table 3: Applicability of Cooling Technologies to Different Value Chains

Cooling Technology	Fruits & Vegetables	Dairy	Fish	Meat
Vapour Compression Cycle (VCC)	High	High	High	High
Evaporative Cooling	High	Medium	Low	Medium
Sorption Cooling	Medium	Medium	Low	Low
Ice Making	Low	Medium	High	High

High	Medium	Low

Below are examples of CCI solutions in Kenya that use the technologies and innovations discussed here:

Table 4: Overview of CCI Solutions Utilized in the Four Agriculture Value Chains in Kenya

Cold Chain Infrastructure Solution	Description	Value Chain	Power Sources	Examples of Companies[1]
Walk-in cold rooms	Fixed or portable cold rooms with a walk-in option. They can be solar, or grid powered. A walk-in cold room's capacity can be customised depending on the customer's needs.	FFV, Meat, Milk	Solar, on-grid	InspiraFarms, FreshBox, Ecozen, BaridiBox, Solar cooling engineering
Off-grid refrigerators	Standalone refrigerators powered by solar or other sources of energy. They can be used for homes, retail shops or commercial centres.	Milk, Meat, Fish, FFV	Solar, on-grid	SureChill, Phocos, SunDanzer, Youmma, Koolboks
Cooling boxes	Variable-sized cooling boxes using dry or water ice and solar-powered technology with a thermal energy battery pack. They are portable.	Fish, FFV	Off-the-grid (dry or water ice), solar	Vakava Technologies, Raino Tech4Impact
Ice machines/Icemakers	Icemakers use solar energy to drive a chemical reaction separating liquid refrigerant from a solid absorbent. The solid absorbent stays in the solar collector, while the liquid refrigerant is stored in the evaporator. Various sizes of icemakers on the market can make different quantities of ice. For instance, the icemaker developed by Save the Food under the ISAAC Solar Icemakers systems can make up to 50 kg of ice on a sunny day, which can chill up to 100 kg of milk.[xxi]	Fish, Milk	Solar, on-grid	SunDanzer, Adili Solar Hubs
Refrigerated trucks/ reefer trucks	Trucks that have temperature controls and insulated lining to maintain cold temperatures. They can be of varied capacities.	FFV, Milk	Battery	Isuzu, Toyota
Biogas-powered milk chiller[2]	A cooling system that uses bio-gas energy to cool produce and can cool milk from 35°C to 7°C within 3.5 hours.[xxii] The chiller's capacity is tailored for smallholder farmers who own between 2-10 cows (there are ~1.2 million such farmers in Kenya).	Milk	Biogas	SimGas[3]

Cold Chain Infrastructure Solution	Description	Value Chain	Power Sources	Examples of Companies[1]
Charcoal /brick/ sand coolers	Charcoal, brick and sand coolers are low-tech solutions that use evaporating cooling technologies. These are often used at farmgate to preserve produce but lack temperature controls.	FFV, Milk	Off-the-grid	N/A
Cold water bath	A low-tech innovation whereby milk cans are wrapped in a wet sack or blanket or stored in a cold-water bath or a hole in the shade. This technology only preserves milk for a short time.	Milk	Off-the-grid	N/A
Cooling boxes	Variable-sized cooling boxes using dry or water ice and solar-powered technology with a thermal energy battery pack. They are portable.	Fish, FFV	Off-the-grid	N/A
Surface milk coolers	Surface coolers are constructed from horizontal stainless-steel pipes attached to a vertical metal plate. Cool water is passed through the pipes, while warm milk is fed onto the vertical plate from a small tank mounted at the top of the unit. The milk cools as it passes over the plate and is collected in milk cans. Since this technology is open to the air, surface coolers are subject to contamination from dust and insects.	Milk	Off-the-grid	N/A
Refrigerated immersion cooler or cooling rings	Immersion cooling rings use pressurised water to cool milk in cans. A perforated tubular ring is placed over the neck of the milk container, and cold (or iced) water is passed through the ring outside the can to cool its contents. A small-scale refrigeration system can be used for immersion cooling with a single-phase power supply. The refrigeration sys-tem is attached to a cooling head and inserted into a can of warm milk or a specially designed insulated stainless-steel container. A refrigerant is passed through the immersion coil to reduce the milk tem-perature. This system often includes a trolley to allow easy transportation of the milk containers.[xxiii]	Milk	Off-the-grid	N/A
Bulk Milk Coolers (BMC)	A two-shelled container consisting of an inner and outer stainless-steel shell with injected polyurethane foam insulation between the two shells. The BMCs have an in-built, lightweight, low-rpm (25–32) agitator; a refrigeration system; an additional milk reception unit; a pumping device; and a generator set.	Milk	On-grid	N/A

1. These are only a few examples of cold chain solution companies and is not an exhaustive list.
2. Although some of these assets are still being utilized by farmers, the company (SimGas) that produced them for the Kenyan market was shut down in 2018 after declaring bankruptcy due to working capital challenges and a lack of product financing.
3. Although some of its assets are still in use, SimGas was closed in 2018.

Cold Chain Infrastructure Solution	Description	Value Chain	Power Sources	Examples of Companies[1]
Bulk Milk Coolers (BMC) contin.	The refrigeration system has a hermetically sealed compressor, controls and safety features that make the BMC extremely reliable and energy efficient. The milk is poured into the reception unit and stored in a BMC where it is cooled to 4°C within 2–3 hours of collection.	Milk	On-grid	N/A
Milk cooling tanks/ chillers	The basic refrigeration system is made up of a refrigerated bulk tank (made of stainless steel), a refrigeration compressor unit and an air-cooled condenser unit. The refrigeration unit can use any of the following technologies: **Ice Bank Tank (IBT)** in which refrigerant gas flows inside copper pipes around the surface of the milk cooling tank, allowing heat transfer from milk to the refrigerant. **Refrigeration Heat Recovery (RHR)** units make a refrigeration system more efficient by collecting heat in the air and using it for water heating, preheating it before it enters a water heater. **Scroll compressors** are 15 to 20% more efficient than traditional reciprocation compressors. They also have fewer moving parts. **Well water precoolers** are heat exchangers using well water to cool milk before it reaches the bulk tank.	Milk	Battery, solar, on-grid	Savannah Circuit Techwin (formerly Finken Holdings), ASL
Portable cooling systems	Portable solar-powered cold rooms and chillers.	Milk, Meat, Fish, FFV	Solar, battery	Dairy Pesa, SunDanzer

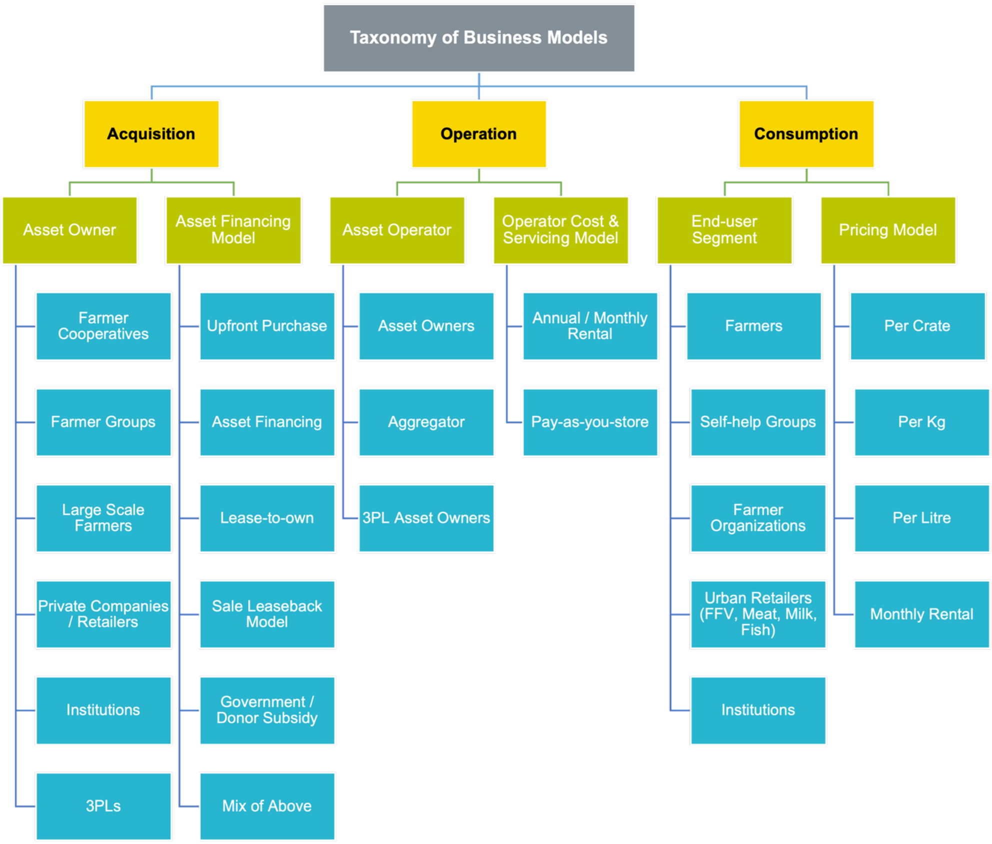
2.4. Business Models and CCI Ownership

Because CCI solutions are considered too expensive for individual use, enterprises and service providers tend to target segments that can afford them. These include farmers' collectives, cooperatives, and large-scale private farms. Innovative pricing models have been adopted to ensure that the assets are commercially affordable at the first mile, including CaaS, lease-to-own and rental models.

Donors have also been able to help last-mile users to acquire some of these assets through subsidised business and ownership models. These include providing grant financing to acquire assets or shifting the maintenance of the asset to farmers' cooperatives.

Figure 6: Examples of Cold Chain Infrastructure Solutions in Kenya

Figure 7: Summary of the Taxonomy of Business Models and Ownership in Kenya



The following section highlights the benefits and challenges of some specific business models used in Kenya. These include sales/upfront purchase, lease-to-own, asset financing, sale and lease back, and rental, as well as CaaS.

2.4.1. Existing Commercial Business and Ownership Models

Direct sales/upfront purchase: Target customers for this model include governments, NGOs and donor agencies with the financial capacity to purchase CCI equipment upfront. A two-to three-ton walk-in cold room (10-11 cubic metres) could cost between US$11,000 and US$30,000, depending on the level of sophistication and customisation required and the installation location.[xxiv] Often, this equipment is donated to a cooperative group by donor agencies or installed in government facilities. Cooperatives acquire innovations such as cool boxes to avoid financial burdens on a single farmer.

The benefits and challenges of this model are summarised below:

Benefit Analysis of Direct Sales/Upfront Purchase Model
Benefits
Limited risks of non-payment and bad debts: Since the price of the asset is paid upfront, it protects the seller from the risks of default or late payment, thus improving a seller's cash management cycle.
Challenges
Cashflow constraint: Users unable to afford to directly purchase a CCI asset upfront often consume savings or take loans, impacting cash flows for other requirements.

Lease-to-own model: Customers targeted in this model include cooperatives, aggregators, large-scale farmers and processors in need of cold solutions but have limited ability to pay. In lease-to-own, customers are required to pay only a small amount of the total cost of the CCI asset upfront, with the remaining balance staggered and spread across a fixed term ranging from 20-24 months.[xxv] After the lease period (once the payment cycle is over), ownership of the asset is transferred to the customer. InspiraFarms offers 12–36-month leases for cold storage rooms, with instalments to be paid every six months after a 20 to 50% down payment.[xxvi] According to the firm, this translates to 10% p.a., which is considered the market rate for the type of customers they target. They also observe that while financing is costly, it allows the customers to benefit from the upside of each unit sold to generate additional revenue in the long term.

Benefit Analysis of the Lease-to-Own Model

Benefits

- **Payment flexibility:** This model provides payment flexibility to the customer and reduces concern about working capital, as customers can negotiate the repayment period based on their ability to pay.
- **Cashflow management**: Since rental costs are usually fixed, it is easier to budget and forecast cashflow.

Challenges

- **More expensive option in the long term:** To cover the risk of default from the buyer, the seller of the asset takes additional capital, meaning that the overall price over the lease tenure is higher than the actual price. This is more expensive for the buyer than purchasing the asset upfront.

Asset financing: In this model, financial institutions finance the acquisition of assets on behalf of customers, and customers then pay back the amount of money borrowed with interest. For instance, SunFunder invested US$500,000 in InspiraFarms as part of a new collaboration on a pioneering asset financing structure to support the rollout of Inspira Farms' units.[xxvii]

Benefit Analysis of the Asset Financing Model

Benefits

- **Limited risk for the financier of the asset:** To limit their risk, financial institutions often partner with enterprises that conduct initial due diligence and ensure asset maintenance, thus improving chances of repayment.

Challenges

- **More expensive option in the long term:** Due to high-interest rates, the overall price of the asset is higher than with other models.

Sale-lease back model: In this model, a financial institution purchases the equipment on behalf of a processor or large-scale farmer and then leases it back to them. This is an asset-backed transaction where an asset is leased to the technology provider for the duration of the contract, offering a more secure form of financing for the finance provider.[xxviii] This model has been implemented in countries such as the United States, Jamaica and the Dominican Republic, and has been earmarked for testing in Sub-Saharan Africa and Asia. An early example of it being adopted in Kenya can be found in negotiations between Grit and Imperial Health Sciences Kenya Limited to set up a distribution facility that comprises pharmaceutical, consumer and cold-chain pallet locations.[xxx]

Benefit Analysis of the Sale-Lease Back Model

Benefits

- **Increase working capital:** a business can gain liquidity tied up in a particular asset by selling it and leasing it back.
- **Eliminate costs associated with traditional loans:** In a sale-lease back model, the asset is acquired by a financier and leased back to the user. All costs related to borrowing, such as interest, are eliminated.

Challenges

- **Change of ownership:** In a sale-lease back model, the ownership of the asset is shifted to the financier purchasing the asset. Thus, the ownership and control of the asset shifts, and this could bring risks if the owner decides to lease it to another stakeholder.

Pay as you store or Cooling as a Service (CaaS): In this model, customers pay a fixed rate for using the CCI facility for a particular weight and time duration rather than purchasing the infrastructure upfront (which is unaffordable for small players). For example, farmers can pay per crate/kg of produce stored in the facility or per litre of milk. Farmers pay about KES 50 (~US$0.5) per crate stored at the first-mile level, each carrying around 30 kg of produce. [xxxi]

Financing in CCI is an issue and even at the cooperative level, it would require a high number of members to form a group to be able to afford the upfront cost of CCI. CaaS reduces this challenge and enables even small players to use the service.

Strathmore Energy Research Centre

Benefit Analysis of the CaaS Model

Benefits

- **Cheaper for the user:** Since there is no need to pay upfront, this option is more affordable for smallholder farmers who pay based on the amount of produce stored.
- **Access to better technologies at a lower price:** This model enables access to modern, efficient cooling technologies that are costlier than traditional products and otherwise unaffordable.

Challenges

Operational challenges: If the CaaS model is implemented at a large scale, it can be difficult for a supplier to enforce large numbers of CaaS contracts, particularly if they are enforcing it themselves rather than through a third party.

Rental models: Rental models exist in Kenya in which users pay either (a) a flat rental fee per annum or month or (b) a rental fee per kg of produce stored per day (like the CaaS model). For instance, Soko Fresh provides cold chain services for a flat rental fee per cold storage per day (through which the company earns approximately US$8,800 per cold storage per year), plus a rental fee per kg stored per day (which earns them approximately US$15,000 per cold storage per year).[xxxii] To incentivise users, Soko Fresh complements their service by providing market linkages and data analytics.

Benefit Analysis of the Rental Model

Benefits

- **Cheaper model:** Since the user of the asset only pays for the period the asset is rented, this is a relatively cheap model. Further, maintenance of the asset is done by the asset owner, making it more efficient.
- **Access to more sophisticated technology**: Users have access to more sophisticated technology, since it is cheaper to rent than to buy the asset.
- **More expensive option in the long term:** To cover the risk of default from the buyer, the seller of the asset takes additional capital, meaning that the overall price over the lease tenure is higher than the actual price. This is more expensive for the buyer than purchasing the asset upfront.

Challenges

- **Contractual obligations:** Since the asset is rented for a fixed period, the user of the asset may still have to pay the rent during times of low production.

Third-party logistics (3PL): This model has been identified as a critical growth driver in any country's scaling of CCI solutions.[xxxiii] Through 3PL, importers or exporters requiring cold chain services outsource these to third-party companies, which provide cold chain services throughout the supply chain. This model is largely underdeveloped in Kenya; few companies provide such services due to the high capital requirements of setting up a 3PL cold chain company. 3PL cold chain companies that do operate in Kenya include Big Cold and Southern Shipping Services Ltd (SSL)/Alpha Group.

3PL is nascent in East Africa because there is not enough production to justify the creation of 3PL, especially with the huge investment required to develop 3PL mechanisms.

BrightHouse Consulting

Benefit Analysis of the 3PL Model

Benefits

- **Utilises sophisticated technology and technical experts**: 3PL companies usually use sophisticated technology during storage and transportation and employ technical experts within their teams. Users can take advantage of this to fulfill their cold chain needs in the most efficient way.

Challenges

- **Limited trust in the model**: By using 3PL companies, farmers/traders lose some sense of control over the stored produce being transported. They have to trust that the 3PL company is able to deliver the service to their customers' satisfaction.

2.4.2. Existing Subsidised Models

- **Grant financing**: Donors, foundations and other development partners provide grants or patient capital for users to acquire cold chain assets to help offset high upfront costs. One example is USAID's Powering Agriculture programme, through which various companies received grant financing for their cold chain solutions. Through its YieldWise Initiative, the Rockefeller Foundation makes strategic investments to streamline the supply chain from farm to market, including cold chain technology. Besides financing, donors also provide technical assistance to manufacturers of CCI solutions to ensure they become sustainable. Others are supporting the introduction of some of these technologies into the market and working to increase consumer awareness of CCI. For instance, SNV worked with SimGas to introduce the first biogas-powered milk chiller for smallholder dairy farmers in Kenya (this programme closed in 2018).[xxxiv]

- **Results-based financing (RBF) facilities**: Donors use this model to support the sector and ensure that users of CCI solutions can realise their full potential. For example, to offset the high upfront costs of acquiring refrigerated units, Global LEAP, implemented through the Efficiency for Access Coalition and managed by CLASP, provided RBF incentives in Kenya, Tanzania, Rwanda and Uganda for the acquisition and utilisation of PAYG refrigerated units.[xxxv] Note that this support has only been available for standalone refrigerator/freezer units, not walk-in cold rooms or other CCI technologies.

CASE STUDY

Fresh Box

CCI Element: Solar-powered walk-in cold storage room

Company Information

Website: www.freshbox.co.ke
Country of Operations: Kenya
Year of Registration: 2018
Agriculture Value Chain: Fruits & Vegetables.

FreshBox designs, manufactures, and distributes solar-powered cold storage solutions across the food supply chain. They have installed over 27 units across East Africa and Somalia, each customised on the temperature requirements of their customers. FreshBox initially started with commercial refrigeration, but they have since modified their products to make them more energy efficient by adopting phase change material (PCM) and thermal cooling technology. These technologies are cheaper than the gel the company used previously. FreshBox's target customers include small scale farmers, farm produce organisations, aggregators, retailers, and market vendors.

Although the majority of FreshBox's customers are in the FFV value chain, the company has started distributing their units to buyers in the dairy, meat, and fish value chains as well. Adoption of the units is higher in FFV, driven by the large quantities of produce in the value chain.

Product Specification

- **AC/DC:** DC
- **Voltage range:** 12/24
- **Production cost:** US$8,200
- **Storage capacity:** 2 - 4 tonnes of fruits and vegetables
- **Operating temperature:** 0°C - 10°C
- **Power (energy consumption):** 2 - 4kWh (per day)
- **Product dimensions:** 2.2*2*2.5m (11 cubic metres)
- **Capacity of PV modules required:** 1,000W-1500W
- **PAYG integration capabilities:** Available
- **Selling price:** US$11,480 -12,300. This is dependent on a number of variables, including the location where the units will be installed.

Revenue Models

Driven by the demand for more flexible payment terms from users, the company has adopted a few different pricing models. These are described below:

a) **Lease-to-own**: About 55% of customers use this model. FreshBox leases cold rooms, then transfers ownership of these assets to the buyer once payment is complete. This model has been adopted mostly by farmer producer groups and cooperatives who in turn sell cold chain as a service to individual farmers, thereby earning enough to pay for the asset. The payment term is usually 12 months from the date of purchase, but this can be negotiated.

b) **Rental model**: About 15% of customers use this model. FreshBox rents out space within a cold room to farmers and retailers, who pay the company directly based on one of the following subscription models:

(i) Per-use basis

FreshBox charges farmers/retailers by the number of crates they store in the cold room and how many days they have been stored for. The company designed this model to give users with limited means some payment flexibility, while still providing access to the technology. Initially, FreshBox charged about KES 70 cents (US$0.007) per crate per day. The company found this model difficult to enforce, however, given the number of CaaS contracts it had with users and the challenges of collecting revenue from so many different sources. FreshBox is thus shifting towards a fixed monthly rental model.

(ii) Fixed monthly terms

FreshBox sees more potential in this model, which is easier from an operational and revenue collection perspective. It was developed in early 2021, and the company is planning to adopt it as their main business model. The baseline monthly rental prices are as follows:

	Product 1	Product 2	Product 3
Capacity in tonnes	0.5 tonnes	1.5 tonnes	3 tonnes
Capacity in crates	~20 crates	~50 crates	~100 crates
Rental fee (in months)	Up to US$300	Up to US$450	Up to US$550

CASE STUDY

c) **Upfront purchase**: About 30% of FreshBox customers use this model. FreshBox units are sold to NGOs and development partners who can afford to pay upfront. These organisations then make the technology available to farmers who pay for CaaS, and the revenue is used to maintain the asset. Upfront sales provide the company with better margins since there is no need to manage the day-to-day operations of the asset post sale.

Figure 8: Examples of FreshBox Units

CASE STUDY

Tree_Sea.mals

CCI Element: Off-the-grid solar-powered walk-in cold rooms

Company Information

Website: www.treeseamals.org
Country of Operations: Kenya
Year of Registration: 2018
Agriculture Value Chain: Meat

Tree_Sea.mals designs and manufactures solar-powered cold rooms to solve the challenge of post-slaughter meat loss. These losses reduce butchers' revenue by three-fold (instead of selling meat at KES 300 (US$3) per kg, meat is sold at KES 100 (US$1) per kg).[xxxvi] The company's product portfolio includes 10Ft (Nanos), 20Ft (Minis) and 40Ft (Mega) chillers. They have established a unit at the "Burma" market in Nairobi, with a business model based on delivering communal refrigeration in densely populated urban areas. Target customers include meat vendors who supply to butcheries and agribusiness institutions exporting meat that must be chilled before selling.

Product Specification

- **AC/DC:** DC coupled with AC output
- **Voltage range:** 240Vac, single phase
- **Production cost:** KES 3.3 million (~US$33,000)
- **Storage capacity:** 4 tonnes of meat
- **Operating temperature:** 0°C - 5°C
- **Power (energy consumption):** 3.5kW
- **Product dimensions:** 6*2*2m (24 cubic metres)
- **Capacity of PV modules required:** 4.7kW
- **PAYG integration capabilities:** Available
- **Selling price:** KES 3.8 million (~US$38,000)

Revenue Models

Driven by the demand for more flexible payment terms from users, the company has adopted a few different pricing models. These are described below:

a) **Cooling as a Service (CaaS):** The company adopted this model because retailers – their primary customers – considered it more affordable and were willing to pay for the service. Tree_Sea.mals charges KES 10 (~US$0.1) per kg per day to access the communal refrigeration spaces. The company sees potential in this model because, in a nascent market, more users are willing to pay for CaaS rather than purchase a unit themselves.

b) **Lease-to-own model:** In this model, a large private firm or agribusiness processor buys a unit on a lease-to-own basis, with the asset's cost paid off over 24 – 48 months (repayment terms are negotiable).

Figure 9: Examples of a Tree_Sea.mals Unit (Baridi Project)

Image credit: Baridi website

2.5. Existing CCI Policies/Regulations

Very few government policies drive the CCI sector in Kenya, with most policy guidelines covering cold chain within the healthcare context only. For example, the Kenya National Policy on Immunization (2013) regulates the maintenance, distribution, and use of cold chain technologies for vaccines. The Ministry of Health has also developed a comprehensive multi-year plan (2015-2019) to address some gaps in cold chain inventory assessments.[xxxvii] These efforts can offer lessons for other sectors, including agriculture.

Table 5: Illustrative CCI Policies in the Healthcare Sector[xxxviii] and Lessons for the Agriculture Sector

Healthcare Policy Aspect	Description	Lessons for the Agriculture Sector
Cold Chain Maintenance	Maintenance of cold chain applications ensures vaccine potency during patient use. The following parameters gauge the respective cold chain's efficiency: (a) assessment of the integrity of the Vaccine Vial Monitors (VVMs) on each vaccine vial; (b) temperature recordings of the vaccine refrigerator, taken at least twice daily; (c) verification of thermometer readings of the vaccine refrigerator; and (d) provision and availability of alternative energy sources for the vaccine refrigerator (i.e., extra-full gas cylinder or standby generator).	Frequent maintenance of cold chain assets in the agriculture sector should be done at specified times and described in a comprehensive guide. There is a need to build technical expertise in the agriculture sector to provide for maintenance and after-sales services.
Cold Chain Administration	The Division of Vaccines & Immunisation is responsible for supplying public health facilities with adequate and fit-for-purpose vaccine refrigerators using the known workloads of the facilities as a benchmark. Requisitions for vaccine refrigerators and other cold chain equipment from individual health centres are done through the respective District/County Medical Officers of Health, who in turn provide a summary request to the Head of the Division of Vaccines & Immunisation.	There should be a body (other than KEBS) under the Ministry of Agriculture at the national and county government level to ensure that the agriculture sector's cold chain is streamlined and policies are well implemented.
Cold Chain Replacement	Vaccine refrigerators and other cold chain equipment should be replaced after ten years. This is to prevent any loss of potency of vaccines stored inside due to wear and tear of rubber seals, hinges, etc.	There is a need for dedicated mention of replacement and after-sales service to maintain the quality of CCI solutions in the agriculture sector.
Cold Chain Requirements	The policy states the government's intention to adhere to the Montreal and Kyoto Protocols, necessitating that all cold chain equipment be CFC-free. All cold chain equipment should be able to maintain a vaccine temperature range of +2°C to +8°C, with a holdover period of not less than four hours for refrigerators and 17 hours for freezers.	Comprehensive cold chain policies should be developed specifically for the agriculture sector, including de-fined temperature requirements and timelines for refrigeration. These policies should be implemented to ensure that the benefits of cold chain are available to the first mile.

In the agriculture sector value chain, Kenya's CCI policies and regulations are driven by the requirements of the export market. Although specific policies exist in some value chains, implementation still poses a challenge. Some of these value chain-specific policies include:

- **Dairy value chain-related regulations**: CCI in the dairy value chain is more established and better regulated than in other value chains. The Dairy Industry Regulations (2018) prohibit the sale of raw milk and mandate that milk is cooled to between 4°C - 7°C within two hours of milking. All pasteurised dairy products, except those to be cultured, must be cooled to 7°C or less immediately before filling or packaging in approved equipment unless drying begins immediately after condensing.[xxxix] Implementing these policies, especially at the first mile, is still challenging; most milk is still marketed through informal channels in Kenya, and farmers are not incentivised to take their milk through cold chains. In response to public demand, the Dairy Industry Act (2021) later permitted the sale of raw milk by producers if it met the relevant standards of raw milk.[xl]
- **Meat value chain-related regulations**: The Meat Control Act provides cold chain regulations for the purposes of meat preservation. It states that after preparation of the meat carcass, there should be no delay in cooling it to an internal body temperature of 4°C or lower and that giblets should be chilled to 4°C or lower within two hours of the time they are removed. It goes on to state that meat should be transported in insulated carriers that allow the temperature of the meat to rise by no more than 1°C per hour.[xli] However, since the meat value chain in Kenya is largely a hot meat value chain, most of these policies are only implemented by registered private and government abattoirs.

Other policies affect the renewable energy sector and, by extension, the CCI sector, specifically technologies that use renewable energy as a source of power. These policies include:

- **The Value Added Tax (VAT) Exemption Act**: This was reinstated in July 2021 and mandates that VAT be exempt for the specialised equipment used for the development and generation of solar and wind energy, including photovoltaic modules, direct current charge controllers, direct current inverters and deep cycle batteries that use or store solar power.[xlii] Due to VAT exemptions, the production cost of CCI assets that use solar power is projected to decrease.
- **The Kigali amendment**: The Kigali amendment to the Montreal Protocol is an international agreement signed in January 2019. This amendment mandates cuts in the production and use of hydrofluorocarbons (HFCs), intending to achieve over 80% reduction in HFC consumption by 2047.[xliii] Kenya is one of the countries bound by this treaty. This not only provides an opportunity to improve energy efficiency in the cooling sector and increase climate gains by replacing HFCs, but it also allows for the sustainable expansion of cold chain in developing countries.[xliv]
- **KEBS regulations**: The Kenya Bureau of Standards (KEBS) has developed Minimum Energy Performance Standards (MEPS) that provide guidance on the minimum energy efficiency to which all manufacturers must adhere. Some of these standards cover commercial display refrigerators.

Creating an ecosystem of supportive regulations requires the involvement of stakeholders – including asset providers, asset users, retailers, export associations, government bodies, financial institutions, and donors – who have recently supported technical working groups on policy development. Ongoing efforts by stakeholders like CLASP, the Kenyan Industrial Research and Development Institute (KIRDI), GIZ Green Cooling Initiative, the Ministry of Environment and Forestry, the Energy and Petroleum Regulatory Authority (EPRA), Kenya Power and Lighting Company (KPLC), the Ministry of Agriculture, the Kenya Association of Manufacturers (KAM), the Ministry of Energy and the Kenya Bureau of Standards (KEBS) may eventually result in the development of a National Cooling Action Plan (NCAP), a comprehensive guide to increasing access to sustainable cooling for all Kenyans. NCAPs have been implemented in countries such as China, India, and Rwanda, where the focus has been on improving energy efficiency and increasing demand for green and energy-efficient cooling products.[xlv] Implementing NCAP in Kenya can open new markets, thereby increasing the need for comprehensive policies to govern the sector.

2.6. Challenges that Inhibit the Uptake of CCI Solutions

Several factors inhibit the adoption of CCI technologies on the side of both users and manufacturers. These challenges are as follows:

- **Financing challenges**: Financing is challenging for enterprises/service providers and consumers/beneficiaries. Limited financing is available to enterprises creating and providing CCI, as well as to end consumers looking to acquire these technologies.
- **Technological challenges**: While technological innovation has been seen in the CCI sector, several challenges still exist. These include the availability of technicians required to manage installation and after-sales services, both critical to adopting new technologies. Meanwhile, poor-quality products negatively impact how customers view the entire sector, while limited local manufacturing capacity hinders local job creation and leads to import substitution.
- **Market and operational challenges**: These include policy gaps regarding supply-side and demand-side incentives at the national and county levels. The immaturity of the market limits economies of scale regarding sector consolidation, bulk procurement, and the ability of individual companies to absorb commercial funding. As a result, most value chains remain primarily informal.
- **User challenges**: The most common user-related challenge is limited familiarity with CCI solutions, including key product features like energy efficiency, usage and maintenance, and temperature control. Since most smallholder farmers are rain-dependent, the seasonality of their produce also impacts the utilisation rates of CCI assets, especially those using CaaS models. This has long-term impacts on technology providers' margins, leading to more extended payback periods.

2.6.1. Financing Challenges

There are very few capital providers in the sector due mainly to the following factors:

- **Long payback periods and delayed returns on investment**: CCI technologies take a long time to become commercially viable (relative to other technology innovations) and subsequently provide delayed returns to potential investors. Thus, the sector appears unattractive to short-term commercial investors who want to see returns within five to seven years. Since the target market for CCI solutions is smallholder farmers, the price point must also be attractive to incentivise uptake. But at this price point (usually about US$0.5 per crate), profit margins are negligible compared to the operational sophistication and costs required to maintain a CCI asset. This disincentivises commercial funders from deploying capital into the sector, which they see as not commercially viable. Financiers deploying patient capital, including donors and development partners, are more suitable to finance CCI technologies in Kenya.

- **Operational challenges of enforcing innovative models like CaaS**: Manufacturers adopting a CaaS pricing model often face operational challenges in enforcing their contracts with farmers or traders, especially due to the risk of a payment default. This becomes especially difficult if the supplier of the asset is offering the CaaS directly rather than through a third party. The result is high rates of non-performing assets (NPAs) for manufacturers, further impacting their ability to attract investment or support from financial institutions.

- **Forex variability**: Foreign investors prefer to deploy capital in Kenya in USD or Euros, which enjoy more forex stability than KES. However, this can be problematic for investee companies (especially for debt investments) since they might find their debts appreciating by 5 to 10% per annum.[xlvi] Hedging options that could reduce forex risk are usually expensive. This forex variability, therefore, affects payback and inhibits capital deployment into the sector.

- **High-interest rates of debt facilities**: High-interest rates on debt (+4% above the central bank rate, which currently stands at 10%) restrict debt investment from banks. Credit terms also tend to be inhibitive, especially for asset financing. Enterprises that have adopted a lease-to-own pricing model need low-cost debt since their cash is sometimes tied up with customers, and the manufacture or assembly of new CCI solutions involves a cash crunch. Financial institutions' inability to provide affordable working capital loans is a significant constraint to scale.

- **Obsolescence of the asset before payback**: Acquiring a cold chain asset requires a considerable investment, and the payback period tends to be long, especially for the target market. But with new technologies emerging frequently, there is also a risk that when the initial investment in a cold chain asset is paid back, the asset itself may already be obsolete. A CCI asset's depreciation may also lead to obsolescence over a long payback period. This, coupled with a lack of technical experts to provide after-sales service to ensure efficiency, further dissuades financiers from deploying capital into the sector.

- **Low usage rates of the assets**: Farmers have traditionally used rudimentary storage methods to increase the shelf life of their produce. The usage and acceptance of sophisticated technology is still relatively low, which results in low revenues from modern CCI assets. These may not be enough to pay back the initial investment, disincentivising investors.

- **Servicing costs**: Most CCI products require operations and maintenance structures to support customers. There currently needs to be more in-house or third-party players who can provide such services, particularly for service-based models. More appropriate financing structures to support such business models are also required.

- **Cultural gaps**: Switching to cold chain use requires a culture change for smallholder farmers and a change in their business model. This is not always straightforward; consumer financing means convincing farmers to part with a portion of their disposable income to spend on these assets, either in a lease-to-own or a PAYG scenario.

- **Business maturity gaps**: Financial institutions often discover during due diligence that prospective CCI businesses require more maturity to attract commercial capital. Among other gaps, they often suffer from a limited execution track record and a low asset base in their balance sheets, making it challenging to meet the collateral requirements of capital providers.

Despite these challenges, the CCI sector has seen the participation of investors, donors and other private-sector players interested in supporting the cold chain market. Financial institutions focusing on innovations in the nexus of clean energy and agriculture are deploying capital into the sector. These financiers include:

a. SunFunder provides debt capital and technical assistance to companies in the cold chain sector through their US$ 70 million Solar Energy Transformation (SET) Fund. The SET Fund is supported by partners such as the IKEA Foundation, Ceniarth, Swedfund and the US International Development Finance Corporation. SunFunder has deployed investments into companies such as InspiraFarms.

b. The ARCH Cold Chain Solutions East Africa Fund is an equity fund targeting greenfield investments in cold chain solutions in East Africa. Target clients are active mainly in the agriculture/food (~90%) and vaccine/medicine (~10%) sectors. In July 2020, the fund announced a US$70 million investment to construct temperature-controlled warehouses across Kenya, with its flagship warehouse (15,000 square meters) planned in the Tatu City Special Economic Zone in Nairobi.[xlvii]

c. Kawi Safi is a growth-stage equity fund focused on renewable energy in East Africa. It led a series B funding in InspiraFarms.

d. USAID, through its Powering Agriculture programme, has provided grant support to cold chain companies such as SunDanzer.[xlviii] The programme was launched in 2012 and came to an end in 2019.

e. Other investors include Persistent Energy Capital, GE Capital and Acumen Fund.

Since the sector is nascent, most commercial funding has been deployed to a few companies that have been able to grow and demonstrate traction and customer uptake. Generally, more patient capital or grants are deployed to companies in the pilot phase of their operations.

Limited consumer financing: Consumer financing is also limited in the sector. Cold rooms that comply with food safety certifications are costly for smallholder farmers, with some CCI solutions (those with 2–4-tonne capacity) costing at least KES 1-3 million (US$11,000-30,000).[xlix] There are very few financial institutions providing consumer financing at the last mile for customers wishing to purchase these solutions. This is due to the perceived risk profiles of farmers, who do not tend to keep proper records. Moreover, their income is seasonal, and weather changes negatively impact their income and ability to repay loans.

It is important to note, however, that the MFI sector in Kenya is strong; the reported 2020 membership of the Association of Microfinance Institutions Kenya (AMFI-K) includes 12 MFI Banks (MFBs), 34 Credit-Only MFIs (COMFIs), 1 SACCO, 3 Wholesale MFIs (WMFIs) and 2 Development Institutions.

2.6.2. Technological Challenges

The CCI sector also suffers from a range of technological challenges:

- **Design-related challenges:** By nature, many walk-in cold rooms are large and often require on-site local assembly. This increases the costs and installation complexity. As individual units break down, a supply chain for after-sales infrastructure needs to be in place as part of the installation package. Refrigeration gases also need to be available, and leaks and other potentially damaging situations are prevented or limited.
- **Limited technical skills to provide after-sales services:** Kenya has very few experienced CCI technicians who can adequately install and repair CCI technologies. This results in the breakdown and reduced lifespan of the equipment. Reliance on foreign experts leads to slower deployment and installation of CCI technologies, such as cold rooms and warehouses, making after-sales services considerably more expensive. This dissuades stakeholders from installing cold chain assets that rely on sophisticated technologies.

> ***The country has very few experienced technicians that provide after-sales service for CCI technologies. In fact, a food retailer has to import the product for replacement every time there is a fault in the installed cold rooms. This is very unsustainable.***
>
> **Powering Agriculture/Tetratech**

- **Lack of trained personnel:** There needs to be more trained personnel in the country who can operate sophisticated CCI assets, which can lead to misuse and damage. This, compounded by the need for more technical skills to provide after-sales services, limits the uptake of CCI solutions.
- **Availability of second-hand products:** Since new and emerging CCI technologies tend to be unaffordable, second-hand products dumped by or from European markets often meet these requirements. The performance and efficiency of these older technologies are reduced by outdated components, which perform poorly in temperature controls and holdover times compared to newer models. A lack of awareness of new technologies makes consumers more likely to turn to second-hand products. Incentives should be provided to pilot new equipment in the country, which could increase the uptake of CCI solutions.
- **Limited local manufacturing capacity**: Kenya needs more manufacturing units. Most players only assemble CCI in the country and import most parts from countries like China, making the final product unaffordable and inhibiting uptake. Kenya needs to increase its ability to manufacture and assemble these assets locally, which would significantly reduce the price by eliminating import duty. Donor programmes sponsoring local education or exchange programmes, in partnership with the Kenyan government, would hone the technical skills of local experts and eventually make Kenyan manufacturing possible.

> ***Most cold chain companies in Kenya import CCI components as there is very limited local manufacturing. For instance, the BYD lithium ions used in the units can only be accessed via import.***
>
> **Tree_Sea.mals**

2.6.3. Operational and Market Challenges

- **Infrastructure challenges:** Approximately 56% of Kenyans have access to grid electricity. This percentage is much lower (35%) in rural areas, where most smallholder farmers live. A stable power supply is necessary to uptake CCI solutions that rely on grid power. Off-the-grid CCI innovations have been deployed in rural areas, including solar-powered walk-in cold rooms, dry ice cool boxes and charcoal cooler boxes. But poor roads make many first-mile locations challenging to access, hindering installation and contributing to low uptake in such regions.

> ***Import duty for cold rooms could be as high as 40% of the manufacturing cost. These costs are transferred to the end customer, making CCI technologies much more expensive.***
>
> **Ecozen**

- **Import taxes on CCI components:** Import taxes are levied on all imported goods, including CCI products. There have been several revisions to the tax regime regarding the import of solar products and PV components, with mixed results; a lack of clarity by the Kenya Revenue Authority (KRA) regarding which solar systems qualify for exemptions has resulted in the inconsistent application of duties. Requirements for solar PV companies also vary when it comes to completing import declaration forms, with different taxes and duties charged for different items.[li] These taxes and port processing fees make CCI solutions very costly to assemble locally, which is subsequently passed on to the consumer.

- **Market maturity:** Most of the produce in Kenya is sold in domestic markets, and some is sold through informal channels. For instance, over 99% of the meat produced in the country is consumed through domestic markets.[lii] In comparison, 96% of fruits and vegetables are grown locally (purchased at farmgate or through domestic markets).[liii] Unlike export markets, domestic markets generally lack CCI regulations and standards. Although some players may use CCI to increase the shelf life of their produce, the use of cold chain is optional and therefore tends to be suboptimal. In the milk value chain, informal markets also discourage the uptake of CCI solutions.
- **Weak direct market linkages to end consumers**: Produce taken through CCI solutions should ideally be priced higher to ensure that the costs of cold chain use are recovered from the margins. However, consumers in Kenya are price sensitive and often unwilling to pay more. Thus, the benefits of CCI solutions from a consumer perspective could be more evident. This lack of a direct market linkage between CCI and the consumer makes it more challenging for traders and retailers to profit from cold chain solutions.

2.6.4. User Challenges

- **Limited consumer awareness:** There needs to be more awareness of the benefits of CCI solutions, especially among smallholder farmers in rural areas. Smallholder farmers are often sceptical of new technologies, while the high costs and limited accessibility of these innovations lead to further misconceptions. So, while the potential demand for CCI solutions should be high, cold chain is still perceived by farmers as a luxury service; many prefer to rely on their traditional storage techniques.[liv] There is a need for increased consumer awareness of the technologies available and the opportunity cost of more rudimentary ways of storing produce.
- **Seasonality in agriculture:** Smallholder farmers in Kenya rely on rain-fed agriculture, so their income is seasonal. This poses a challenge regarding CCI assets since cold chain solutions are only used during specific cropping seasons and lie idle during the rest of the year. This increases the payback period for farmers, making them warier to invest in CCI solutions.

2.7. Potential Interventions to Increase the Uptake of CCI Solutions

Various strategies could be adopted to increase the uptake of CCI solutions in the country and to ensure they scale by 2030. Some of these strategies are as follows:

- **Increase patient capital in the sector**: The uptake of CCI across these four value chains is constrained by a lack of financing. There is a need for more patient and catalytic capital to be deployed in the sector; this could consist of either long-term equity capital from commercial investors considering the nexus of energy and agriculture or grant financing support. Financing should target either companies that manufacture or distribute CCI solutions or MFIs and cooperatives providing consumer financing for farmers to increase the uptake of CCI technologies. Financing structures that could support the sector include:

    a. **A first loss default guarantee programme** in which a donor agrees to deploy grant capital as part of the investment to reduce losses in case the ROI is negative, thus catalysing participation from more commercial co-investors.

    b. **Results-based or performance-based financing**, where an investor or financier provides patient capital to achieve measurable impact; this could be the amount of food the CCI solution "saves" from wastage.

    c. **Public Private Partnerships (PPPs**) include a mechanism whereby the government provides financing for an asset while the private sector player is responsible for its repair, maintenance, and the technical support required to ensure sustainability.

Re-evaluate the tax regime and reduce prices: Import duties and other taxes imposed on CCI parts and components considerably increase these assets' price, accounting for close to 40% of the production cost.[lv] The high price of CCI inhibits its uptake, especially at the first mile. The government and other stakeholders need to re-evaluate this tax regime; while some off-the-grid CCI components are tax-exempt, more efforts must be made. This can be accomplished by setting up multistakeholder taskforces to provide tax subsidies, resulting in cheaper CCI solutions and incentivising their market uptake.

Increase donor programmes that promote market development activities: There is a need to build technical skills to augment local manufacturing and assembly of CCI assets and provide after-sales services. Companies in the sector also need technical assistance to ensure that they become sustainable. Such programmes could be sponsored by donors and could cover thematic areas such as the design of innovative pricing models, market entry strategies, value chain analysis, and optimal technologies to be adopted. Increased education and awareness among farmers and consumers could also increase the uptake of CCI solutions. Multi-year donor programmes could ensure awareness in the market by preparing materials such as market scan reports, consumer and investment data analysis, recent trends, etc., for dissemination among CCI users and other stakeholders in the sector. More effort should also be put towards funding, operating, and advocating around successful pilots that demonstrate the possibilities of CCI technologies and decrease risk perception among consumers, financiers, and other stakeholders.

Increase processing and exports: Part of Kenya's Big Four Agenda is the augmentation of local manufacturing, including processing and value addition. The government has already begun the process of establishing agro-processing zones, and in its ten-year agricultural sector transformation and growth strategy (2019-2029), it identified value addition as a key driver of growth.[lvi] These processing zones should result in increased local food processing, which has the potential to augment the uptake of CCI technologies as processors seek to ensure the preservation of the bulked produce needed for processing. Increasing agriculture exports from Kenya also has the potential to increase CCI uptake significantly, especially since most of the country's agricultural cold chain policies are already driven by the export market; host markets require minimum quality standards from Kenyan exports, and the use of CCI solutions from farmgate to the destination would minimise the risk of rejection. One way to increase exports is by ensuring that Global Agricultural Practices, including cold chain, are adhered to.

Develop and implement policy: There needs to be more dedicated policy support to uptake CCI technologies in Kenya. The few existing policies are not widely implemented, either due to large informal markets or the limited availability of veterinary officers to conduct inspections. Yet, supportive policies need to be developed and fully implemented for markets to grow. Ongoing efforts include the establishment of the NCAP, a multi-stakeholder taskforce, but these policies still need to be signed into law. Others could include regulations on thematic areas such as the optimum temperature of produce before it is sold, the optimum price for produce that has gone through cooling solutions, or the empanelment of certified technical providers available in the country. For example, a publicly-funded capacity building of cooling engineers would increase the national skilled labour pool and enhance skills across Kenya.[lvii]

In addition to the above key recommendations, the following are specific recommendations that could apply to the household refrigerator market, the small commercial refrigerator market, and the commercial ice-maker market:

For the household refrigerator market:

• Resolve PAYG compatibility, appropriate system controls and improved reliability.

• Develop financing solutions through micro-finance and PAYG contracts in mini-grid markets.

• Provide after-sales technical support and the means to deliver appliances to remote regions.

For the small commercial refrigerator market:

• Encourage the development of appliances specifically for target markets and identify suppliers to work with, such as regional business associations and SACCOs. Examples include "solar stalls" for markets and roadsides, soft drink coolers for shops, and portable coolers for farmers and fish, meat, and dairy producers, focusing on reliability.

• Develop financial case templates for entrepreneurs based on their revenues; encourage suitable financing packages, particularly with mini-grid suppliers for whom the increased business revenues enabled by refrigeration could justify power upgrades.

• Provide after-sales technical support.

For the commercial ice-maker market:

• Encourage the development of appliances specifically for target markets and help suppliers to work with farmers' cooperatives and other SACCOs. Examples include small agricultural, meat, fish and dairy storage and transportation systems.

• Develop financial case templates for entrepreneurs based on their revenues; encourage suitable financing packages, particularly with mini-grid suppliers for whom the increased business revenues enabled by refrigeration could justify power upgrades.

•Develop the means to provide after-sales technical support.

Conclusion

CONCLUSION

Although use cases vary across value chains, overall, CCI in Kenya is underdeveloped in the agricultural sector, resulting in significant quantities of food lost yearly due to a lack of cold chain technology. The fruits and vegetables, dairy, meat, and fish value chains would benefit from expanded cold chain solutions at nearly every level. Still, factors such as high costs, a lack of financing, poor infrastructure, large informal markets, and low levels of customer awareness inhibit the uptake of CCI technologies among producers, distributors, aggregators, transporters, and retailers. In some cases, CCI assets such as milk chillers or cold boxes are not used at all outside urban centres, with various actors in the value chain preferring rudimentary, low-cost methods of cooling and preserving produce; in other cases, these assets have been acquired and installed, but are underutilised due to a few factors that make them unattractive or unviable.

This gap presents a tremendous opportunity for market innovation on the technical, financial and policy sides. **CCI manufacturers and distributors must ensure that their products correspond to the needs and capacities of the first-mile market segment, particularly concerning the power sources they use and the payment models they adopt.** Donors and financiers can help facilitate the purchase of CCI assets by providing more grants and patient capital to those looking to acquire them since high costs and long payback rates tend to discourage more traditional investors. Meanwhile, the government, recognising that CCI expansion corresponds to its long-term policy goals for agricultural production and food security, could drive down the price of these assets by reevaluating the tax regime. A more supportive and better-enforced regulatory framework would also improve the uptake of CCI solutions in Kenya.

In supporting innovations in cold chain technology, there should be a particular focus on products powered by renewable energy. Millions of smallholder farmers need access to the grid-quality electricity required to maintain low cold storage temperatures. So, off-grid solutions are often the only cold chain option at the production level. But conventional refrigeration technologies – including the refrigerants they use – are also a significant source of greenhouse gases; a shift towards more renewable energy sources would solve the problem of climate-related negative externalities while simultaneously tackling the challenges of rural poverty and food security.

The level of agricultural production in Kenya is considerable, and proper preservation techniques would mean that a much higher proportion of domestically produced food would reach the Kenyan population. Reducing food losses would also boost the incomes of smallholder farmers and small-scale distributors, creating jobs and improving food security for rural people. **However, solving this problem requires more than the proper technology; a system-wide approach combining education, financing, and policy changes is needed to fully realise the cold chain market's potential and for Kenyans to reap its benefits eventually.**

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This section highlights the findings of the study across each value chain. While the overall insight was that CCI penetration is minimal, unique dynamics are at work within different value chains.

3.1. Fresh Fruits and Vegetables

3.1.1. Market Overview of the Fresh Fruits and Vegetables Value Chain

The horticulture sector comprises approximately 36% of Kenya's agricultural GDP and is growing at an estimated 15 - 20% annual rate. The industry employs over six million Kenyans, both directly and indirectly. Its main sub-categories include floriculture, fruits, and vegetables. Vegetables comprise around 44.6% of the total horticulture production, while fruits comprise 29.6% and flowers 20.3%; nuts, medicinal plants and aromatic plants account for the rest.[lviii] Kenya is a significant supplier of horticulture to Europe, contributing almost 40% of all flowers imported to the continent.[lix] As of 2017, fruits and vegetables accounted for about 47% of horticulture exports by volume.

Production of fruits and vegetables in the country has been steadily increasing. It is characterised by the participation of smallholder farmers involved in 80% of production. This growth is due to factors like the availability of better inputs, including seeds and fertilisers, and increased extension services to farmers leading to better yields.

96% of Kenya's fresh fruits and vegetables (FFV) are grown for local consumption, purchased at the farm gate or through domestic markets.[lxi] Only 4% of FFV produced are exported, primarily to European countries like the Netherlands, France, and Spain. Import requirements for the cooling of fresh produce vary across countries; China, for instance, requires fresh fruit to be frozen at -30°C after peeling off the skin, and temperatures are maintained at -18°C during export. Most smallholder farmers cannot meet such stringent requirements, so they do not directly export FFV. But the local demand for fruits and vegetables is high, with per capita consumption of 147 kg and 73 kg among urban and rural dwellers, respectively.[lxii]

To supplement local production, Kenya imports fruits and vegetables through the regional Common Market for Eastern and Southern Africa (COMESA), with over 50% of imported fruits coming from South Africa.[lxiii] The high cost of local production and low adoption rates of modern technologies by Kenyan farmers also lead to more processed fruits and vegetables imports. However, imports of FFV are still low compared to local production. As production increases, imports decrease.

FFV processing is limited in Kenya, with most fruits and vegetables consumed fresh. The volume of processed fruits and vegetables was stagnant at 6,000 tons between 2015 and 2017, less than 0.05% of total production.[lxiv] There was a significant dip in 2018 to about 1,000 tons, a volume that remained the same in 2019.[lxv] Most processing is to make fruit juice and pulp, though other value additions include sorting, grading, topping, and tailing.

3.1.2. Utilisation of CCI within the FFV Value Chain

Cold chain infrastructure in the FFV value chain is relatively fragmented. CCI tends to be concentrated in urban centres near exit ports like airports and shipping ports. Jomo Kenyatta International Airport (JKIA) provides cold chain facilities with temperature controls (-18°C to 2°C), which exporters can use on a pay-per-use basis. Most CCI in the FFV value chain consists of large packhouses with cold storage rooms. In the first mile, rudimentary solutions are used instead of more sophisticated ones, but donor partners have begun piloting CCI solutions that will benefit this segment. Figure 11 summarises how CCI technologies are used at each value chain level.

Production and Aggregation Level: It is estimated that in Sub-Saharan Africa, over 50% of fruit and vegetable food losses occur at the farmgate level.[lxvi] This is attributed to poor handling practices and a lack of cold chain facilities. The use of CCI technologies at the farm level is expected to increase farmers' net income by 30% as post-harvest losses are reduced.[lxvii]

Figure 10: Production, Export, and Import Quantities of FFV (000's tonnes)

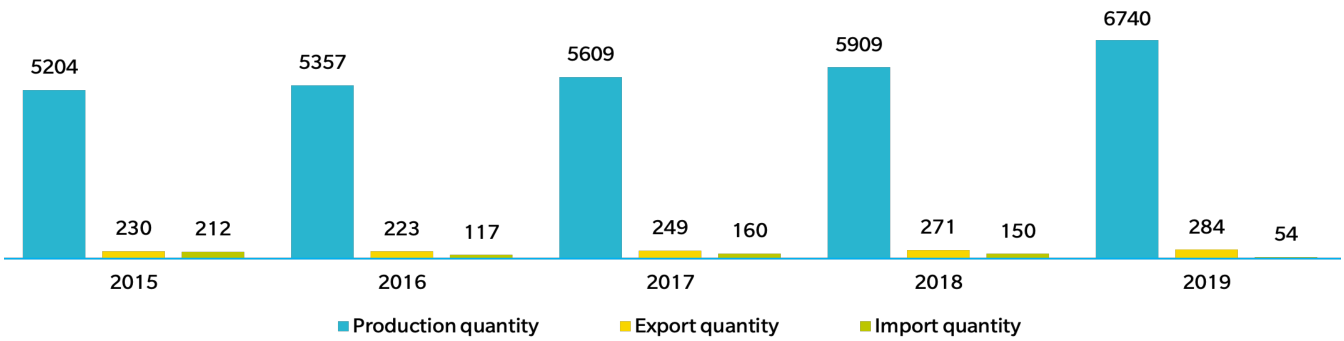


Figure 11: Current Use of CCI Components at Different Levels of the FFV Value Chain

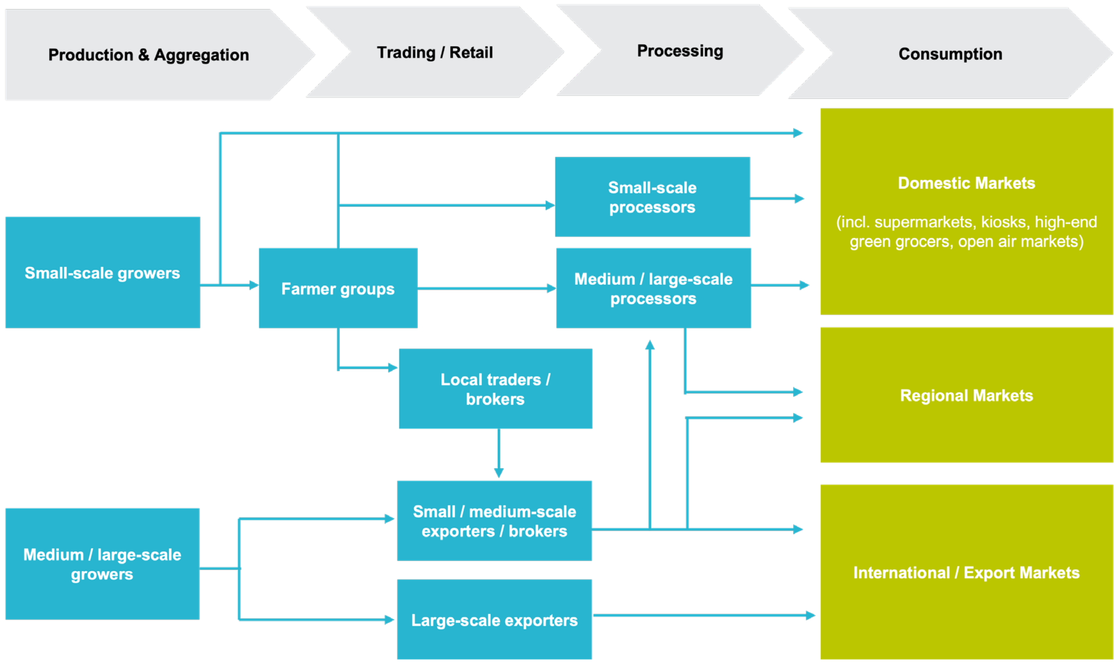
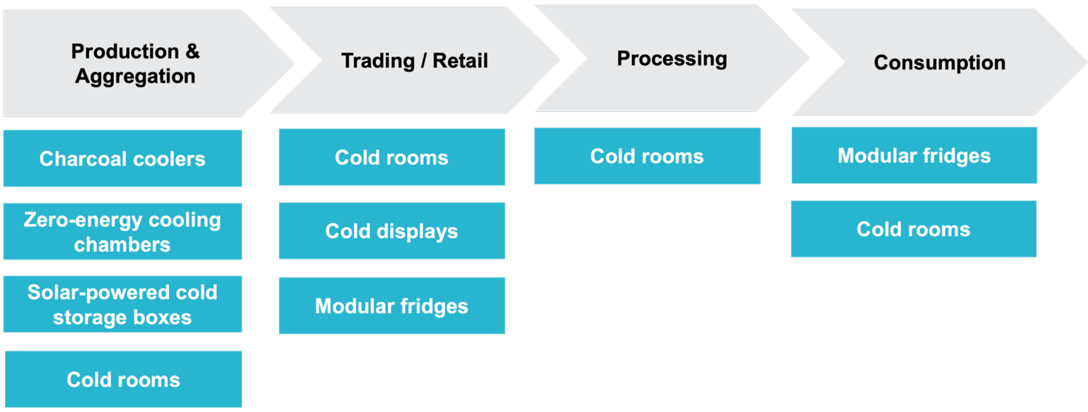


Figure 12: Examples of CCI Solutions Utilised Across the FFV Value Chain



At the **aggregation level**, most CCI technologies consist of both off- and on-grid cold rooms with operating temperatures of between 0°C -10°C, which can be customised depending on the type of crop. The size of these cold rooms can be customised as well, depending on the number of farmers they are intended to serve, but the standard size is a 40-foot container measuring 12mx2.4mx2.4m. At this stage, farming cooperatives or farmers' groups aggregate their produce before it is distributed to the market (it should be noted that most farmers skip this stage entirely, selling their produce directly to middlemen or to markets). Some counties in Kenya, such as Elgeyo Marakwet, have allocated funds to cold room solutions (including compressors) for farmers at the aggregation level.[lxviii] Exporters who need to maintain quality throughout the value chain also have aggregation points where farmers can bring their produce, storing it in packhouses with cold chain facilities. Other value-addition processes (including sorting, grading, topping, and tailing) are conducted at this level. It is estimated that about 26% of FFV is lost due to a lack of topping and tailing, which is done to prepare the produce for export. Importers also have packhouses fitted with CCI facilities where produce is stored awaiting distribution.

Retail Level: At this stage, fresh produce is sold directly to markets or brokers for further distribution. Historically, CCI solutions have rarely been used at the retail level. But traders' associations and other groups have recently begun purchasing CCI as a collective, allowing traders to store their FFV to increase shelf life. FreshBox, for instance, has sold several units to a traders' association on a lease-to-own basis.

Transport Level: Cold chain solutions for transport are used mostly by retailers who export their FFV; most FFV consumed locally are transported without cold chain solutions. Reefer transport is most common in the floriculture industry, as CCI in this value chain is more advanced, but they are being increasingly used for FFV as exports increase. 3PL companies providing reefer truck services charge by the distance travelled, and such services are more expensive than hiring a standard truck. Thus, retailers prefer to transport FFV at night when temperatures are cooler as a rudimentary method of preservation.

Processing: As mentioned above, processing of FFV in Kenya is limited, with most produce consumed "fresh." However, processors such as Delmonte and Kevian Industries have their own ripening chambers and cold rooms in their warehouses. Twiga Foods, a B2B distributor of fresh produce in Kenya, has cooling and ripening chambers in its warehouses installed by InspiraFarms, where bananas and other crops are cooled and ripened before being distributed.

Export: FFV need to be stored before being exported. Most Kenyan exporters do not have cold chain infrastructure from farmgate to export, since they focus on less perishable products like fresh legumes and avocados. Those who do use it rely on 3PL companies to provide this infrastructure. Because 3PL in Kenya is underdeveloped due to the high investment cost required to set it up, most such services are being offered by multinational firms.[lxxi]

3.1.3. Challenges in Utilisation of CCI in the FFV Value Chain

There are several barriers to adoption within the FFV value chain, particularly relating to affordability and last-mile access to CCI solutions. Some of these challenges are highlighted below:

Concentration in urban areas: Most of the cold storage technologies in the FFV value chain are concentrated in urban areas where there are packhouses with cold storage rooms. Since cold chain infrastructure is generally limited in rural areas, particularly at the first-mile level, FFV are not immediately cooled, which results in further food losses that continue along the value chain.

Poor infrastructure that does not support the sustainable use of CCI technologies: Over 80% of smallholder FFV farmers live in rural areas with limited access to grid electricity and paved roads. This impacts the distribution of FFV from the first-mile level and presents significant challenges for investment in cold chain technologies. Furthermore, not all the cold rooms at the first-mile level are currently in use due to a lack of water and drainage systems.[lxxii] These are necessary because water is required for cleaning the cold room with water jets, and in some cases, the conditioning system can be quickly replaced with a simple water-type connection. The temperature control unit of the cooling system sometimes also uses a combination of refrigerant and water heat exchange technologies. A drainage system is required for draining the excess water produced by the cold room through defrosting and condensation.[lxxiv]

Limited financing and investment in the sector: Stakeholders complain of limited access to capital to facilitate the acquisition of CCI solutions, especially considering the high upfront costs.[lxxv] As described above, financing challenges include a lack of consumer financing for farmers and users that could increase the uptake of these technologies. Challenges such as long payback periods, the opportunity cost of investment versus returns, and low-profit margins on these assets further limit investment in the sector.

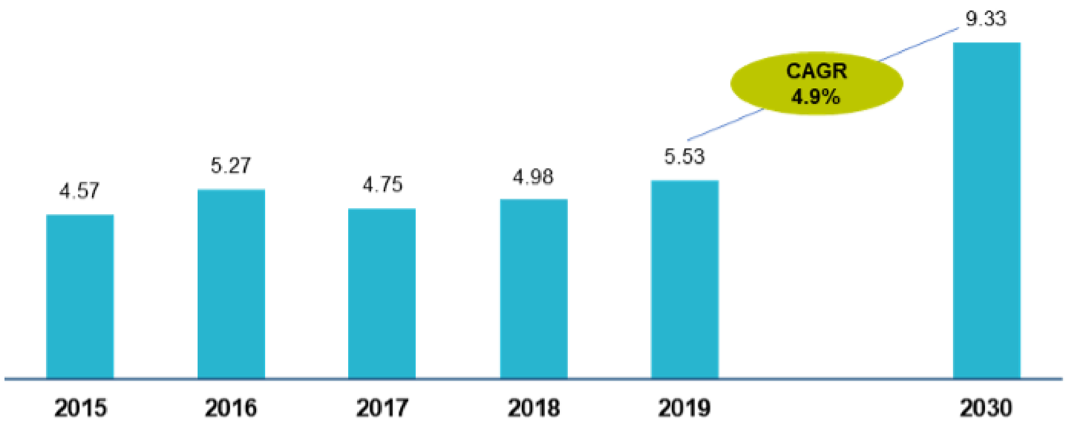
Limited sophisticated technologies: Due to the high cost of assembling CCI in Kenya, the cooling solutions most used are low-cost technologies such as charcoal coolers, night transportation and wet baths, all of which make temperatures difficult to regulate. This affects the quality of the produce, which prevents traders and exporters of FFV from obtaining food safety certifications.

3.1.4. Potential Interventions to Increase Uptake of CCI in the FFV Value Chain

The following strategies should be considered to help Kenya meet its CCI needs, specifically in the FFV value chain, where reduced food waste will improve farmers' income:

Decentralise CCI technologies to increase access and uptake at the first mile: Currently, most CCI technologies in the FFV sector are concentrated in urban centres. Decentralising these technologies to reach the first mile would increase uptake. One way to do this is by including cold chain asset acquisition in county government budgets. Some counties, such as Nyandarua county, have already invested in setting up packhouses with cold chain facilities; these efforts need to be replicated across the country for the potential market size to be achieved. Donors could also support farmers' groups and cooperatives in setting up CCI solutions in decentralised areas closer to farms. The Rockefeller Foundation, for instance, is helping mango farmers in Makueni County acquire cold chain facilities and providing technical assistance to the asset owners to ensure that the cold rooms are sustainable.

Figure 13: Milk Production Quantities in Kenya (Mn, tonnes)[lxxxii]



3.2. Dairy Value Chain

3.2.1. Overview of the Dairy Value Chain in Kenya

The dairy industry contributes around 14% of Kenya's GDP and 30% of its agricultural GDP, with about 1.8 million smallholder farmers (who have two to ten cows) in the sector. Kenya's total annual milk production for 2019 was about 5.5 million tonnes,[lxvii] making it the third-largest milk producer in Eastern Africa after Ethiopia and South Sudan.[lxviii] The sector's growth has been driven by promoting smallholder farming and reviving cooperatives. With a CAGR of 4.87%, annual milk production is expected to increase two-fold by 2030, to over 9 million tonnes.[lxix] Currently, the average annual yield of milk per animal in Kenya is about 371.3 kg, which is projected to increase to 385 kg.[lxxx] Growth drivers include better animal husbandry practices, proper feeding practices and improved herd genetics through artificial insemination.[lxxxi]

Kenyans consume more milk per capita than any other country in Africa – an estimated 120 litres annually, compared to an average consumption of 50 litres.[lxxxiii] This is projected to double by 2030, as the demand for milk and milk products is boosted by population growth, urbanisation, increased incomes, diversification in consumption (yoghurt and cheese) and increasing milk usage in baking, confectionary, and fast foods. Approximately 50% of milk produced is consumed at farm level, while the other half is sold. About 80% of what is sold goes through informal channels and is consumed raw,[lxxxiv] due largely to inefficiencies in the supply chain, consumer habits and the price difference between raw and processed milk (processing increases the cost of milk by 30%[lxxxv]).

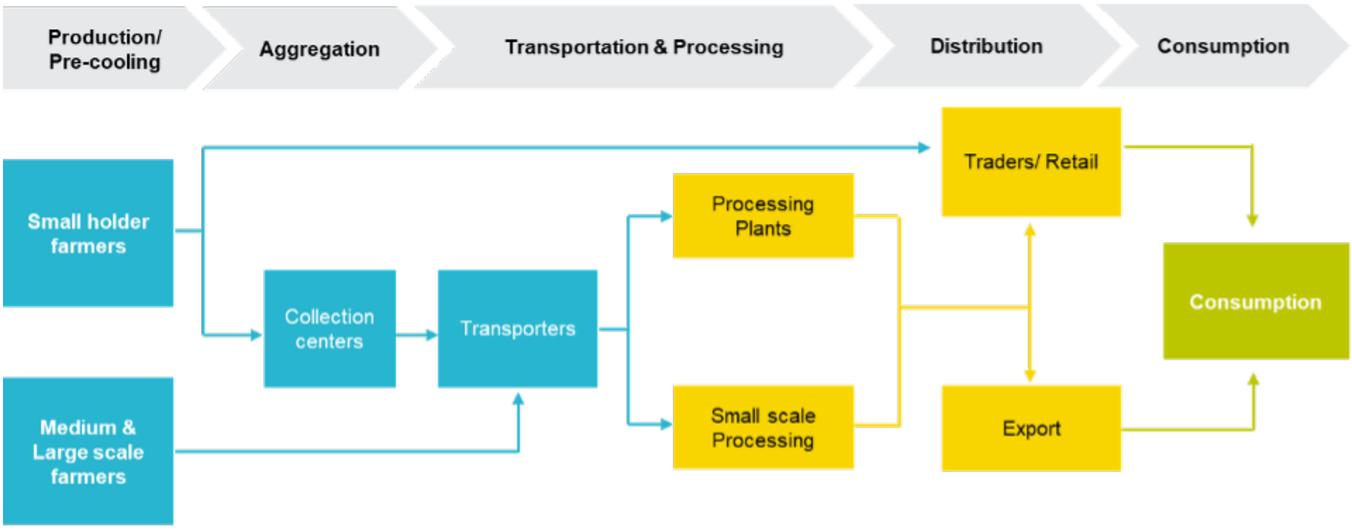
There is increasing momentum to grow the formal market and address the quality and safety concerns around raw milk, and the number of milk vending machines (milk ATMs) has grown rapidly in the country. There are currently about 500 licenced milk ATMs in Kenya,[lxxxvi] all required to sell pasteurised milk with in-built cooling units to ensure refrigeration. Procuring such a machine saves a trader the additional cost of acquiring cold storage facilities (especially standalone refrigerators).[lxxxvii] Milk ATMs are expected to grow the formal market to 30% of the total.[lxxxviii]

Dairy cooperatives and farmers' groups manage around 13% of the total milk produced in the country.[lxxxix] Cooperatives in Kenya aim to improve the incomes of smallholder farmers, selling milk at higher prices on behalf of their members. They also store milk in bulk and provide it to processors either in raw or pasteurised form, thus enhancing market participation by farmers; county governments and donors have helped a few such cooperatives acquire milk chillers for bulk storage. However, since the liberalisation of the dairy sector in Kenya in the early 1990s, the role of cooperatives has been reduced. Some farmers are now reluctant to sell through cooperatives due to factors such as better competitive pricing of milk sold at the farmgate, poor pay-outs by the cooperatives, poor management of the cooperatives, and corruption.[xc] But due to the importance of cooperatives in the dairy value chain, there have been recent efforts to revive them.[xci]

Milk processors handle more than 80% of the milk that is sold formally.[xcii] The industry is dominated by two processors, Brookside and New Kenya Creameries Cooperation (KCC), which together handle up to 60% of the overall processed milk.[xciii] Although there are over 30 licensed milk processors in Kenya and over 60 licensed mini dairies with a total processing capacity of about 3.75 million litres per day, the four largest processors together process more than 80% of the total milk.[xciv] These four also export processed milk, mostly to East and Central Africa, the European Union and the Middle East.

Kenya also imports milk from Uganda, primarily because milk production costs are lower. This impacts the growth of the local dairy market, as Uganda's Lato Milk and Fresh Dairy have established a sizeable footprint in the country. Kenya imposed a ban on milk imports from Uganda in 2020 to protect the domestic market, but dairy imports are still taking place both formally and informally. Most of this imported milk comes in the form of processed liquid and powder.

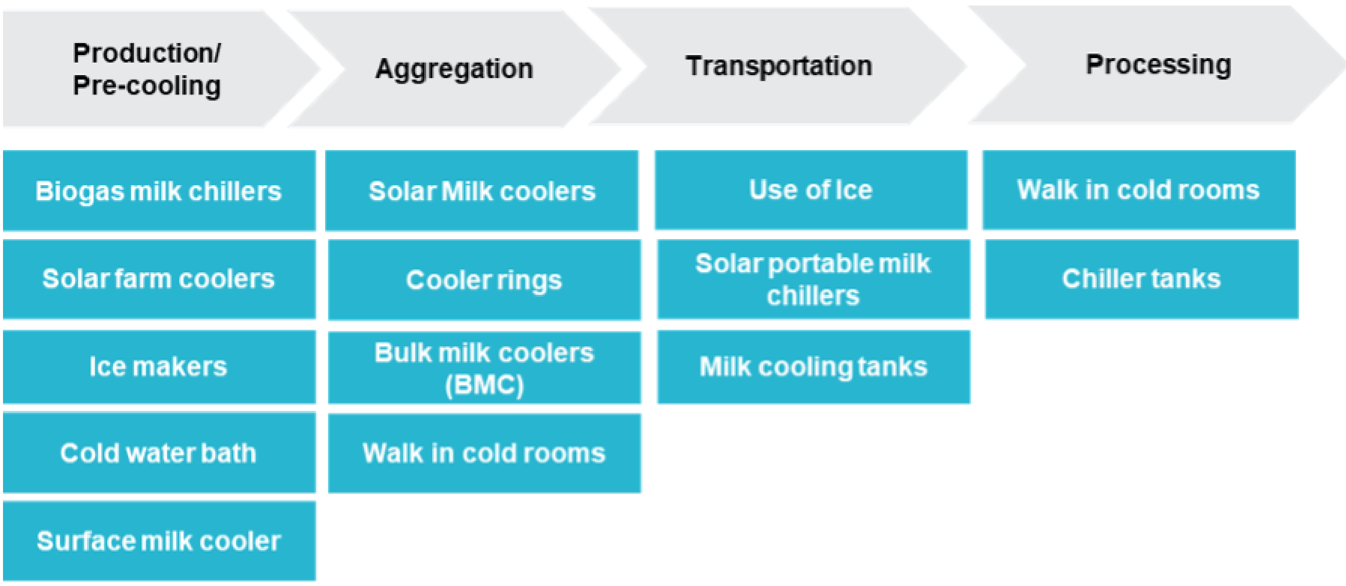
Figure 14: Summary of the Dairy Value Chain in Kenya



3.2.2. Utilisation of CCI within the Dairy Value Chain

Kenya suffers from post-milking losses of around 95 million litres of milk annually,[xcv] largely due to poor handling practices and lack of cold chain facilities. Because electrification in rural areas is limited, over 85% of Kenya's 800,000+ dairy farmers do not have access to refrigerated storage facilities. However, the Government of Kenya has launched a US$22 million nation-wide programme to install milk coolers to help reduce this wastage.[xcvi] The distribution of these milk coolers will happen through registered cooperatives and farmers' groups, reinforcing the revival of cooperatives. As of 2020 the government had bought over 180 coolers with a total capacity of 3,000 litres,[xcvii] though only around 80 had been installed due to infrastructure challenges including a lack of electricity and water.[xcviii]

Figure 15: Current Use of CCI Components at Different Levels of the Dairy Value Chain



CCI at Precooling Level: Precooling is the cooling of milk after the milking process, either by the farmer or by extension service providers. At the production level about 7% of total milk produced is wasted, mainly the evening milk[4] due to a lack of cooling facilities at the farm[xcix] where the absence of reliable electricity makes sophisticated CCI technologies unworkable. Instead, farmers use low-tech solutions such as biogas chillers, cold baths, and milk coolers. Because there is no reliable temperature control with these methods, it is difficult for farmers to ensure that milk is kept cold enough to maintain quality.

CCI at Aggregation/Cooperative Level: At this level, the milk is brought by farmers to a collection centre for retail sale or processing. Aggregation of milk is done through cooperatives and farmer or producer groups. County governments are playing a key role in the development of CCI at the aggregation level; in 2015, for instance, the county government of Tharaka Nithi constructed a solar-powered milk cooling facility for the Kibumbu Dairy Farmers' Association. The government bore the cooling plant's initial set-up cost, but ownership was later transferred to the association, with the farmers expected to pay for maintenance of the asset (10% of the farmers' earnings were deducted for this purpose). As of 2015, there were around 500 operational milk coolers in the country, with a capacity of 3.4 litres per day.[c]

CCI at Transport Level: The use of refrigeration for transportation depends on the total volume being transported, as well as the buyer's ability to pay. For small-volume local consumption (from farmgate to bulk collection point), seamless stainless-steel cans and or plastic cans are used to transport the milk without any refrigeration. Major processors, on the other hand, have their own collection and transportation systems and use refrigerated tanks to transport milk to the main processing plant.

CCI at Processing Level: At this stage, milk is taken through formal channels for processing, pasteurisation, and sale to retailers. Milk processors tend to operate an end-to-end value chain, mostly using milk chillers as their primary CCI technology.

3.2.3. Challenges in Utilisation of CCI in the Dairy Value Chain

There are several barriers to CCI adoption within the dairy value chain. Some of these challenges are highlighted below:

Limited incentives for cooled milk: The price difference between chilled milk and warm milk is almost negligible. The 2021 Dairy Regulations set a minimum farmgate price for un-chilled milk at KES 33 (~US$0.33) and for chilled milk at KES 35 (~US$0.35) per litre.[ci] This implies a price differentiation of only KES 2 (~US$0.02) per litre. Most smallholder farmers, who produce seven to nine litres daily,[cii] need a more significant price differentiation to incentivise them to chill their milk. Since most milk is sold through informal channels to price-sensitive consumers, the regulated prices are generally not enforced, and chilled milk sells for the same price as un-chilled milk.

High electricity costs and unreliable grid connection: Electricity costs account for 20-40% of the total expense of a milk chiller.[ciii] This is unaffordable for a small-scale dairy processor, and CCI solutions powered by solar systems tend to be too expensive. Large processors can afford these assets as they make better margins due to economies of scale. Small-scale processors' inability to afford CCI solutions limits their ability to store large volumes of milk during aggregation.

Informal market channels: The sale of milk in Kenya is mostly through informal channels, where farmers and traders sell milk directly without cooling it. This is a barrier to using already installed CCI solutions, causing most of them to lie idle. If this informal market expands, it will stifle the need for CCI solutions in the value chain. Therefore, there is a need to formalise the sector to enable the sale of milk through formal channels like cooperatives, whose cold chain solutions can ensure refrigeration and reduce losses.

Limited financial support: Kenya experiences a financing gap for CCI technologies which can be attributed to the opportunity cost compared to financing other sectors with quicker payback periods and higher returns on investment. The CCI sector is asset heavy and viewed by many commercial financiers as a non-viable market. There are also few consumer financing opportunities available to farmers with limited purchasing power. This further hinders the uptake of such solutions.

Poor infrastructure: Many feeder roads in Kenya that lead to dairy farms are in poor condition. The logistical inefficiencies this causes in milk collection and access to CaaS services significantly hinder CCI solutions' uptake.

3.2.4. Potential Interventions to Increase Uptake of CCI Utilisation in the Dairy Value Chain

Several potential interventions to consider in the dairy sector could help Kenya achieve the estimated CCI 2030 market size. These include:

Support for the institutionalisation of milk vending machines: Milk vending machines, which are required to sell pasteurised milk, can potentially increase the formal market's share of the total market by 30%. Expanding the adoption of milk ATMs would also boost the uptake of CCI solutions since milk traders would require CCI technologies to store milk.

Increased milk processing to produce high-value products: Since most milk sales are through informal channels, milk processing is limited in Kenya. More milk processing to produce high-value products such as cheese or UHT milk can increase the uptake of CCI solutions, as processors would need to store larger quantities of milk and therefore require cold storage.

Expansion of formal channels for selling milk: The 2021 Dairy Regulations set minimum farmgate prices for chilled and un-chilled milk. However, only players in the formal market observe these prices, which account for just 20% of the total. Formal channels need to be expanded by reviving more cooperatives and providing additional incentives for farmers to support chilled milk, potentially increasing the utilisation of CCI solutions.

4. Evening milk refers to milk that is collected from cows during the evening or night times.

Enforcement of milk cooling regulations: The Dairy Industry Regulations (2018) stipulates that milk should not be sold in raw form and that it must be cooled to 4°C - 7°C within two hours of milking. But given the prevalence of informal channels for milk sales in Kenya, these laws were rarely enforced. Due to public demand, the Dairy Act of 2021 later permitted the distribution of raw milk, only regulating cooling at the processor level. Reinstating the earlier, more stringent cooling regulations would increase the uptake of CCI solutions in the sector.

3.3. Meat Value Chain

3.3.1. Overview of the Meat Value Chain in Kenya

Annual meat production in Kenya is around 809,706 tonnes (2019) and is projected to grow to approximately 1 million tons by 2030.[civ] There are eight main types of Kenyan meat: beef, poultry, camel, rabbit, goat, sheep, pork and game. Red meat – primarily from beef cattle, dairy cattle, sheep, goats, and camels – accounts for about 80% of all meat consumed, with an average per capita consumption of 15.5 kgs. Beef is the main source of red meat and represents over 60% of total meat consumed in the country; mutton and goat represent around 13%. Over 80% of red meat is produced by pastoralists, while another 2% comes from ranches – this is primarily sold and distributed in high-value markets. Dairy cattle contribute 10% - 15% of Kenya's red meat supply.[cv] Although domestic beef production is high, demand still exceeds supply, so beef is imported from countries such as Tanzania, Ethiopia, Somalia, and Uganda. These deficits are due to the inefficiencies of Kenya's meat value chain, which is disorganised and poorly managed. This limits the country's competitiveness in the meat sector.

Demand for white meat has also grown, mainly driven by increased awareness of the health benefits of white meat over red meat and rising consumer incomes.[cvii] White meat from poultry and pork constitutes over 10% of meat consumed in the country.[cviii] Chicken is the second most popular meat after beef, as shown in Figure 16. As the population, urbanisation and incomes grow, meat consumption is projected to increase exponentially.

Over 99% of the meat produced in Kenya is consumed domestically,[cix] with small volumes exported through the Kenya Meat Commission (KMC), private meat exporters and individual ranches. Most exports go to the UAE, Somalia, and Tanzania.

Over 60% of Kenyan meat goes through formal channels, where animals must be slaughtered in registered and certified slaughterhouses. There are approximately 65 such slaughterhouses in Kenya, 63 of which deal in red meat. They are supposed to conform to specific standards, including inspection by a qualified veterinary officer before and after slaughter. Poultry standards include a requirement to chill giblets to 4°C (39°F) or lower within two hours of slaughter. However, these standards are not always applied. 70% of chicken broilers, for instance, are slaughtered on the farm, and a veterinarian does not inspect 50% of these.[cx]

Post-slaughter losses in the meat value chain can be as high as 50%.[cxi] These losses are largely because it is primarily a hot meat retail value chain, meaning that meat is consumed within two days of slaughter without undergoing cold chain preservation. The lack of modern cold chain facilities alone – especially during slaughter, transportation, and processing – leads to post-slaughter losses of up to 14%.[cxii] Other factors include limited value addition and processing of meat, poor hygiene of meat handlers and poor handling practices during transportation. Increased use of CCI can reduce these losses significantly.

3.3.2. Utilisation of CCI within the Meat Value Chain

Except for premium meat products, the meat value chain in Kenya needs a well-developed cold chain infrastructure.[cxiv] There is little cold storage during transportation, as transporters use galvanised steel boxes to carry meat. Since processing is minimal, few CCI technologies are used at the processing level. This lack of cold chain facilities results in meat carcasses being exposed to ambient temperatures for long periods, reducing shelf life and increasing losses. However, as urbanisation and incomes increase and consumers shift to purchasing meat in bulk,[cxv] public perceptions of meat quality and hygiene will likely change. More people will start to prefer cold meat over hot, which is expected to increase the uptake of CCI solutions in the meat value chain.

Figure 16: Kenya's Meat Production (000's Tonnes)[cxiii]

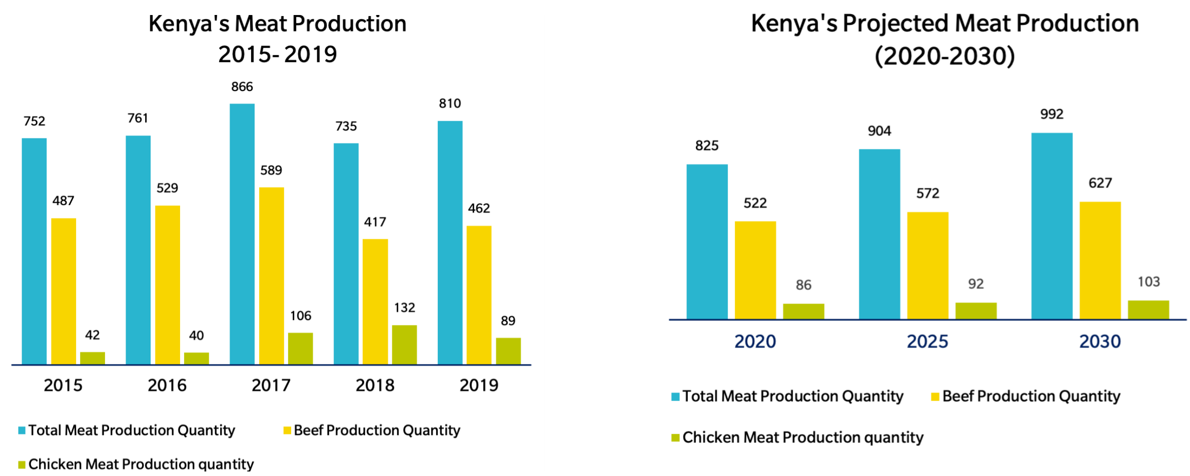
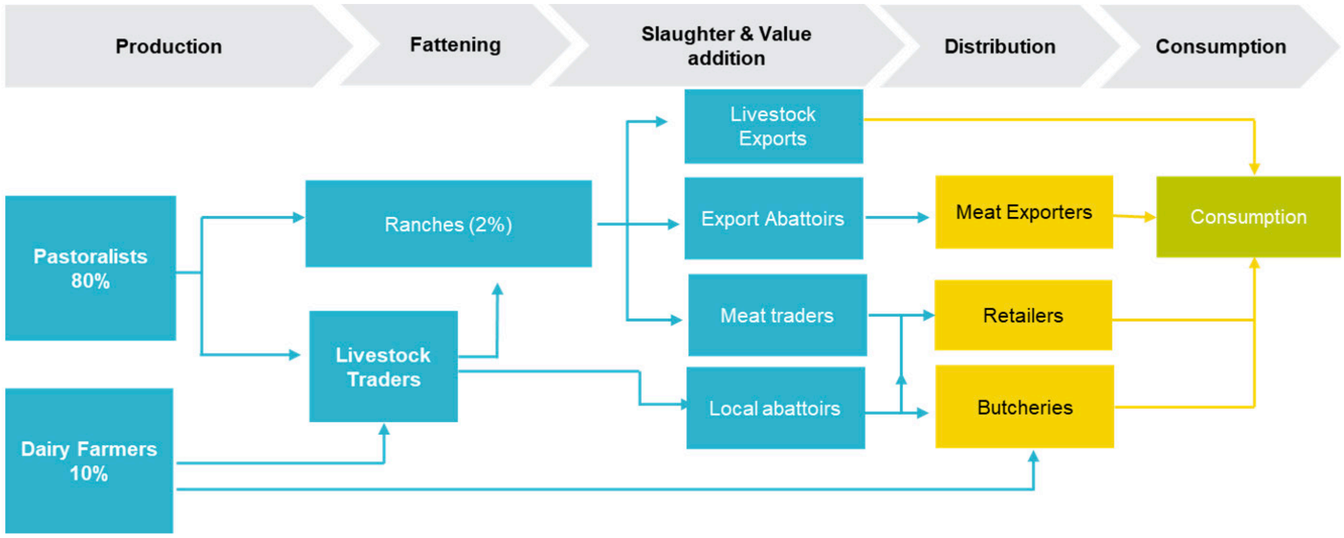


Figure 17: Summary of the Meat Value Chain in Kenya



CCI at Farmgate/Production Level: Approximately 80% of the red meat slaughtered in Kenya comes from pastoralists.[cxvi] These animals are transported live to the abattoirs and slaughtered there, eliminating the need for cold chain. In some cases, farmers manage these slaughterhouses through their cooperatives. Approximately 2% of beef comes from ranches, some operating their slaughterhouses.[cxvii] To achieve certification, these slaughterhouses must have chilling and freezing facilities. In the poultry value chain, more than 90% of all birds in Kenya are slaughtered on farms or in homesteads, and most of the CCI at this level consists of household refrigerators.

CCI at Abattoir Level: Approximately 63 registered slaughterhouses in Kenya deal with red meat, of which 32 are private-owned. The law requires that Category A abattoirs (large slaughterhouses) have separate chilling facilities (-2°C to 4°C)[cxviii] and freezing facilities (-12°C and below) to ensure the meat remains fresh and suitable for human consumption.[cxix] The Kenya Meat Commission (KMC) is one of the largest slaughterhouses in the country, with a capacity of 1,250 large animals and 2,000 small stocks per day. At KMC, all products are stored in chilling facilities where the meat is aged or cured. These chilling facilities have a capacity of 1,750 carcasses, which they maintain at temperatures of between 0°C and 2°C for 5 - 7 days to age the meat. KMC also has additional freezing storage areas to store frozen carcasses before dispatch.[cxxi]

CCI at Transport Level: The Kenya Meat Control Act recommends that meat is transported in insulated carriers equipped with mechanical refrigeration or sufficiently refrigerated to ensure that the temperature increase of the meat is less than 3°C during 12 hours of daylight transport.[cxxii] However, beyond the premium meat market segments, few CCI facilities are used in meat transportation; most use galvanised steel boxes that lack cooling technologies.[cxxiii] Major abattoirs in Kenya, such as the KMC, have licensed meat carriers either refrigerated for long-distance deliveries or insulated for short-distant deliveries from their various outlets.[cxxiv]

CCI at Retail Level: Most meat consumed in Kenya goes through a hot meat value chain. However, consumer preferences and patterns are shifting towards cold meat, especially in premium retail markets.[cxxv] According to a survey done by the Kenya Markets Trust, an estimated 57.9% of retailers reported that they had deep freezers, 24.2% had refrigerators, 10.7% had display chillers, and 2.2% had cold rooms.[cxxvi] However, retailers were careful to ensure that consumers were unaware of meat storage in cold chain facilities, afraid that the customers would not perceive the meat as fresh if they knew.

3.3.3. Challenges in the Utilisation of CCI in the Meat Value Chain

CCI faces various barriers to adoption within the meat value chain, particularly in the lower market segments. Some of the challenges are highlighted below:

Consumer preferences and perceptions: Many consumers in Kenya consider meat from cold chain storage as not being "fresh", having lost its taste and nutritional value. They would prefer hot meat that has been slaughtered the same day. A survey conducted by the Kenya Markets Trust indicates that 17%, 22% and 23% of respondents in the high, middle, and low-income segments, respectively, think that meat loses its freshness when chilled.[cxxvii] These perceptions inhibit the uptake of CCI solutions in the meat value chain.

Cost of CCI solutions: Despite the previously discussed government recommendations regarding refrigerated transport, meat transportation in Kenya is primarily in galvanised boxes. This can be attributed to the high cost of purchasing refrigerated trucks, especially for traders selling to local markets where the margins are too low to cover the cost of acquiring CCI technologies.

Limited need for CCI at the first-mile level: Livestock at the first-mile level is transported to abattoirs and slaughterhouses while still alive, limiting the need for CCI at this stage. Cold chain is only required after slaughter to reduce spoilage.

Limited ability to pay for service, especially in rural areas: Most butcheries and retailers in rural areas cannot afford cold displays and cold chain solutions. Further, the use of these assets in the meat value chain is not well perceived by consumers. Thus, despite the potential market in rural areas, most CCI solutions in the meat value chain tend to be concentrated in urban areas among high-end consumers.

3.3.4. Potential Interventions to Increase Uptake of CCI Utilisation in the Meat Value Chain

Increase awareness: Kenyan consumers' perception of a lack of freshness in cold meat is detrimental to the uptake of CCI solutions across the meat value chain. It is necessary to increase awareness and educate consumers on the benefits of cold meat for nutrition and to reduce post-slaughter losses. This could shift preferences from a hot meat value chain to a cold meat value chain, thereby increasing the uptake of CCI.

Enforcement of cold chain policies: The Kenya Meat Control Act defines recommended temperatures at the slaughterhouse, transportation, and meat canning levels. However, these policies are not enforced since most meat goes through a hot meat value chain. Increasing the number of meat inspectors in abattoirs could improve enforcement; currently, there are only 33 inspectors in export slaughterhouses and 2,000 in domestic slaughterhouses.[cxxviii] This would increase the uptake of CCI solutions across the meat value chain.

3.4. Fish Value Chain

3.4.1. Market Overview of the Fish Value Chain in Kenya

There are two types of fish production in Kenya: freshwater and marine. The freshwater fish output is sourced from freshwater lakes and fish farming practices; Lake Victoria alone contributes 62% of total fish production. In 2019 the fisheries sector generated US$237 million in revenue, a 7.4% decrease from the previous year. It is also estimated that the annual demand for fish is 700,000 tonnes, against current production of 120,000-146,500 tons. This highlights a clear market gap due to several challenges faced by fish producers, traders, processors, distributors and exporters.

Using proper CCI, fish can be safely stored for 10-15 days at 0°C; without chilling, it can deteriorate completely after a few hours in hot weather. Cold chain solutions can help support the industry by reducing post-harvest losses, increasing revenue, and boosting the government's food security efforts in the long run.

The fish value chain consists of fishermen, aggregators, traders, distributors, and processors. Figure 19 shows an overview of the key pathways within the fish value chain in Kenya:

3.4.2. Utilisation of CCI within the Fish Value Chain

CCI at Production/Fishing Level: Most CCI technologies used at the fishing stage involve ice blocks stored in cooling boxes fitted onto boats. Fish is stored in these cooling boxes as soon as it is caught. The main disadvantage of this method is that the ice blocks often melt during transit, which results in losses. Big fish farms around Lake Victoria, such as Victory Farms, have installed ice-making machines on-site. But as the value chain matures, more sophisticated technologies are being adopted. Players like Vakava, for example, are distributing ice boxes that use dry ice instead of water ice.

Figure 18: Fish Production in Kenya (000's tonnes)[cxxix]

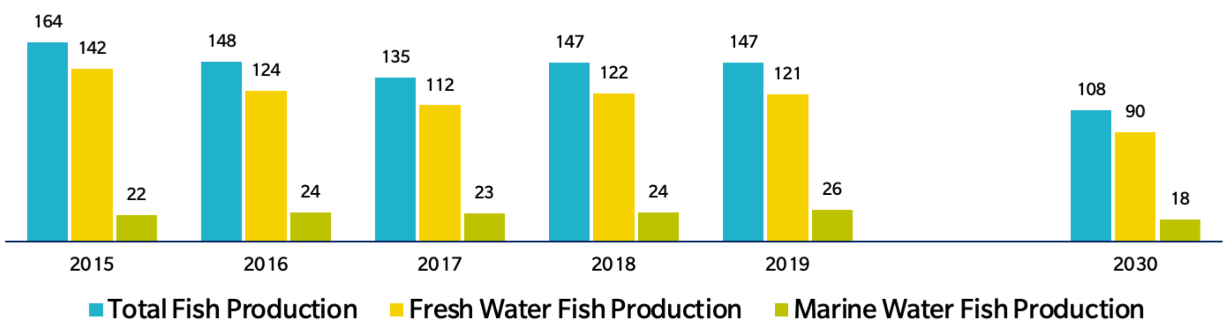
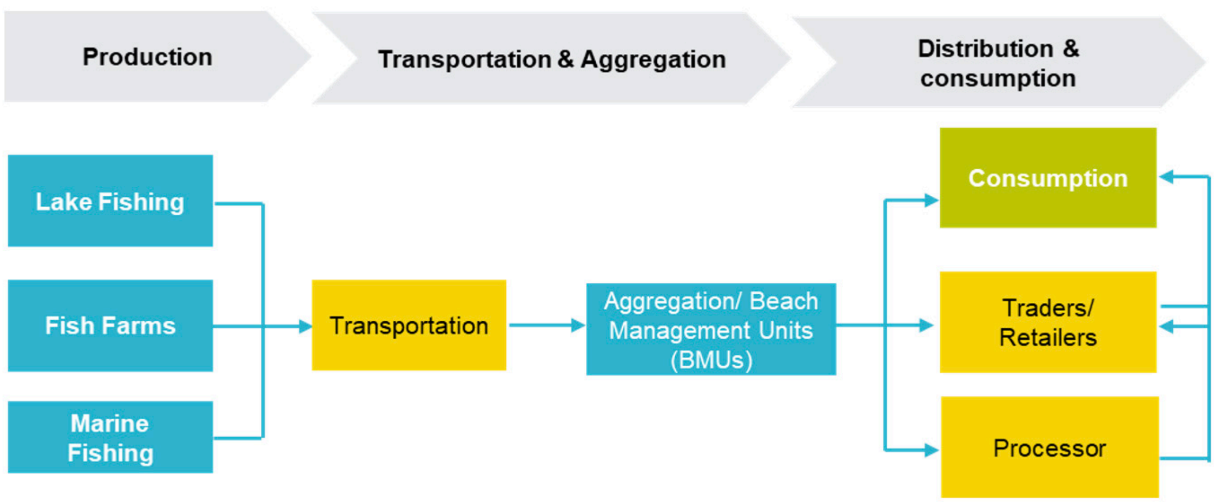


Figure 19: Summary of the Fish Value Chain in Kenya



CCI at Transport Level: Fish is gutted to increase its shelf life before transportation. Most caught fish is transported overnight when temperatures lower, minimising losses. This is due to the limited cold chain infrastructure in the fish transport value chain. A CCI technology that does exist at the transport level is ice blocks, often used to fill transport crates.

CCI at Aggregation and Retail Level: Various CCI technologies are utilised at this level, including solar-powered freezers, cool boxes, and cold stores/rooms. Several fish value chain stakeholders support fishermen by storing their fish once it reaches the shore for aggregation; the Kenyan government, for instance, has built refrigerated storage rooms in Vanga, Shimoni, Malindi, Mombasa and Lamu, but due to power cuts, only the storage room in Mombasa operates regularly. Development partners are also helping to set up CCI technologies at this level. Under its Green Cooling Initiative (GCI), GIZ has supported installing cold rooms near Lake Victoria that fishermen can use; these cold rooms can store up to five tons of fish and keep them fresh for two to three days.[cxxx]

CCI At Processing Level: Fish processing in Kenya is very minimal and generally only for imported fish. CCI technologies at this level include on-grid and solar-powered cold rooms.

3.4.3. Challenges in Utilisation of CCI in the Fish Value Chain

CCI faces various barriers to adoption within the fish value chain. Some of these challenges include:

Affordability gaps: Some cold chain solutions may be outside the disposable income limit of customers. Smallholder fishermen typically earn as little as UDS$5.5/day, so they may not be able to pay upfront for equipment that could cost anywhere from US$880 to 2,750. Solution providers need to innovate and introduce low-cost products for this target market.

Large market share of cartels and middlemen: Certain market actors appear to be monopolizing distribution. Large, predatory distributors, who have access to ice and cold storage technology, compel fishermen to sell their fish at low prices.

Limited awareness: With no central repository of information about CCI technologies and little support for start-ups in the sector, fishermen and traders require access to more information. There is also limited research on cold storage technology related to fisheries and no clear policy guidelines supporting CCI growth among fishing communities. Although fishing remains widespread around Lake Victoria, CCI solutions are yet to be widely adopted. There is a need to increase awareness of CCI in the fish sector.

Lack of affordable finance: Access to finance is a challenge mentioned by all stakeholders. Local fish processors and aggregators cannot compete with the Chinese products on the market, which are often cheaper to the end user due to economies of scale. Fishing communities don't have the affordable financing support needed to procure modern equipment or CCI technology. PAYG solutions for CCI in the fish sector are also underdeveloped, making it even less viable for fishermen.

3.4.4. Potential Interventions to Increase the Uptake of CCI Utilisation in the Fish Value Chain

Technology support: Start-ups and SMEs need support to help them embed PAYG technology into their CCI offerings, particularly those targeting small-scale fishermen. Given the tampering and theft risks associated with portable coolers, increasing technical support can help to equip these products with GPS tracking, remote monitoring, and other security solutions. Products that meet minimum energy performance standards should also be promoted, focusing on energy efficiency, low carbon emissions, stability, and other key variables. This will enhance market confidence and build consumer trust.

Enable affordable financing: Financing interventions like research and development support could enable CCI business models to pilot in new regions, helping companies to refine their go-to-market strategy. Affordable patient capital is also required for companies serving smallholder fishermen that have demonstrated scale and are looking to become viable.

Market development support: The fish value chain can be enhanced by aggregating small fishermen who can adopt CCI solutions using group ownership models. For example, fishing communities around Lake Victoria can pilot this approach. The market could be further developed by working with tertiary institutions at the community and county levels, increasing awareness of and technical capacity to create low-cost, high-quality solutions.

Policy development support: Policy support is required to grow the CCI market for the fish value chain. For example, awareness-raising drives to encourage fish farming in new regions would boost the demand for cold chain solutions. Other policy interventions include favourable taxation regimes for CCI technology providers and highlighting the needs of fish CCI technology in the broader institutional framework around agriculture and food security. This could be achieved through more inter-county coordination working groups to discuss CCI, piloted in Western Kenya, along the marine coastline, and in other regions where fishing is widespread.

Annexure 2: List of Stakeholders for Primary Interviews

Sr. No.	Company / Organization	Type of Organization	Name of Stakeholder
1.	Fosera	Enterprise	Maylin Kaeppeler & Konstatin Lelovas
2.	Sure-Chill	Enterprise	Tim Rump
3.	Powering Agriculture (Tetra Tech)	Consultancy	Headley Jacobus
4.	Vakava	Enterprise	Harry Omondi
5.	Ecozen	Enterprise	Devendra Gupta
6.	Danifoss	Enterprise	Naveen Sivakumar & Friedrich von Muenchow-Pohl
7.	SunFunder	Investor	Rim Azirar
8.	Power Africa Off-grid Project (PAOP)	Development partner	Joc Ngen'y
9.	InspiraFarms	Enterprise	Julian Mitchell
10.	FreshBox	Enterprise	John Mbindyo
11.	Strathmore Energy Research Centre	Consultancy	Thomas Bundi
12.	Self-Chill (Phaesun GmbH)	Enterprise	Geraldine Quelle
13.	Fresh Produce Exporters Association of Kenya (FPEAK)	Association	Patric Ngenga
14.	Acumen EA	Investor	Ivy Macharia
15.	Tree_Seal.mals	Enterprise	Tracy Kimathi
16.	Open Capital Advisors (OCA)	Consultants	Keru Munene
17.	Interveg Exports Ltd.	Enterprise	John Maina
18.	GCCA	Association	Rusty James
19.	Freight in Time (FIT)	Enterprise	Shamit Shah
20.	Solargen Technologies	Enterprise	Cosmas Koech
21.	NorthRift Dairy	Enterprise	Haron Cherutich
22.	ENdep Limited (Baridi Box)	Enterprise	Rugola Mtandu
23.	D Grid Energy	Enterprise	Eugene Faison & Solomon Asad

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