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ASSESSMENT OF THE COLD CHAIN MARKET IN INDIA

MARCH 2023

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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. Current Efficiency for Access Coalition members have programmes and initiatives spanning 62 countries and 34 key technologies. It is co-chaired by UK aid and the IKEA Foundation.[i] This report seeks to provide EforA stakeholders with an understanding of the role and potential of 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 India across key value chains (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.

This study was carried out by pManifold (authors: Rahul Bagdia, Yamini Keche, Ankit Agrawal, Apurva Parakh and Akshay Gattu) and Intellecap, and was supported by CLASP.

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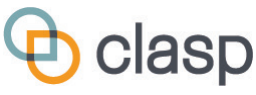

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ABBREVIATIONS

AIF	Agriculture Investment Fund
APEDA	Agricultural and Processed Food Products Export Developing Authority
APLM	Agricultural Produce & Livestock Marketing
APMC	Agricultural Produce Market Committee
BCD	Basic Customs Duty
BEE	Bureau of Energy Efficiency
BMC	Bulk Milk Chillers
CA	Controlled Atmosphere
CAGR	Compounded Annual Growth Rate
CCI	Cold Chain Infrastructure
CS	Cold Storage
CSO	Civil Society Organisation
CY	Commercial Year
DAC & FW	Department of Agriculture Cooperation and Farmers Welfare
DCS	Dairy Cooperative Societies
DFI	Doubling Farmers' Income
EE	Energy Efficient
EESL	Energy Efficient Services Limited
EV	Electric Vehicle
FAO	Food and Agriculture Organisation
FDI	Foreign Direct Investment
FFV	Fresh Fruits and Vegetables
FI	Financing Institution
FPO	Farmer Producer Organisation
GDP	Gross Domestic Product
GOI	Government of India
GPS	Global Positioning System
GST	Goods and Service Tax
HMNEH	Horticulture Mission for North East and Himalayan States
ICAP	India Cooling Action Plan
ICAR	India Council of Agriculture Research
INR	Indian Rupee
ISAM	Integrated Scheme for Agricultural Marketing
ITDP	Integrated Tribal Development Project
JLG	Joint Liability Groups
MIDH	Mission for Integrated Development of Horticulture
MOFPI	Ministry of Food Processing Industries
MPEDA	Marine Products Export Development Authority
MT	Metric Tonne
NABARD	National Bank for Agriculture and Rural Development
NAM	National Agriculture Market

ABBREVIATIONS

NCCD	National Cold Chain Development
NE	North East
NFDB	National Fisheries Development Board
NGO	Non-Governmental Organisation
NHB	National Horticulture Board
NHM	National Horticulture Mission
NISE	National Institute of Solar Energy
OEM	Original Equipment Manufacturer
PACS	Primary Agricultural Credit Societies
PCM	Phase Change Material
PMKSY	Pradhan Mantri Kisan SAMPADA Yojana
PMMSY	Pradhan Mantri Matsya SAMPADA Yojana
PPP	Public Private Partnership
PSU	Public Sector Units
PV	Photovoltaic
ROI	Return on Investment
SFAC	Small Farmer Agri-Business Consortium
SHG	Self-Help Groups
SWP	Solar Water Pump
TERI	The Energy and Research Institute
TFO	Total Financial Outlay
VCC	Vapour Compression Cycle
WHO	World Health Organisation

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GLOSSARY

Capital Expenditure	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
CCI projected 2030	Projected market size for CCI by 2030
'As is' market size	Cold chain infrastructure market size from 2019, which is the latest historical data available based on FAO's data sets
First mile	Stage between production at farmgate and the point of aggregation or collection of produce
Third Party Logistics (3PL)	An organisation (a third party) provides logistics services, such as warehousing & storage or transportation, to farmers' collectives or companies in need of cold chain inventory management and distribution
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
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

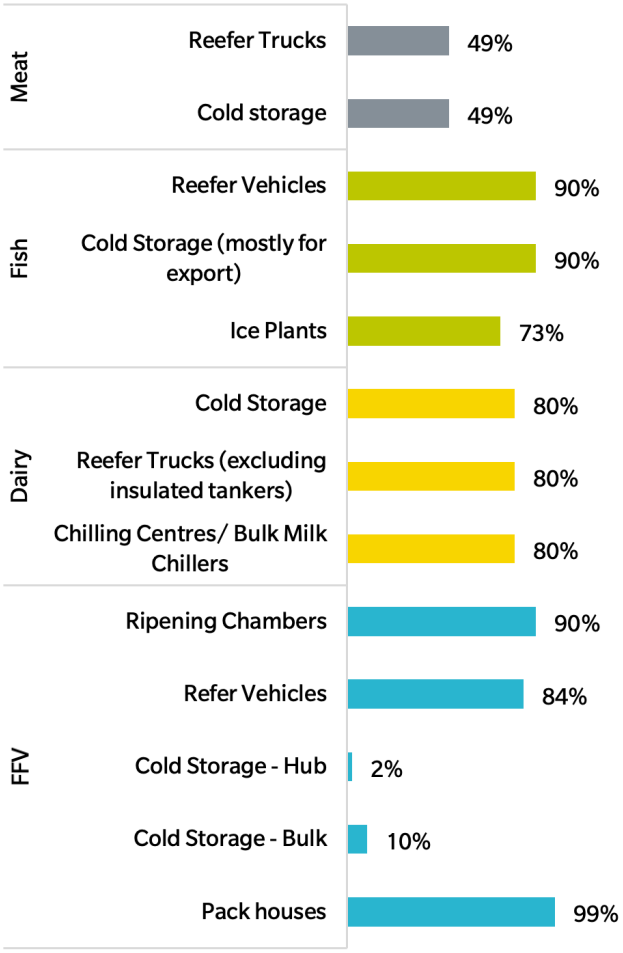
India is the world's highest milk producer and the second-largest food producer. Agriculture, alongside its associated sectors, is India's largest source of livelihood. 70% of rural households depend primarily on agriculture, and 86% of farmers are smallholders. Despite this production level, India is still home to over 190 million malnourished people, a quarter of the world's total. The Global Hunger Index 2020 report ranks India 94th out of 107, lagging behind neighbouring countries like Bangladesh, Pakistan and Nepal. Farmers and food producers, especially smallholder farmers, still struggle with low-income levels, and 4.6-15.9% of fruits and vegetables (FFV) are lost annually throughout the supply chain. The country loses approximately INR 926 billion (US$14.33 billion) every year due to post-harvest losses, and US$19.4 million worth of crops are wasted in India daily due to rejection at the farmgate and delays in the distribution process with significant impacts on the environment in terms of toxic waste, water pollution, long-term damage to ecosystems, hazardous air emissions, greenhouse gas emissions and excessive energy use. Effective Cold Chain Infrastructure (CCI) is one intervention that could mitigate many of these challenges.

A cold chain is an environmentally controlled chain of logistics activities that cools and preserves 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 carbon 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 FFV, dairy, fish and meat value chains in India and the Cold Chain Infrastructure (CCI) required. It establishes and 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, the capital expenditure (CAPEX) business method was considered, whereby CCI technology users purchase the asset upfront.

CCI deployment in India is underdeveloped for required value chains. The bulk of India's cold storage consists of single commodities like potatoes and grains, with less than 10% of agricultural produce passing through a cold chain. Though some CCI components exist, an integrated system still needs to be added for most value chains. Most FFV losses occur between the farmgate and post-harvest handling (the first mile). But there is a 99% gap in required CCI (i.e., packhouses) at this first mile, weakening post-harvest management. This CCI gap persists in the dairy sector (~80%) and fish (70%) value chains.

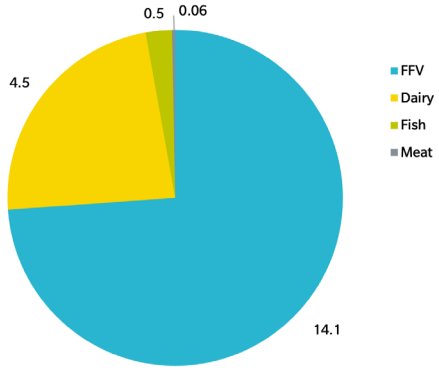
Figure 1: CCI Gap Across Value Chains in 2020



Not all value chains have the same CCI needs. Compared to FFV, fish and dairy, the CCI required for meat is negligible, as 90% of the meat market is informal. Most meat is consumed at the abattoir level immediately after slaughtering, without the need to pass through a cold chain.

The total market opportunity for CCI deployment is estimated at US$19.2 billion by 2030 under a CAPEX market sizing model. FFV provides the most significant opportunity for CCI deployment, followed by dairy (Figure 2). Both are highly perishable products and therefore have high requirements. This value excludes other major CCI markets, like floriculture and healthcare; however, they are beyond the scope of this study.

Figure 2: CCI Market Opportunity by 2030 Across Different Value Chains (in US$ billions)



Different CCI will grow at different rates for each value chain considered. Packhouses and reefer trucks are the main CCI drivers in the FFV cold chain (CAGR of 51% and 34%) 2021-2030. **Government incentives will accelerate the high estimated growth** and are also expected to drive the deployment of more ripening chambers. The growth rate of cold storage is likely to shrink to 2.5% for 2020-2030 since the government's initial focus was on developing cold storage that bridged the most significant infrastructure gaps. Finally, the industry is expected to shift from single-commodity cold storage units to multi-commodity units with higher utilisation rates throughout the year. Multi-purpose cold storage accounted for only 23% of the total capacity in 2009 but has since risen to 30% in 2020. By 2030, bulk milk chillers could be installed at around 60% of Dairy Cooperative Societies (DCSs). The export-oriented fish and meat value chains expect future growth based on a doubling of capacity in the last ten years: cold stores and reefer vehicles will be the most significant.

Despite India's near-universal electricity coverage off the grid, CCI still has a role to play. Given India's 98% electrification rate, the total potential off-grid CCI market is estimated to be only US$191 million by 2030, reducing over time as the electrification rate improves. However, power supply in rural areas remains intermittent, and with cold chain solutions requiring an uninterrupted power supply, there will likely be a continued need for off-grid CCI solutions. A few thousand solar cold rooms are already installed, generating interest and acceptance among farmers for the storage of FFV. Utility in other value chains like fish and meat is not yet proven, given the lower temperature requirements that translate to high costs of technically accommodating these requirements on an off-grid system. Biomass-powered bulk milk chillers are being piloted In the dairy value chain.

India's cold chain needs are primarily driven by growth in the formal food retail, food processing and biomedical markets. Major dairy companies, retail chains and online grocers have received approval from the government to set up cold chain infrastructure under its sanction of 101 new integrated CCI projects, which is expected to attract investment of INR 3,100 crore (US$41 million) to the sector.

The growing penetration of formal-sector food retail is dictating the development of efficient cold chain supply management, with companies like Amazon, Zomato and Licious (an online frozen meat distributor) engaging with farmers and government bodies to develop a sustainable farm-to-fork model.[ix]

There is existing government support for cold chain infrastructure. The Government of India is implementing schemes for financial assistance in setting up cold storage for agricultural products throughout the country. The Mission for Integrated Development of Horticulture (MIDH), implemented by the Department of Agriculture Cooperation and Farmers Welfare (DAC&FW), provides financial assistance for horticulture activities, including cold storage installation. Assistance is available in subsidies equal to 35% of the project cost, which increases to 50% in hilly and scheduled areas. To reduce post-harvest losses and provide higher prices to farmers, the Ministry of Food Processing Industries (MOFPI) is implementing its Scheme for Integrated Cold Chain, Value Addition and Preservation Infrastructure as one component of a programme called Pradhan Mantri Kisan SAMPADA Yojana (PMKSY). A recently established Agriculture Investment Fund (AIF) of INR 100,000 crores provides collateral-free loans and an interest subvention of 3% for CCI development.

Cold chain development requires full-cycle 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 considered in CCI in the choice of power, technology choice, refrigerants and in its 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.

India has several challenges in growing CCI:

- Low public awareness of the added value of CCI, which is perceived as a luxury rather than a necessity.
- Affordability is a significant challenge for CCI deployment due to factors such as long payback periods for CAPEX-intensive assets and margins that need to be higher to make these assets affordable to the smallholder farmers who form the mass market. CCI in India is owned and operated by Agriculture Product Marketing Committees (APMCs)[2] and private players. Such assets are unaffordable for small and medium-sized farmers but within reach for large farmers or farmers' groups with some financial assistance. Rental or pay-as-you-store business models, for which uptake is currently low, could help solve the problem of high upfront costs of CCI assets, thus improving accessibility. Combining cold storage units with other post-harvest management or processing

1. In November 2020, the government announced a production-linked incentive scheme for ten key sectors. For the food processing sector, an outlay of INR 10,900 crore has been proposed over the next five years.
2. An APMC is a marketing board established by state governments in India to ensure farmers are safeguarded from exploitation by large retailers, as well as ensuring that the farm-to-retail price spread is not excessive.

solutions could also provide additional market linkages, thus making the units more viable.

- Access to financing is a challenge. Long payback periods often result in lower investment returns and present the risk of assets becoming obsolete as the technology evolves, dissuading commercial investors from deploying capital into the sector. More patient capital is required, with support from donors willing to fill the gap by providing grant capital and results-based financing to incentivise financiers to deploy capital, especially financiers in the clean energy and agriculture nexus.
- Available capital should align with the expected cashflows of CCI business models from a tenor and cost perspective to align the interests of funders and enterprises.
- Another significant barrier to CCI growth is access to market linkages, which is particularly important for nascent Farmer Producer Organisations (FPOs) and those intending to use a CCI asset to diversify their businesses.

Recommendations

India'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 India'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 of the Study

CLASP mandated pManifold and Intellecap to evaluate and segment the market for cold chain technologies across four value chains (fish, dairy, meat and fruits & vegetables) in India. The objective of this research was 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:

- 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 CCI value chain for each of the given value chains
- Developing case studies on innovative business and financial models deployed by off-grid solar refrigeration enterprises in India

Methodology

To assess the cold chain market in India, data was collected from both primary and secondary sources. The key components of this research were as follows:

- **Secondary research:** An extensive literature review was conducted to understand the state of the CCI market in India. This included industry research reports, press releases, official government websites, media articles and blogs. Some of the major reports on CCI include the All India Cold-Chain Infrastructure Capacity Assessment of Status & Gap by NCCD; Demand Analysis for Cooling by Sector in India in 2027 by AEEE; and the India Cooling Action Plan (ICAP) by the Ministry of Environment, Forest and Climate Change. Based on these sources, a comprehensive framework was developed to estimate current and future CCI deployment.
- **Stakeholder consultations:** Interviews were conducted with approximately 15 industry experts, and the resulting data and insights were collated to conduct qualitative and quantitative analysis of the challenges, opportunities and market size of CCI across value chains. Stakeholder consultations also helped fill data gaps and validate the secondary research findings. The stakeholder groups that were consulted were CCI technology providers, system integrators and service providers.
- **Calculation of the market size of CCI in India:** Based on analysis of the quantitative and qualitative data, we triangulated the overall current market size and 2030 potential market size, and identified CCI growth drivers and challenges for each value chain.

Various market models were analysed in order 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 market from two perspectives: (a) a capital expenditure (CAPEX) perspective, whereby users of CCI technologies purchase the asset upfront; and (b) a Cooling-as-a-Service (CaaS) perspective, whereby users of CCI technologies are paying on a per-use or a per-crate basis and do not own the asset themselves. These were identified as the two most common business models in the sector.

Each value chain is unique. The following factors have been taken into consideration for this analysis:

- In the dairy market, the most commonly-used CCI component is bulk milk chillers installed at dairy cooperative societies. Estimates for the number of bulk chillers are based on the number of dairy cooperatives in that country.
- In the fish and meat value chains, CCI is mostly export-driven. The CCI assessment for fish and meat therefore focuses on cold storage and transport (reefer vehicles), not on retail market applications.

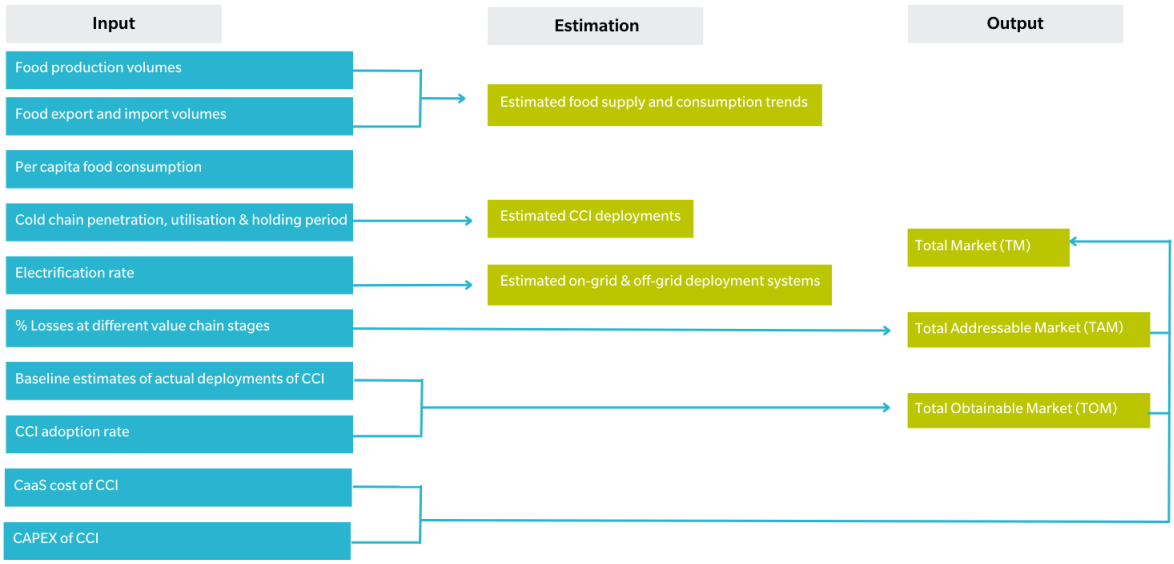
1.2. Limitations of the Study in India

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

- **The absence of a database specific to the dairy, fish and meat value chains:** CCI analysis in India was done in 2015 by NCCD, but was focused only on fruits and vegetables and did not cover the dairy, fish and meat value chains. There was also limited data on the losses attributable to a lack of CCI. To overcome this challenge, data gaps were filled through stakeholder consultations.
- **Potential market:** Healthcare and floriculture are major markets for CCI development in India, but are outside the scope of the study. All the market sizing numbers relate therefore only to the FFC, dairy, fish and meat value chains.

The CCI market size was estimated using the following framework:

Figure 3: Framework for Market Analysis



Market Assessment

2.1. Cold Chain Infrastucture in India

CCI in India largely consists of bulk cold storage, mostly for single commodities like potatoes and grains. There is little awareness of the need for farmgate packhouses (pre-cooling units with cold rooms) or other CCI components, resulting in low deployment and adoption rates. In 2015 the National Centre for Cold Chain Development (NCCD), formed by the Government of India to promote cold chain, identified a gap of 99% in packhouses and 9% in FFV cold storage. At the time of conducting this study in 2020, we found this FFV gap still exists, and analysis also revealed other significant infrastructure gaps at different stages of all four value chains (as shown in Table 2):

Although major CCI gaps exist in the FFV, fish and dairy value chains, the gap for meat is much lower. This is because 90% of this market is informal, whereby meat is consumed at the abattoir level immediately after slaughtering. For FFV, CCI consists mostly of cold storage units for single commodities like potatoes, onions, and grains, while a significant gap exists in packhouses, reefer vehicles and ripening chambers. For dairy, considering the highly organised nature of the market, there is a nearly 80% CCI gap in CCI components.

Figure 4: CCI Gap Across Value Chains in 2020

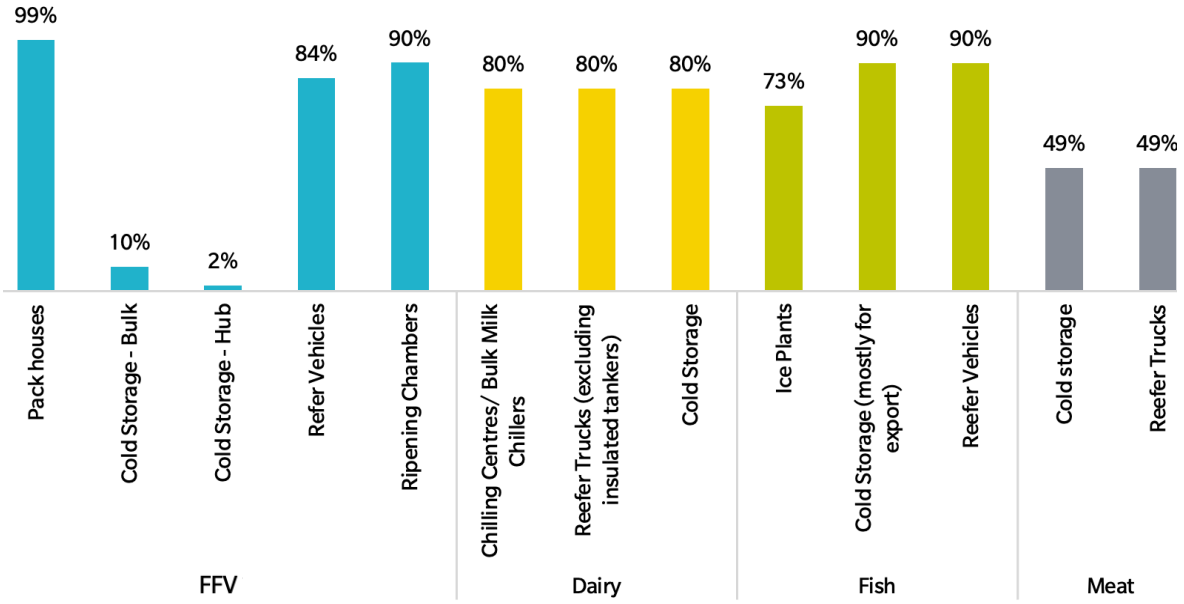


Table 2: Estimated CCI Deployment and Requirements in India Across Different Value Chains (2020)

VALUE CHAIN	CCI COMPONENT	REQUIRED (NOS.)	CREATED (NOS.)	GAP (%)
FFV	Packhouses	83,041	675	99%
	Cold Storage - Bulk	6,669	6,026	10%
	Cold Storage - Hub	231	225	2%
	Reefer Vehicles	70,035	11,000	84%
	Ripening Chambers	12,654	1,232	90%
Dairy	Chilling Centres / Bulk Milk Chillers	260,737	52,147	80%
	Reefer Vehicles *	8,733	1,747	80%
	Cold Storage	196	39	80%
Fish	Ice Plants	1,017	272	73%
	Cold Storage**	6,294	624	90%
	Reefer Vehicles	6,104	606	90%
Meat	Cold Storage	37	19	49%
	Reefer Trucks	1,776	910	49%

*excluding insulated tankers **mostly for export

2.2. Summary of Cold Chain Infrastructure Market Size Projections by 2030

This report focuses on four value chains requiring cold chain solutions: fresh fruits & vegetables (FFV), dairy, fish and meat. Assuming a CAPEX market sizing model, the study has identified a total opportunity for CCI deployment of US$19.1 billion by 2030. The FFV market has the most potential for CCI growth, followed by dairy. In both these markets, first mile CCI like packhouses and bulk milk chillers has the most potential for growth, based on both CAPEX and CaaS models (Figures 5 and 6).This report focuses on four value chains requiring cold chain solutions: fresh fruits & vegetables (FFV), dairy, fish and meat. Assuming a CAPEX market sizing model, the study has identified a total opportunity for CCI deployment of US$19.1 billion by 2030. The FFV market has the most potential for CCI growth, followed by dairy. In both these markets, first mile CCI like packhouses and bulk milk chillers has the most potential for growth, based on both CAPEX and CaaS models (Figures 5 and 6).

Figure 5: Projected CCI Market Size (until 2030) CAPEX Model Across Value Chains (USD million)

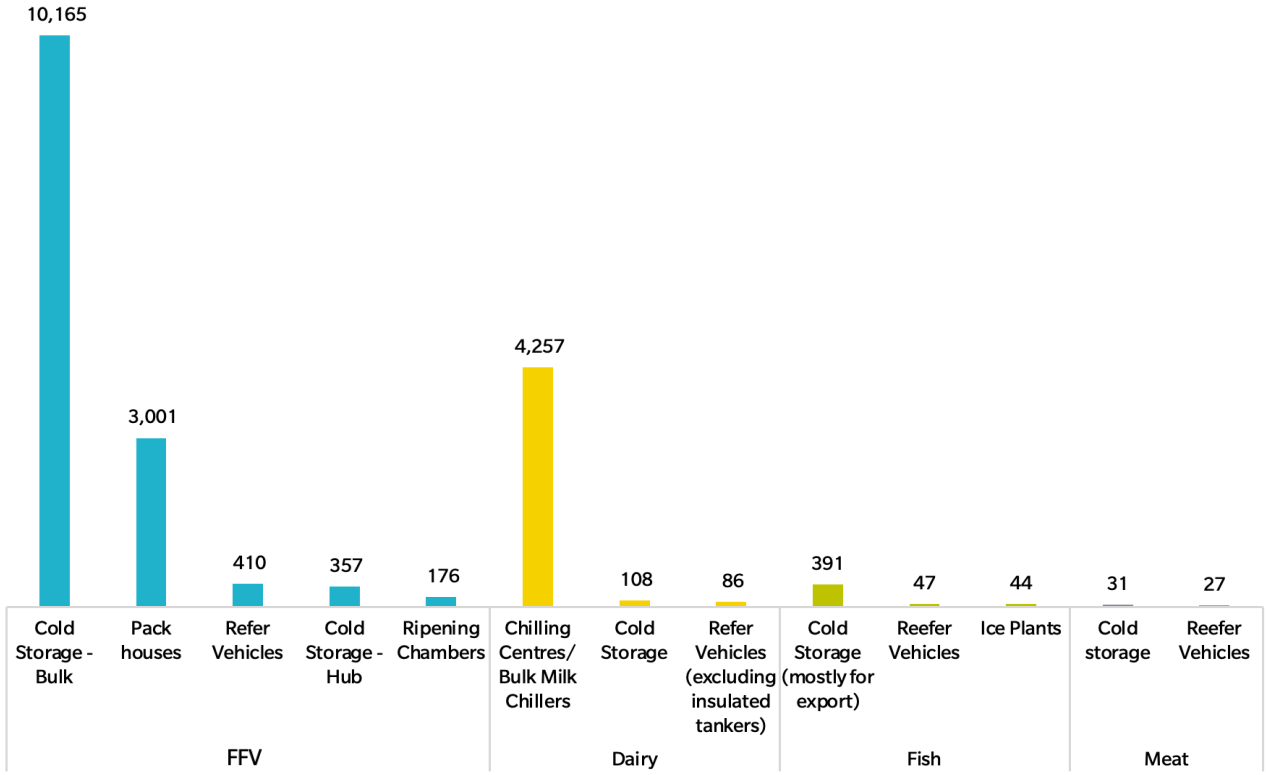
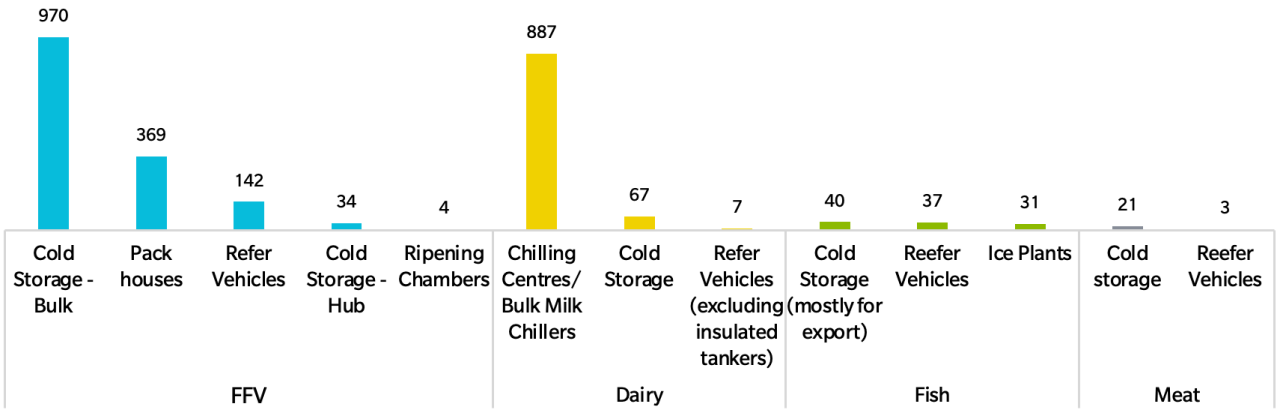


Figure 6: Projected CCI Market Size (until 2030) CaaS Model Across Value Chains (USD million)



Fresh Fruits & Vegetables (FFV)

The CCI market focus for FFV needs to shift from cold storage to other components of CCI, especially first mile cold chain solutions like packhouses.

- Packhouses and reefer vehicles are expected to benefit most from the Doubling of Farmers' Income (DFI) initiative, and are estimated to grow at a CAGR of 51% and 34%, respectively, from 2021-2030.
- Deployment of packhouses is expected to drive demand for reefer vehicles. It is estimated that two reefer vehicles would be required for every packhouse,[xii] provided that the round-trip distance between the packhouse and the consumption centre is more than 450 km.
- The historical growth rate of cold storage (including both bulk and hub storage) created in the country between 2014-2020 is approximately 2.7%. This is expected to shrink to 2.5% for the period 2020-2030, since the government's initial focus was on developing cold storage that bridged the most significant infrastructure gaps; there should be fewer gaps going forward.
- The industry is expected to shift from single-commodity cold storage units to multi-commodity units, which have higher utilisation rates throughout the year. Multi-purpose cold storage accounted for only around 23% of the total capacity in 2009, but has since risen to 30%.
- Government incentives are expected to drive the deployment of more ripening chambers, which are estimated to grow at a CAGR of around 30% from 2020-2030.[xiv]

The table below shows the Total Market (TM), Total Addressable Market (TAM) and Total Obtainable Market (TOM) for different CCI components in the FFV value chain, based on CaaS market sizing.

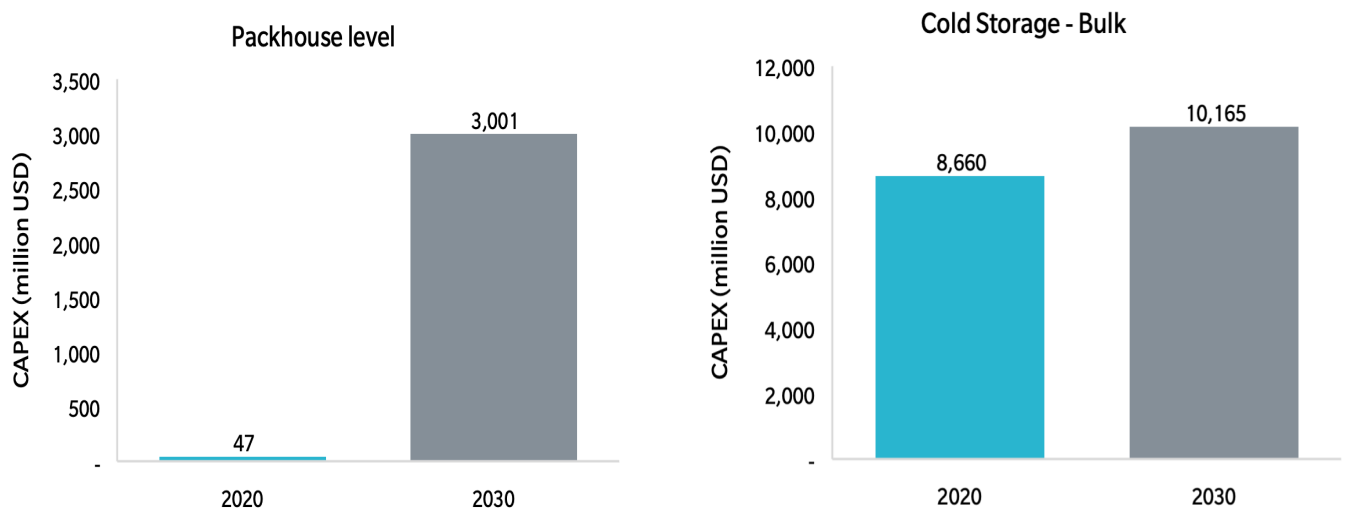
Table 3: Total Market, Total Addressable Market and Total Obtainable Market for different CCI components in the FFV Value chain, based on CaaS

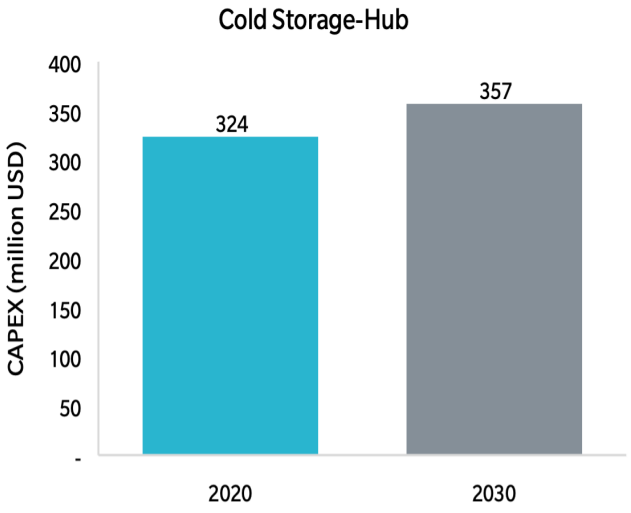
USD million

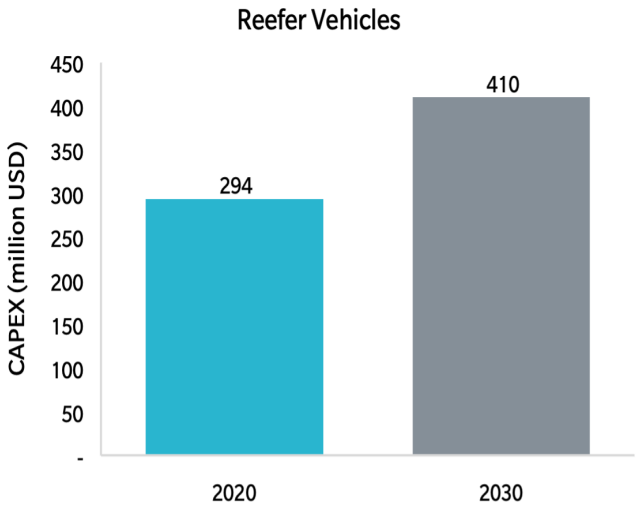
	Packhouses	Cold Storage - Bulk	Cold Storage - Hub	Reefer Vehicles	Ripening Chambers
Total Market (TM)					
2020	9.8	1,307	45	2,401	156
2030	10.7	1,409	52	2,708	221
Total Addressable Market (TAM)					
2020	7	915	32	1,681	109
2030	9	1,198	45	2,303	188
Total Obtainable Market (TOM)					
2020	0.1	827	31	264	11
2030	4	970	34	369	142

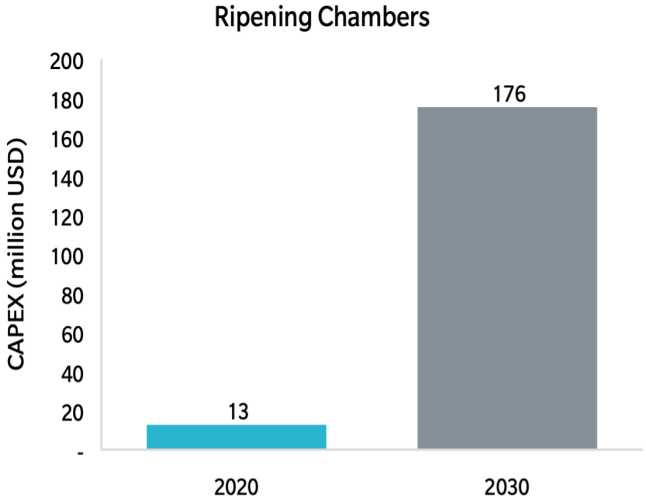
Using the TOM assessment, we can map the CAPEX investment that needs to be unlocked for each CCI component in the FFV value chain (Figure 7):

Figure 7: Projected CCI Market Size (until 2030) CAPEX Model Across FFV Value Chains (USD million)









Note: The per-unit average capacities considered in these calculation are: Packhouses=16MT per day; Cold Storage-Bulk=5,000 MT; Cold Storage-Hub=5,000 MT; Reefer Vehicles=10 MT; Ripening Chambers=10 MT per day

Dairy

In the dairy market, stakeholders and market experts expect bulk milk chillers (BMCs) to be installed at each dairy co-operative in remote and rural areas. By 2030, BMCs could be installed at around 60% of Dairy Cooperative Societies (DCSs); 80% of DCS in Gujarat have already installed them.

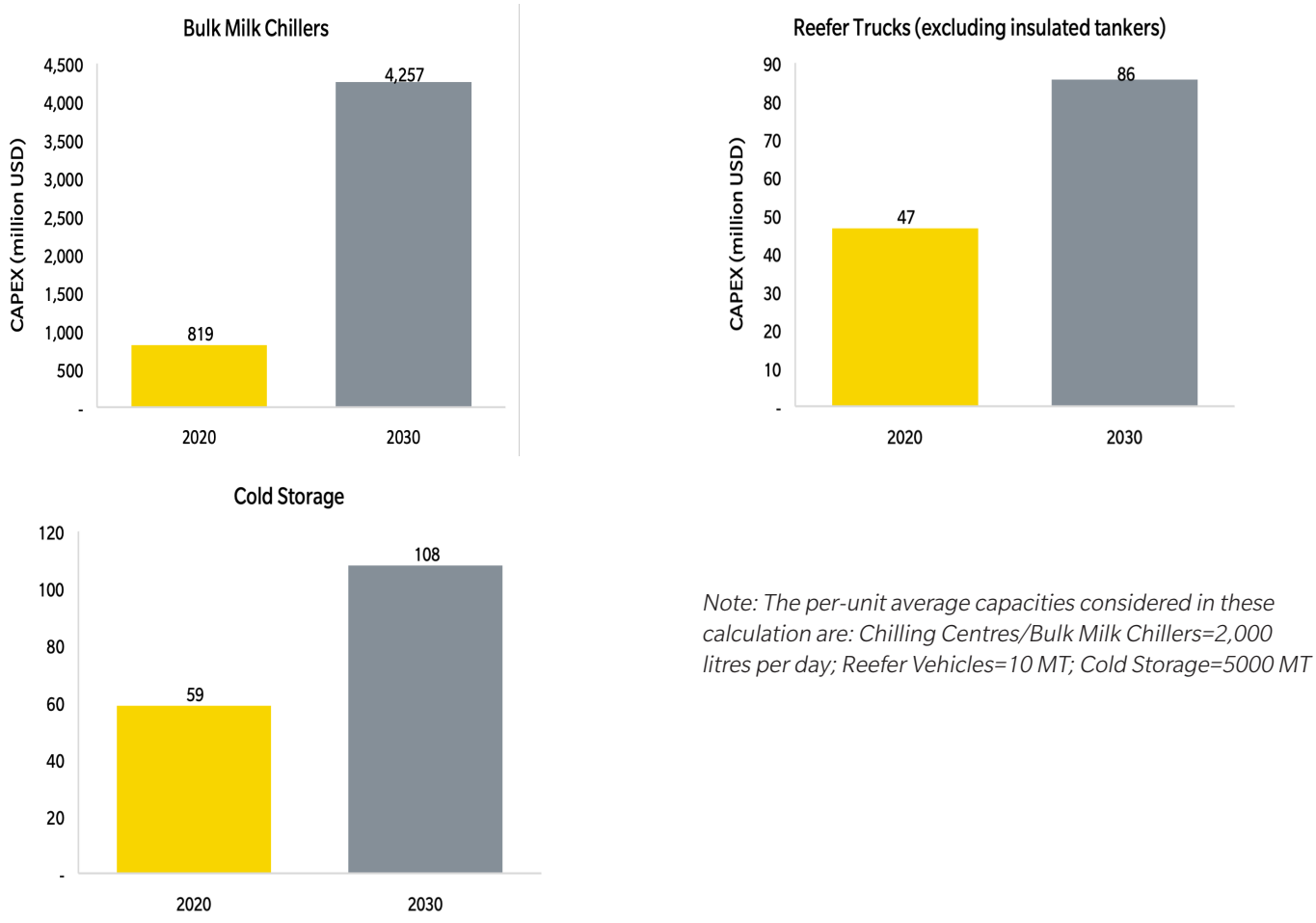
Table 4 shows the CCI Total Market (TM), Total Addressable Market (TAM) and Total Obtainable Market (TOM) for different CCI components in the dairy value chain, based on CaaS market sizing.

Table 4: Total Market, Total Addressable Market and Total Obtainable Market for Different CCI Components in the Dairy Value Chain Based on CaaS

			USD Million
	Bulk Milk Chillers	Reefer Vehicles	Cold Storage
Total Market (TM)			
2020	879	189	20
2030	4,571	347	37
Total Addressable Market (TAM)			
2020	853	183	20
2030	4,434	337	36
Total Obtainable Market (TOM)			
2020	171	37	4
2030	887	67	7

Using the TOM assessment, we can map the CAPEX investment that needs to be unlocked for each CCI component in the dairy value chain, as shown in Figure 8.

Figure 8: Projected CCI Market Size (until 2030) CAPEX Model Across Dairy Value Chain (USD million)



Note: The per-unit average capacities considered in these calculation are: Chilling Centres/Bulk Milk Chillers=2,000 litres per day; Reefer Vehicles=10 MT; Cold Storage=5000 MT

Fish

In the fish and meat value chains, both meat and fish cold storage capacities are estimated to have grown at a CAGR of 11.3% from 2014-2020; growth for these value chains is higher than for FFV, because both these markets are export-oriented. The total cold storage capacity for meat and fish has increased from 0.8% to 1.8% over the past ten years.

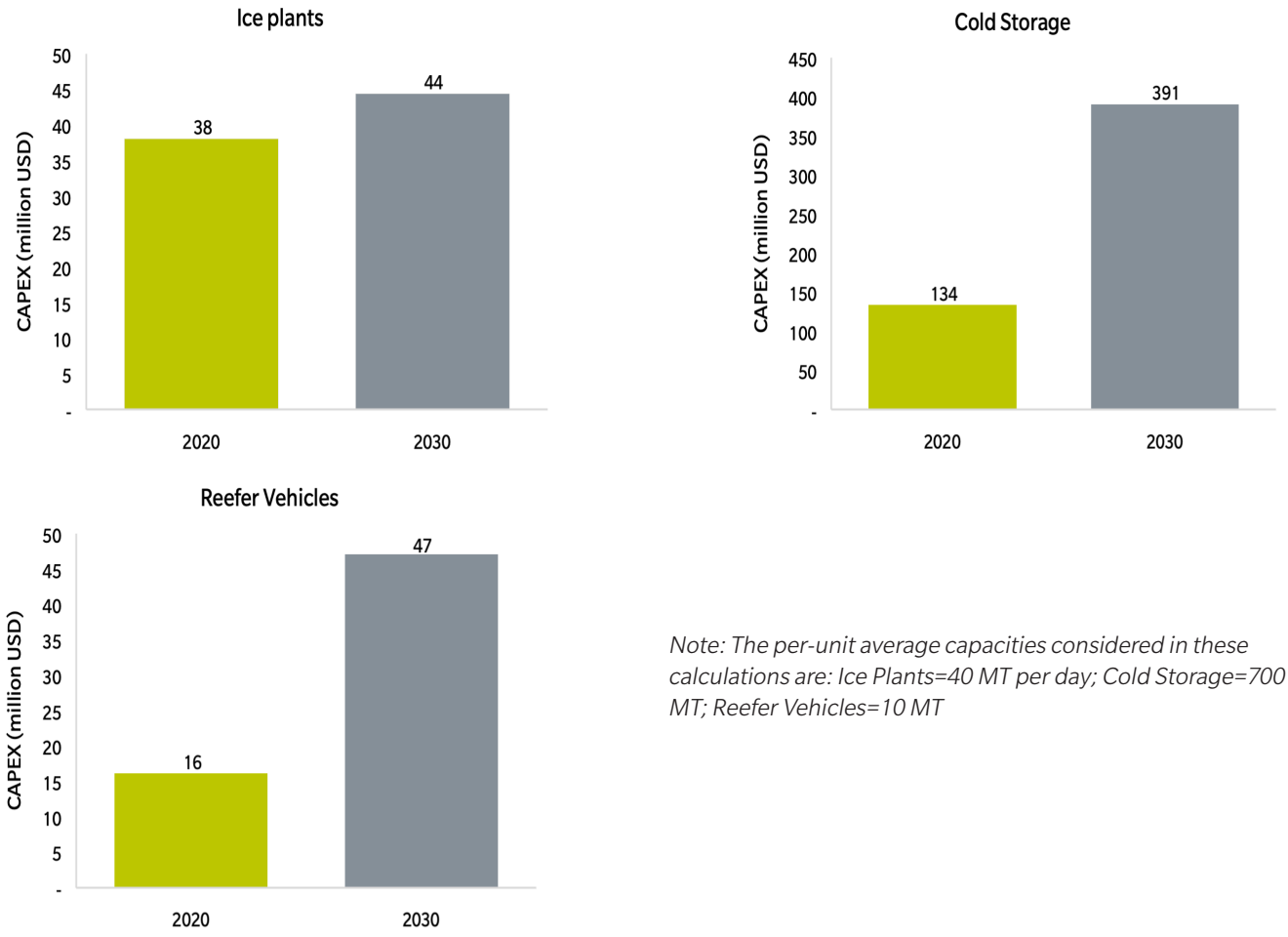
Table 5 shows the CCI Total Market (TM), Total Addressable Market (TAM) and Total Obtainable Market (TOM) for different CCI components ins the fish value chain, based on CaaS market sizing:

Table 5: Total Market, Total Addressable Market and Total Obtainable Market for different CCI components in the Fish Value Chain based on CaaS

			USD Million
	Ice Plants	Cold Storage (Mostly Exports)	Reefer Vehicles
Total Market (TM)			
2020	137	249	174
2030	265	481	336
Total Addressable Market (TAM)			
2020	128	183	128
2030	248	281	196
Total Obtainable Market (TOM)			
2020	34	18	13
2030	40	31	37

Using the TOM assessment, we can map the CAPEX investment that needs to be unlocked for each CCI component in the fish value chain, as shown in Figure 9.

Figure 9: Projected CCI Market Size (until 2030) CAPEX Model Across Fish Value Chain (USD million)



Note: The per-unit average capacities considered in these calculations are: Ice Plants=40 MT per day; Cold Storage=700 MT; Reefer Vehicles=10 MT

Meat

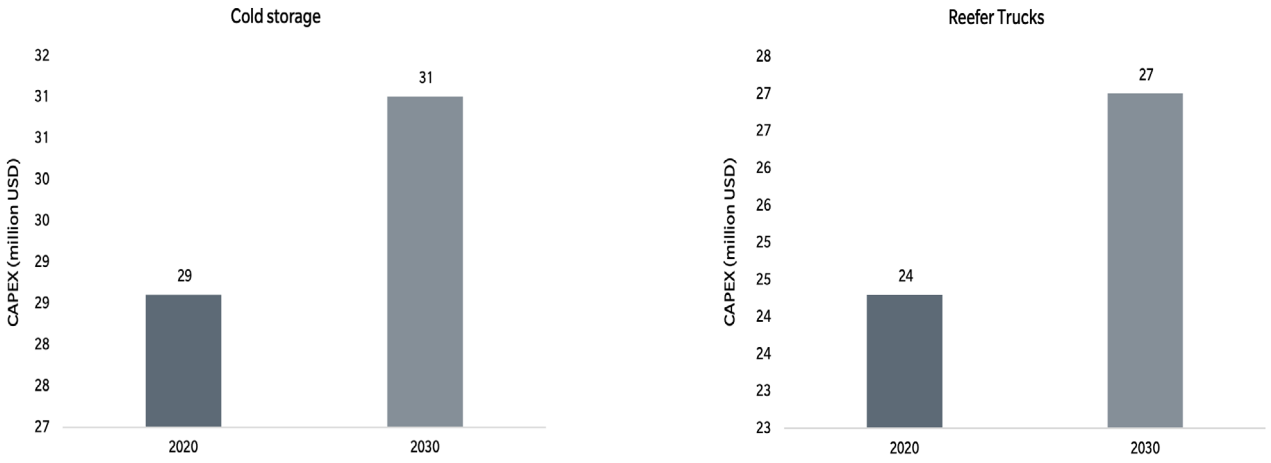
Table 6 shows the CCI Total Market (TM), Total Addressable Market (TAM) and Total Obtainable Market (TOM) for different CCI components in the meat value chain, based on CaaS market sizing.

Table 6: Total Market, Total Addressable Market and Total obtainable market for different CCI components in the Meat Value Chain Based On CaaS

		USD Million
	Cold Storage	Reefer Trucks
Total Market (TM)		
2020	6.2	38
2030	9.4	59
Total Addressable Market (TAM)		
2020	6.0	37
2030	9.1	57
Total Obtainable Market (TOM)		
2020	3.1	19
2030	3.4	31

Using the TOM assessment, we can map the CAPEX investment that needs to be unlocked for each CCI component in the meat value chain, as shown below:

Figure 10: Projected CCI Market Size (until 2030) CAPEX Model Across Meat Value Chain (USD million)



Note: The per-unit average capacities considered in these calculations are: Cold Storage=5,000 MT; Reefer Trucks=10 MT.

2.3. Drivers of CCI Uptake

CCI growth in India is primarily driven by government policies and initiatives to develop the food processing industry. The Government of India (GoI) recognises the importance of first mile cold chain infrastructure and has launched a number of different schemes to support its growth. But while government subsidies have played a vital role in supporting the development of CCI, the biomedical and pharmaceutical industries (including COVID vaccines) are further accelerating this growth. An organised retail sector, growing exports and changing consumption patterns also affect CCI uptake.

The following are key drivers for the uptake of CCI across the supply chain, from the first mile to the retail level:

First Mile Infrastructure:

1. Government initiatives and capital subsidies: The GoI is implementing various schemes through which financial assistance and capital subsidies are provided for setting up CCI for agriculture produce, including perishable horticulture produce. Some of these include the Pradhan Mantri Kisan SAMPADA Yojana (PMKSY) and the Mission for Integrated Development of Horticulture (MIDH), as well as sub-schemes like the National Horticulture Mission and National Horticulture Board.

- Under PMKSY, the Ministry of Food Processing Industry (MoFPI) has approved 41 Mega Food Parks, 353 cold chain projects, 63 agro-processing clusters, 292 food processing units, 63 backward- and forward-linkages projects, and 6 Operation Green projects across the country. Of these, 53 are in the FFV sector, 33 in the dairy sector and 15 in the meat, poultry and marine products sectors.[xv]
- In 2020, the Department of Fisheries launched the Pradhan Mantri Matsya SAMPADA Yojana (PMMSY) scheme to create and upgrade fishery infrastructure facilities (including CCI), to double fish exports, and to bring about a Blue Revolution (Neel Kranti) in the fisheries sector.
- Agricultural Produce & Livestock Marketing (Promotion & Facilitation) Act (APLM): Passed in 2017, the APLM legally permits cold storage units to function as agricultural markets; this promotes the development of all linked CCI, especially first mile cold storage for fruits and vegetables.
- Development of Gramin Agricultural Markets (GrAMs): Announced in the GoI's 2018-2019 budget, this policy focuses on market linkages at the first mile, encouraging farmers to aggregate their produce in order to gain direct access to local retail markets.
- The government runs a number of programmes to cover project costs. These take the form of credit-linked subsidies ranging from 35% to 50% (MIDH), one-time grants of 50% to 75% (MoFPI) for integrated projects, and low-interest loans of 9.25% to 10% under the Warehousing Infrastructure Fund from the National Bank for Agriculture and Rural Development. These schemes have improved the availability of finance for CCI development,[xvi] and have boosted adoption of CCI at the aggregator and Farmer Producer Organisation (FPO) level.
- These policies and programmes are being supported by higher budgetary allocations and non-budgetary financial resources that create Corpus Funds.[3] The latest major initiative is the Atma Nirbhar Bharat-Agriculture, which includes comprehensive market reforms and the creation of an Agricultural Infrastructure Fund (AIF) worth INR 100,000 crore.[xvii]

2. Agriculture reforms promoting CCI: The government has set a goal of doubling farmers' income. They have rolled out several market reforms to achieve this, including the 2017 Agricultural Produce & Livestock Marketing (Promotion & Facilitation) Act turning private cold storage facilities into regulated markets. 22,000 Gramin Agriculture Markets (GrAMs) are also being developed with packhouses to store and dispatch produce. Other reforms include an Agri-Export Policy that aims to double agricultural exports by 2022, and the development of 10,000 FPOs by 2024.

3. Growth of the export market: India is currently ranked 10th among major agricultural exporters globally, according to WTO trade data from 2016. The country's share of global agricultural exports increased to 2.2% in 2016, up from 1% several years earlier. Recent growth rates suggest that today, agri-food production is rising even faster, and the growth of exports is accelerating; in 2020-21 exports of agriculture and allied products (including marine products) increased by 17% to US$41.25 billion, up from US$35.16 billion the previous year.[xviii] According to the Agricultural and Processed Food Products Export Development Authority (APEDA), frozen vegetable exports alone increased from US$34.62 million in 2017-18 to US$43.39 million in 2019-20.[xix]

There is tremendous potential for India to further grow the export of perishables, from both a demand and supply perspective. But due to stringent quality requirements and regulations, this growth depends on a strong, integrated cold chain. Recognising this need, the Indian government has been ramping up efforts to boost CCI development with a raft of new incentives and policies.

For example, the Agriculture Export Policy (AEP) was launched in 2018 with the aim of creating a robust infrastructure to strengthen agricultural value chains and achieve an export target of US$60 billion by 2022, rising to US$100 billion a few years later. The proposed infrastructure includes packhouses, processing infrastructure, cold storage, exit point infrastructure, air cargo, Mega Food Parks and state-of-the-art testing laboratories.[xx]

3. A Corpus Fund is defined as a capital fund: an amount kept aside for an organisation/entity to operate, exist and maintain itself.

Processing and Retail Infrastructure:

1. Growth of the food processing industry and organised retail: India's food processing industry accounts for 32% of the total food market, making it one of the largest industries in the country. The GoI has recognized the food processing sector as a high-priority industry; it has been promoting it with various forms of fiscal relief and incentives, and is encouraging investments in the sector with a strong focus on supply chain infrastructure. Growth in the food processing industry is also being driven by growth in the formal food retail sector, as well as by increasing urbanisation. The production of processed and frozen FFV, dairy, meat and fish products requires a temperature-controlled supply chain from the point of origin to the last point of the distribution channel. The growing penetration of formalised food retail outlets, where such products are sold, is therefore boosting the development of efficient cold supply chains and cold chain infrastructure.

Most organised retail players acknowledge that strong cold chain infrastructure is a key component of an efficiently managed supply chain. Major dairy companies, retail chains and online grocers such as Amul, Haldiram's Group and Big Basket have received government approval to set up cold chain infrastructure, which is expected to attract investment of INR 3,100 crore (US$41 million) to the sector. Online food delivery and grocery markets in India are still at a nascent stage of development, but are witnessing exponential growth; the e-Grocery market grew 60% from 2019 to 2020, and was expected to expand an additional 41-49% by the first half of 2021. To boost the online food and grocery business, companies like Amazon Fresh, Zomato and Licious are already engaging with farmers and government bodies to develop a sustainable farm-to-fork model by deploying CCI near the farmgate.

2. Changing consumption patterns in urban areas: Urbanisation and changing lifestyle preferences are leading to more consumption of off-season and frozen fruits and vegetables, meat, poultry and dairy products. This increases demand for CCI closer to the consumption centre, and creates an opportunity for the cold chain market in both metropolitan areas and smaller cities. A demand for convenience and reduced cooking time have also led to the emergence of more food service players who require CCI to preserve temperature-sensitive commodities.

2.4. Cold Chain Technologies

The cold chain is a temperature-controlled supply chain, requiring specialised technology to maintain a constant temperature to preserve temperature-sensitive products. Conventional CCI is energy intensive, uses climate-polluting refrigerants, and relies on fossil-fuel intensive vehicles for transportation. A lack of awareness of best practices for handling perishable products also leads to CCI inefficiencies. However, the India Cooling Action Plan (ICAP), launched in March 2019, emphasises that improved design and the use of energy-efficient building material, cooling equipment and information technology could significantly reduce the cooling demand, energy consumption and refrigerant required by CCI technologies.

Because each type of perishable produce has specific storage needs, it is vital to understand these differences and develop the right CCI fit for every product. In some cases, inappropriate cold chain use can actually increase food losses. Freezing, for example, is necessary to transport fish and seafood over long distances, but it is inappropriate for certain fruits and vegetables. Failure to understand a product's needs results in reduced shelf life, deterioration in product quality, increased losses and/or unnecessarily high energy consumption. Table 7 provides an overview of appropriate storage conditions for different products:

Table 7: Appropriate Storage Conditions for Different Fresh Products

	Relative Perishability and Maximum Shelf Life	Ideal Temperature Range	Ideal Relative Humidity	Ideal Atmospheric Composition
Fresh Fruits & Vegetables	• Low – medium perishability • Max. shelf life can vary considerably, ranging from two weeks up to several months	• 0-2°C for non-sensitive crops • 5-15°C for sensitive crops	• Fairly low – very high • Ranging from approx. 70% to close to 100%, but usually high to avoid water losses • Most fruit 85% to 95% • Most vegetables 90% to 98%	Remove oxygen from storage atmosphere and increase CO_2 content to decrease rate of metabolic processes
Dairy	• High perishability • Max. shelf life of up to two weeks for fresh milk	• Approx. 4°C for fresh milk • 10-12°C for cheese	• Low – medium to avoid microbial growth on surfaces	For ethylene-sensitive produce, avoid ethylene build-up to slow ripening
Fish and Meat	• Very high perishability: • Max. shelf life of up to one week for meat and 10-15 days for fish	• 0-2°C for fish • -2-4°C for meat	• Medium–high to avoid water losses • Meat approx. 85%-95% • Fish generally above 90%	Atmospheric composition is of low relevance for storage of most meat and fish products

There are a wide variety of cooling technologies available. They differ in key performance characteristics, such as output temperature ranges, energy and refrigerant use, and capital and operational costs. The following is a snapshot of existing cooling technologies.

First Mile Infrastructure:

1. Government initiatives and capital subsidies: The GoI is implementing various schemes through which financial assistance and capital subsidies are provided for setting up CCI for agriculture produce, including perishable horticulture produce. Some of these include the Pradhan Mantri Kisan SAMPADA Yojana (PMKSY) and the Mission for Integrated Development of Horticulture (MIDH), as well as sub-schemes like the National Horticulture Mission and National Horticulture Board.

- **Vapour Compression Cycle (VCC):** This is the most widely used cooling technology in India, using phase change material to provide cooling. It works by circulating the refrigerant through the system where it is alternately compressed and expanded, enabling the state to change from a liquid to a vapor. 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.
- **Evaporative Cooling:** Evaporative cooling is a physical phenomenon in which evaporation of a liquid, typically into the surrounding air, cools the object or liquid in contact with it. The potential for evaporative cooling is measured by comparing the wet-bulb temperature to the air's dry-bulb temperature;[4] the greater the difference between the two, the greater the evaporative cooling effect.
- **Sorption Cooling:** In this process, refrigeration is thermally-driven and based on the physical/chemical attraction between a refrigerant and an ad/absorbent. When subjected to a low-pressure environment, the refrigerant will evaporate at ambient temperatures. This evaporation absorbs heat from the environment, creating a cooling effect. Once evaporated, the gaseous refrigerant is attached to or absorbed by the ad/absorbent (adsorption or absorption, respectively). Pressure is thereby reduced in the evaporator, allowing for more refrigerant to evaporate. Thermal energy is then used to evaporate the refrigerant out of the ad/absorbent and restore original conditions.

There are a wide variety of cooling technologies available. They differ in key performance characteristics, such as output temperature ranges, energy and refrigerant use, and capital and operational costs. The following is a snapshot of existing cooling technologies:

- **Ice Production:** Ice can be used to cool food products in two ways: it can be applied directly to produce, to packaged produce or to the water in which a product is submerged; or ice can be kept in an ice bank or ice battery to cool the air surrounding stored produce through natural or fan-assisted convection. Ice can be made using any cooling technology suitable for freezing. Most common are either vapour compression systems or absorption cooling, with ammonia-water or lithium bromide-water working pairs applied.

The efficiency of cooling technology depends on the refrigerant chosen and its thermophysical properties for a particular application. There are two main categories of refrigerants:

- **Halogenated refrigerants:** Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs)
- **Natural refrigerants:** CO_2, ammonia, water, air and hydrocarbons such as propane, isobutane and propene

Some refrigerants are more suited than others to certain applications and climate zones. CO_2, for example, is an excellent natural refrigerant in ambient temperatures below 30°C, but less efficient in hotter climates.

In India, ammonia, a natural refrigerant, is heavily employed in bulk cold storage. CFCs were very popular in the past, but have been phased out due to their ozone depleting potential. HCFCs were used for a while as an alternative, but are now also being phased out in stages. HFCs like R134a, R404a and R407c are currently in use, but their global warming potential (GWP) is high. HydroFluorolefins (HFOs) have zero ODP and very low GWP, but because they are expensive to produce, commercial production rates are still low.

Electrically-driven vapour compression technology, also known as mechanical technology, is what is most commonly used for cooling applications. Packhouses, bulk cold storage, reefer transport and retail outlets all rely on this form of cooling, which is suitable for a wide variety of products. However, thermally-driven cooling technologies (sorption cooling and evaporative cooling) can provide for an alternative to mechanical cooling, particularly where a reliable supply of electricity cannot be guaranteed or where a source of thermal energy (mainly waste heat) is readily available.

There are limited cooling technologies currently available for reefer transport. In India, 95% of perishables are transported by road in trucks or trailers powered by diesel engines. According to industry experts and OEMs, most fruits and vegetables are transported in non-refrigerated vehicles, leading to a significant loss of produce and produce quality. Refrigerated transport is used only for select perishables and exotic produce, most of which are exported, as well as for dairy products and meat. Reefer transport uses a diesel-powered refrigeration system, which not only results in higher GHG emissions but also releases pollutants such as nitrogen oxides and carbon monoxides.

Many rural regions where the government intends to set up cold storage facilities suffer from unreliable grid electricity. This presents a market opportunity for off-grid renewable-based CCI solutions, and could be a potential use for decentralised solar energy. India's Cooling Action Plan (ICAP) estimates that over the next seven years solar-powered cold storage solutions will grow from 1% to 10% of the overall market, translating to a market opportunity of US$3.3 billion.[xxi]

4. Wet bulb temperature is the lowest temperature to which air can be cooled by the evaporation of water at constant pressure. Dry bulb temperature is the ambient temperature. The difference between these two temperatures is a measure of the humidity of the air.

There are several off-grid, renewable-based technologies that are emerging for cold chain application. These include solar PV systems, solar thermal systems, biomass gasifiers, solar/biomass co-generation (waste heat recovery), and thermal energy storage by the application of phase change materials (PCM).

Table 8: Snapshot of Conventional Cooling Technologies

Cooling Technology	Energy Source	Temperature Range	Refrigerant Use	Energy Consumption	Cost		Applicability to CCI Component	Applicability to Products
					CAPEX	OPEX		
Vapour Compression Cycle	Electric	Full temperature range, including freezing	Halogenated or natural refrigerants	High	Low	High	All	All
Evaporative Cooling	Thermal (passive)	Temperatures above 10^0C	Water	Low	Low	Low	Bulk cold storage	Chilling-sensitive fruits and vegetables
Sorption Cooling	Thermal	Full temperature range, including freezing	Natural refrigerants	Low	High	Low	All, but limited in transport	All
Ice Production	Electric or thermal	Temperatures around 0^0C	Halogenated or natural refrigerants	Low	Low	High	All	Non-chilling-sensitive produce only, mainly fish and meat

The applicability of these technologies to various value chains has been summarised in Table 9:

Table 9: Applicability of Cooling Technologies Across Value Chains

Cooling Technology	Fresh Fruits & Vegetables	Dairy	Fish	Meat
Vapour Compression Cycle				
Evaporative Cooling				
Sorption Cooling				
Ice Production				

High	Medium	Low

New Leaf Dynamic Technologies Ltd.
Product Photo

INNOVATIVE CHILLING PROSPECTS

New Leaf Dynamic Technologies (P) Ltd. has developed GreenCHILL, an off-grid, compressor-less, renewable-energy-powered refrigeration system that uses farm waste (biogas, cow-dung cakes, biomass pellets, dead wood, husks, hay, bamboo waste, etc.), biomass gasifiers (producer gas) or the waste heat of generators for cooling. It is a vapour adsorption cycle-based refrigeration system meant specifically for small-scale farmers. The units are meant to be used either on or near the farm, by farmers with capacities ranging from 10 - 20 MT.

GreenCHILL can cool 500-1,000 L of milk and 5-10 MT of fruits, vegetables, flowers, fish or other horticultural produce without using grid power or diesel generator backup. **The system has been built to store agricultural produce at the village/farm level (first mile) before it is transported to a market or processing facility, and can be integrated with new or existing industrial-standard cold storage and bulk milk coolers.** It can also be adapted to user requirements to include pre-cooling and other custom features. GreenCHILL's refrigeration technology complies with UNFCCC's Kyoto Protocol 2020 since it uses ammonia for cooling, which has a GWP of zero.

New Leaf Dynamics supports farmers with debt and subsidies while raising their Purchase Order, and provides them with the market linkages they need to fetch better prices for their produce. With affordable cold storage in their arsenal, farmers can stay profitable, store their produce efficiently and sell it at the right time for a better price.

One GreenCHILL customer is an orange farmer from Neemuch village in Madhya Pradesh, who harvests his produce twice a year. His oranges fetch INR 16-20 per kg near harvest time. During the off-season, however, he can sell his cold-stored oranges for INR 40-55 per kg. His income has increased substantially, proving the concept to neighbouring farmers.

Pluss Advance Technologies uses PCM as thermal energy storage (TES), enabling the transportation of goods at a constant temperature without using diesel or petrol to continuously run cooling units in the reefer trucks. Metal or plastic plates filled with PCM – called eutectic plates – are mounted in insulated containers, and charged using electricity when not in use. This system is ideal for inter-city transportation and short-haul services, as the holding time is 14 to 16 hours. PCM offers operating cost savings of up to 80% by eliminating the use of diesel to run the cooling system.

Solar PV and other renewable energies already provide an economically viable alternative to diesel generators, which are typically used to ensure a reliable energy supply in off-grid or intermittent grid situations. High capital costs for renewable energy technologies, however, can pose a significant barrier to adoption. In the absence of suitable financing options, most potential users have difficulty obtaining the necessary starting capital; others simply prefer not to invest in renewable power generation, which they perceive as high risk. This is why energy-efficient technologies using decentralised renewable energy will need government support for widespread CCI application, and to reach economies of scale.

While the application of cold chain technologies helps boost economic development, it can also be counter-productive with regard to climate change. Ideally, CCI should be based on clean cooling technologies combining maximum energy efficiency with natural refrigerants, which have the least impact on the climate.

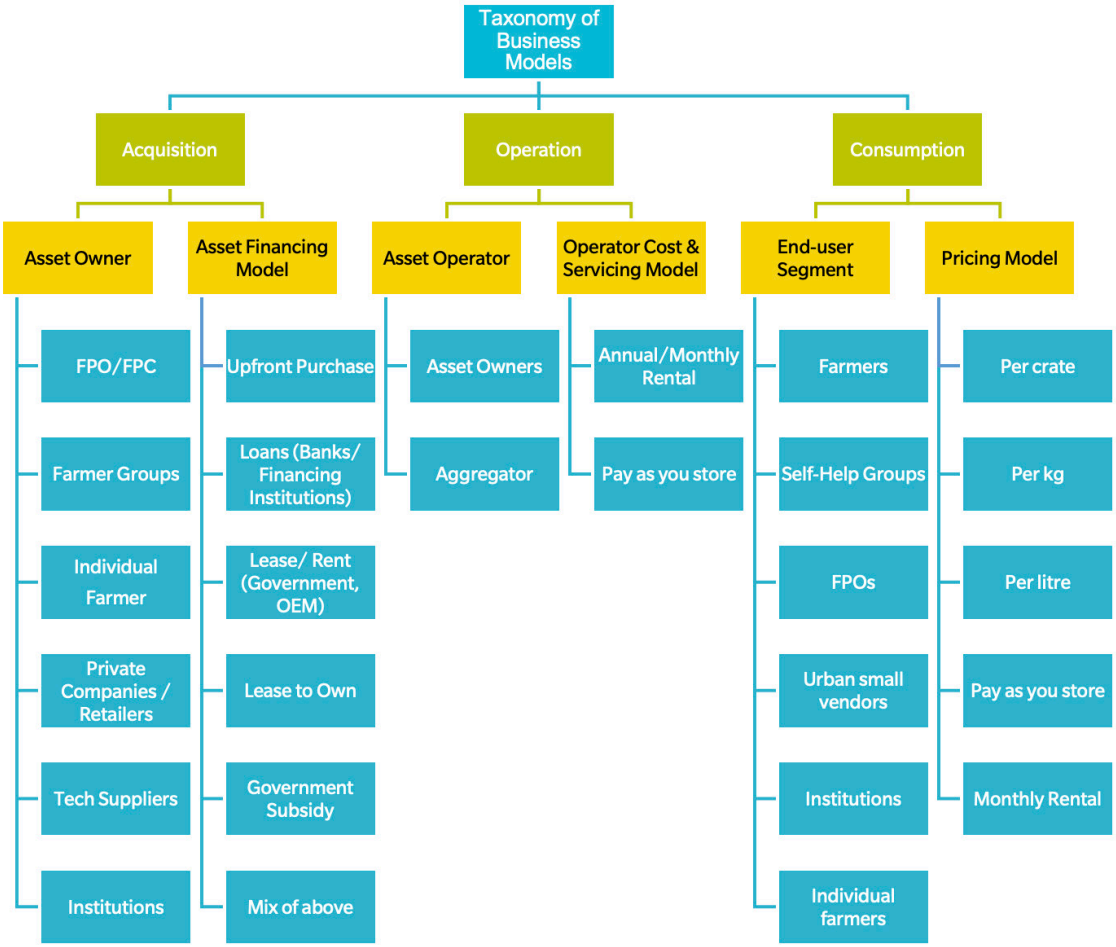
2.5. Business Models and CCI Ownership

Traditionally in India, farmers sells their produce to a trader/aggregator (at a price determined by the buyer), who then sells it in the mandis (local markets) to a wholesaler/retailer. CCI is generally used by the trader/aggregator to store produce at a bulk cold storage facility, so it can be sold later when it will fetch a higher market price. This usually results in farmers receiving a lower price for their produce. Owning and operating a CCI asset is too expensive for individual use, so investment in such assets is generally made by farmers' collectives like Primary Agriculture Credit Societies (PACS), Famer Produce Organisations (FPOs) and farmers' cooperatives, or by large-scale private farms.

Most of the CCI in India is currently owned by state government cooperatives, FPOs and private players. Some of these facilities have been leased to individuals, exporters, cooperative societies or FPOs. However, the informal nature of the sector makes running a CCI business difficult due to operational inefficiencies, a lack of market linkages and a lack of knowledge about operating and managing the equipment. For instance, if a temperature-sensitive commodity like milk is not cooled to the right temperature or is exposed to higher ambient temperatures, the entire batch could be spoiled.

CCI businesses are based on a number of different ownership, financing and service models, while still more potential models are being explored. Figure 11 outlines the roles played by different stakeholders in the acquisition, operation and consumption of CCI assets.

Figure 11: Taxonomy of Business Models



Some of the most prevalent sales and service models include:

- **Direct sales/upfront investment:** Some users have the financial capacity to purchase CCI assets upfront, often with financial assistance from government subsidies, banks or financial institutions. Users of this model include FPOs, large individual farmers, private companies/retailers, NGOs and institutions.

The benefits and challenges of this model are summarised below:

Benefit Analysis of the 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 directly purchase a CCI asset upfront often consume savings or take loans, impacting cash flows for other requirements.

- **Rental/lease model:** In this model the CCI asset is rented/ leased to the user on an annual or monthly basis; the user might also pay by the kg stored, like the pay-as-you-store model. The asset is owned by the CCI operator or at times by a trader/aggregator. While the rental model offers quicker paybacks, demand aggregation remains a challenge. Renting a CCI asset helps the user avoid the upfront purchase cost, and this is the most prevalent business model used today by manufacturers, private companies, retailers, FPOs and farmers' groups.

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. Furthermore, 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.
- **Cashflow management**: Since rental costs are usually fixed, it is easier to budget and forecast cash flow.

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.

Table 10: Rental Model for Strawberry Farmers in Mahabaleshwar

	Rental Model for Strawberry Farmers in Mahabaleshwar
CCI Element	Cold room
Solution	A portable solar-powered cold room based on thermal energy storage, which can maintain low temperatures without any backup power. With the ability to store their crops, smallholder farmers have the potential to increase their earnings by 40% over time.

Product Specification	 • Temperature range: 4-10°C
	• Humidity control rnage: 65%-95%
	• Standalone solar capacity=5kWp
	• Customisable room size
	• Available room size (in ft):
	  • 15x10x10
	  • 12.5x8x10
	  • 16x8x8

Business Model	The company is providing three portable solar-powered cold rooms in Mahabaleshwar for strawberry storage – each has 5 MT capacity, and can store 20 MT strawberries. Farmers rent small amounts of space in the cold room on a per-pallet or per-crate basis.
Impact	• Reduced produce loss at different stages of the cold chain due to pre-cooling in cold rooms • Increased shelf life of the produce, translating to monetary benefits for farmers who can avoid distress sales of their strawberries • Ability to reach distant markets and increase exports • No more dependency on diesel generators
Challenge	Buyers rely on support from government subsidies, so disbursement has been a challenge since subsidies are paid over periods of 6 months to 2 years.

ACQUISITION		OPERATION		CONSUMPTION	
Asset Owner	Financing Model	Asset Operator	Cost & servicing model	End user	Pricing model
Manufacturer	Self + government subsidy	Farmers	Monthly rental (~25K)	Farmers	Per pallet/per crate (~INR 30)

As a result of this model, farmers earn at least INR 20 more per kg for their produce.

- **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/ per kg of produce or per litre of milk stored in the facility. Some of the benefits of adopting this model include:
  - Avoidance of high upfront cost, thereby driving the uptake of CCI
  - Access to modern, more efficient cooling technologies which are costlier than traditional products

While this model is effective, it is not currently implemented at large scale in India. However, it has the potential to sustainably reduce the burden of owning and operating a CCI asset for farmers.

Benefit Analysis of the Pay-as-You-Store Model

Benefits

- **Cheaper for the user**: Since there is no requirement to pay upfront, this option is more affordable for smallholder farmers who then pay based on the amount of produce stored.
- **Access to better technologies at a cheaper 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 doing the enforcement themselves and not through a third party.

CASE STUDY

EMPOWERING FARMERS, PREVENTING FOOD LOSSES

Oorja Development Solutions provides a PAYGo/ CaaS model for smallholder farmers called "Oonnayan." They have deployed a 5MT solar-powered cold storage unit in the Indian state of Bihar that is used by at least 50 farmers, allowing them to store perishable horticulture produce on a per-crate-per-day basis without paying high upfront costs. This has helped farmers extend the shelf life and improve the quality of their produce, resulting in higher prices in the market and therefore higher incomes.

Reefer Transport Business Model in India

Reefer transport tends to be expensive. The cost of a reefer truck averages about 60% higher than that of a conventional truck, though these costs vary slightly depending on capacity. The reefer transport business faces other challenges as well, including high operating costs due to diesel prices, unevenly distributed demand and a lack of scalability. The use of rail for refrigerated cold chain is currently unfeasible for many commodities due to the absence of loading and unloading facilities at intermediate stations.

One challenge with reefer transport is the fact that most terminal locations do not have chilled cargo to carry for the return trip. As a result, reefer trucks are obliged to carry un-chilled cargo at lower rates, or move empty to the next loading location. This uneven demand has a direct impact on the overall price of such transport.

The cost per km depends on the type of vehicle, the trade lane and the temperature requirements. According to industry experts, the direct operating costs of cold chain transportation hover above 85% of the revenue. Limited control over these costs can make the business unviable, and the additional risk of unskilled drivers (with improper knowledge of temperature control) can also impact the quality of the commodity.

Currently, most reefer transport is outsourced to third-party logistics companies;[xxii] the leasing model does not yet exist in India for reefer vehicles.

- **Third party logistics (3PL):** In this model, users (usually importers, exporters and intercity distributors) who require cold chain are able to outsource transport to third-party companies, who then supply cold chain services throughout the supply chain. Very few cold storage operators have their own reefer transportation.

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.

Barriers to Scaling-up CCI Business Models:

Different stakeholders in the cold chain sector face economic barriers that need to be addressed through a sustainable business model. These barriers include:

- **High investment cost:** Large-capacity CCI requires a sizeable investment. For example, a 5,000 MT cold storage facility costs around INR 5-6 crore (US$670,000-800,000), including the cost of the land. A reefer truck with a 7.2T capacity costs around INR 18-19 lakh (US$24,000). Although the government provides subsidies of 35-75%, the remaining cost is still too high for most farmers.[xxiii]
- **High cost of land and its availability to the operator or service provider:** The cold chain business is capital intensive, and installing high capacity (~5,000 MT) cold chain infrastructure (like packhouses and cold storage facilities) becomes even more expensive due to the high cost of land. To access government subsidies the land where the cold storage unit will be installed must be owned by the individual or company, and a 5,000 MT-capacity cold storage unit requires 1-2 acre of land. Securing land near a farmgate can also be challenging for OEMs and operators.
- **High operating costs:** Most rural areas have access to grid electricity, but it is highly unreliable. This is a major issue for CCI near a farmgate, because it requires a constant power supply. Operators are forced to rely on diesel generators for about 30% of total expenses for the cold storage industry in India.
- **Access to financing:** Access to financing is a challenge for smallholder farmers. Low-income earners, many of whom are unbanked and have little financial literacy, find it extremely difficult to secure loans to purchase a cold storage facility since they are considered a credit risk. Loans and subsidies are generally only available to government institutions and FPOs, not to individual farmers.
- **Demand aggregation:** Due to a lack of awareness of the benefits of cooling, demand aggregation is often a challenge for CCI operators, resulting in low utilisation rates.
- **Low utilisation affecting revenue:** Low utilisation rates are a major challenge to the business viability of CCI. 90-95% of CCI assets are owned by the private sector, but due to smallholder farmers' limited ability to pay for storage and transportation, many do not use the cold storage available. CCI funded by the government also lacks modern efficient technology and transport facilities, resulting in low capacity and utilisation.

To ensure better adoption of CCI, it is important to develop sustainable and affordable business models for farmers. The focus should be on decentralising CCI solutions, which would reduce investment costs. Decentralization would also make CCI more accessible to farmers and increase utilisation of the assets, resulting in better revenues for operators and allowing farmers to sell their produce at relatively high prices. The pay-as-you-store model should be scaled up, since it lifts the burden of ownership from the farmer and therefore removes the barrier of financing.

2.5. Government Support for the Growth Of CCI

Government policies and initiatives play a key role in the large-scale development of cold chain infrastructure in India. The Indian government has developed several cold chain infrastructure development schemes involving subsidies or grants-in-aid, some of which are described below. These flagship programmes promote the development of complete end-to-end cold chains, from the source to the end-customer.

1. Mission for Integrated Development of Horticulture (MIDH)

The MIDH is a centrally-sponsored scheme to promote the holistic growth of the horticulture sector (fruits, vegetables, root and tuber crops, mushrooms, spices, flowers, aromatic plants, coconuts, cashews, cocoa and bamboo shoots). Under the MIDH, the Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW) provides financial assistance for various horticultural activities, including the installation of cold storage. Government assistance for the purchase of these assets is available in the form of credit-linked back-ended subsidies equal to 35% of the project cost, or 50% in hilly or Scheduled Areas.

The MIDH provides assistance with setting up multi-chamber cold storage units using energy-efficient technology, with provisions for thermal insulation, humidity control, advanced cooling systems and automation as per the specifications and standards of the Ministry. Long-term storage and distribution hubs of up to 5,000 MT capacity are covered under a sub-scheme called the National Horticulture Mission (NHM) / Horticulture Mission for North East and Himalayan States (HMNEH); storage hubs with capacity between 5,000 MT and 10,000 MT are covered by the National Horticulture Board (NHB) scheme.

a. National Horticulture Mission (NHM) / Horticulture Mission for North East and Himalayan States (HMNEH)

Long-term cold storage and distribution hubs of up to 5,000 MT capacity are eligible for assistance under this open-ended sub-scheme of MIDH. Assistance comes in the form of credit-linked subsidies, amounting to 35% of the capital cost of the project, or 50% in NE, hilly and Scheduled Areas.

b. National Horticulture Board (NHB)

The National Horticulture Board (NHB) is implementing the "Capital Investment Subsidy for Construction/Expansion/ Modernisation of Cold Storages and Storages for Horticulture Products." Under this scheme (a sub-scheme of MIDH), assistance is available for the installation and modernization of cold storage units with capacity between 5,000 MT and 10,000 MT. This is an open-ended credit-linked programme offering subsidies amounting to 40% of the capital cost of a project (limited to INR 30 lakhs per project), or 50% in NE, hilly areas and Scheduled Areas (limited to INR 37.50 lakhs per project) sub-scheme of MIDH. Assistance comes in the form of credit-linked subsidies amounting to 35% of the capital cost of the project, or 50% in NE, hilly and Scheduled Areas.

2. Pradhan Mantri Kisan SAMPADA Yojana (PMKSY)
SAMPADA stands for Scheme for Agro-Marine Processing and Development of Agro-Processing Clusters. It consists of a comprehensive package to create modern infrastructure and efficient supply chain management from farmgate to retail outlet, with the goal of boosting the growth of the food processing sector and improving returns for farmers. This is in line with the GoI's goal to double farmers' income, creating significant employment opportunities in rural areas. It also reduces food waste, using efficient and modern technology to help the food processing industry and export houses convert surplus produce into an export commodity. The following will be developed under PMKSY:

- Mega Food Parks
- Integrated cold chain and value addition infrastructure
- Creation, expansion and modernization of food processing and preservation capacities
- Infrastructure for agro-processing clusters
- Backward and forward linkages
- Food safety and quality assurance infrastructure
- Human resources and institutions

So far, the Ministry has approved 41 Mega Food Parks, 353 cold chain projects, 63 agro-processing clusters, 292 food processing units, 63 backward and forward linkages projects and 6 Operation Green projects across the country.[5]

3. Scheme for Integrated Cold Chain, Value Addition and Preservation Infrastructure
Part of PMKSY, this scheme is implemented by the Ministry of Food Processing Industries (MOFPI) with the aim of reducing post-harvest produce losses and providing better prices to farmers for their produce. Financial assistance (grants-in-aid) is limited to a maximum of INR 10 crore per project for technical civil works, eligible plants and machinery, subject to the following conditions:

- For storage intrastructure (including packhouses, pre-cooling units, ripening chambers and transport infrastructure), grants-in-aid are provided amounting to 35% of total project cost, or 50% for NE and Himalayan States, Integrated Tribal Development Project (ITDP) Areas and islands.
- For value addition and processing infrastructure (including frozen storage and deep freezers integral to processing), grants-in-aid are provided amounting to 50%, or 75% for NE and Himalayan States, ITDP Areas and islands.
- For irradiation facilities, grants-in-aid are provided amounting to 50%, or 75% for NE and Himalayan States, ITDP Areas and islands.
- For reefer vehicles, credit-linked back-ended grants-in-aid are provided amounting to 50% of the cost of a new reefer vehicle/mobile pre-cooling van, up to a maximum of INR. 50.00 lakh.

Integrated cold chain and preservation infrastructure can be set up by individuals, groups of entrepreneurs, cooperative societies, Self Help Groups (SHGs), Farmer Producer Organisations (FPOs), NGOs or central/state PSUs. Standalone cold storage units are not covered under the scheme.

4. Small Farmer Agri-Business Consortium (SFAC) Assistance

These subsidies are available for cold storage facilities set up as part of an integrated value chain project, provided the cold storage component accounts for no more than 75% of the Total Financial Outlay (TFO). Subsidies can amount to 25% of the capital cost of a project with a maximum ceiling of INR 2.25 crores, or 33.33% with a ceiling up to INR 4 crores in NE, hilly and Scheduled Areas.

In order to meet the government's goal of doubling farmers' income by 2022, several market reforms are being rolled out to encourage the development of CCI:

- The establishment of 22,000 Gramin Agriculture Markets (GrAMs) to act as aggregation platforms
- An Agri-Export Policy, which aims to double agri-exports by 2022
- The promotion of 10,000 FPOs by 2024
- The creation of the following Corpus Funds:
    - An agri-marketing fund to strengthen eNAM[6] and GrAMs (INR. 2,000 crores)
    - An Agricultural Infrastructure Fund (AIF) to provide collateral-free loans with an interest subvention of 3% (INR. 100,000 crores)

Apart from this, the government is also providing profit-linked tax holidays, priority sector lending, and lower tax rates for raw and processed products. Cold chain services – including pre-conditioning, pre-cooling, ripening, waxing and retail packing – are also exempt from Goods and Service Tax (GST).

Some of the other key government initiatives in the cold chain sector are as follows:

- **Exemption from Customs and Excise Duty**
    - Customs Duty: A concessional basic customs duty (BCD) of only 5% is applied for cold storage, cold room and industrial projects (including farm-level pre-cooling) for the preservation, storage or processing of agricultural, horticultural, dairy, poultry, aquatic and marine produce and meat. Truck refrigeration units and other refrigerated vehicles are fully exempted from BCD.
    - Excise Duty: Central excise duty has been fully exempted for the installation of cold storage, cold rooms and refrigerated vehicles for the preservation, storage, transport and processing of agricultural, apiary, horticultural, dairy, poultry, aquatic and marine produce and meat. This also applies to air conditioning equipment and refrigeration panels for cold chain infrastructure, including conveyor belts used in cold storage units, mandis and warehouses.

5. A Central Sector scheme for the integrated development of the tomato, onion and potato (TOP) value chain, with an outlay of INR.500 crores to promote FPOs, agri-logistics and processing facilities.
6. The National Agriculture Market or eNAM is an online trading platform for agricultural commodities.

- **Foreign Direct Investment (FDI):** 100% FDI is allowed, leading to an increase in private sector investment. This policy requires a minimum investment of US$100, with at least 50% invested in back-end infrastructure.
- **Fiscal Incentives for Cold Chain**
  - Section 80-IB of the Income Tax Act provides deductions for cold chain-related industrial activity. Deductions apply to 100% of profits for the first five years, then 25-30% for the next five years.
  - Under Section 35-AD of the Income Tax Act 1961, deductions of 150% are permitted for expenditure incurred in setting up a cold chain facility.

Other government institutions providing financial assistance for CCI development are mentioned in the Annex-3. The National Centre for Cold Chain Development (NCCD) has also provided a significant boost to the sector.

2.6. Challenges to the Uptake Of CCI

Despite the clear need for CCI at various stages of the value chain, there are still a number of barriers to its adoption. Compared to the global North, usage of the existing CCI in India is staggeringly low. Key challenges include high costs and a lack of awareness about post-harvest management, both of which inhibit the development and uptake of CCI in the country.

Some of the challenges faced by different stakeholders are described in Table 11:

Table 11: Challenges to the Uptake of CCI

Challenges	Producer (Farmer/FPO/FPC)	CCI Manufacturer/Operator
Policy	• Lack of awareness of existing government policies to support CCI • No additional incentives for the farmer/trader to cold store their produce	• Delayed and complex process for claiming subsidies • Lack of standards promoting energy efficient CCI technologies • Lack of financial support for small-capacity CCI
Technological	• Lack of awareness of post-harvest cooling requirements and technologies, and the benefits of cold chain • Little use of modern harvesting techniques and machinery	• Lack of knowledge of how to identify cooling needs and appropriate cooling technology • Lack of modern, affordable CCI • Lack of standards to guide purchasing decisions • Lack of knowledge about standards for equipment and materials used in CCI, including renewable energy equipment • Lack of expertise in operating CCI in rural areas
Economic	• High investment costs • Unaffordability of investing in or using CCI services • Lack of awareness of available financing support • Lack of access to financing due to perceived credit risk • Uncertain ROI for CCI owners	• Questionable economic viability due to seasonal changes in production volumes • High investment costs • High cost of land procurement, and unavailability of land near farmgate • Lack of government incentives for standalone cold storage • High cost of power • Uneven demand distribution, resulting in the concentration of CCI in clusters
Operational	• Unreliable power supply and uneven access to grid electricity • Lack of knowledge of operating CCI for specific products, leading to inefficient utilisation • Lack of connectivity, access to consumer markets and market linkages • Lack of standard operating procedures, maintenance and installation procedures	• Lack of skilled manpower to operate CCI • Irregular and uncertain power supply • Low utilisation rates, leading to lower revenue • Inadequate demand aggregation, leading to low CCI utilisation

2.7. Potential Interventions to Increase the Uptake of CCI

Various strategies could be adopted to increase the uptake of CCI solutions in India, and to ensure that these solutions scale by 2030. The following are some recommendations for the sector:

For the Government and Donors:

1. Mainstream decentralised CCI at first mile (near farmgate): Most CCI today is centralised and high-capacity, and located near urban areas. Centralised, high-capacity CCI solutions are expensive for farmers (especially smallholder farmers), and are difficult to access. Decentralising CCI has the potential to solve the problem of access, helping farmers benefit from cold storage through improved incomes. Decentralised CCI solutions would also significantly reduce post-harvest losses, since unsold produce could be stored rather than being discarded or spoiling. Such units could provide multi-commodity storage at affordable rates near the farmgate. The government should consider scaling them up through a programmatic intervention similar to the KUSUM scheme, which focused on solar water pumps (SWPs).

2. Promote the use of renewable and alternative energy-based CCI solutions: The government should promote the use of off-grid solar PV for CCI technology, as well as solar thermal systems, solar-biomass hybrid systems and PCM for thermal storage. There are several different ways this could be done: providing additional incentives for renewable energy-based CCI solutions under existing subsidy schemes; integrating support for CCI into existing renewable energy schemes (such as the SWP KUSUM Scheme, since the excess power generated by SWP systems could be used to power small cold rooms near the farmgate); or promoting the Decentralised Renewable Energy livelihood scheme. Deployment of these technologies would both reduce GHG emissions and mitigate the risks associated with weak grid connectivity. It could also significantly bring down operating costs, making CCI less expensive for operators and allowing farmers to store their produce at more affordable rates.

3. Develop a standards and labelling programme for cold chain components: Decentralised renewable CCI solutions are relatively energy-efficient, but energy efficiency, quality and performance specifications should be defined and measured. The Bureau of Energy Efficiency (BEE) is tasked by the Ministry of Power (MoP) with defining the energy performance parameters for various equipment and appliances; BEE could providing overall support in defining minimum energy performance standards (MEPS), and in developing energy performance labels for cold chain technologies under its Standards and Labelling (S&L) programme. This programme has proven to be an effective way to improve the energy-efficiency of various consumer products, and S&L has been developed for more than 26 appliances.

A similar S&L programme could be extended to CCI, and should undergo periodic review to enhance energy efficiency norms. There are currently no guidelines published by MNRE that standardise technical specifications or benchmark costs for renewable-based CCI solutions. As a result, most systems are either under-sized or over-sized. Under-sized systems may not perform as well as expected, while over-sized systems are more expensive for the government to subsidise. Clear standards and guidelines would both drive technology innovations and help consumers identify the best technology available in the market.

4. Develop demand aggregation models for deployment and utilisation of CCI: Today CCI is concentrated near urban areas. It is high capacity and capital intensive, and most often consists of cold storage. The uneven distribution of CCI creates operational inefficiencies, minimising the advantages of cold chain. The high cost of investment makes CCI growth-resistant, and low levels of demand aggregation lead to low utilisation rates for cold chain assets, making them less profitable; these costs are passed on to farmers, who have to pay more to use the available CCI.

There is a need both to develop demand aggregation for the deployment of appropriate CCI (in terms of size and technology) across the cold chain, and to reducing the upfront cost of these assets. This can be achieved by using data to understand and optimise overall cold chain requirements, and deploying storage and transport CCI in an integrated manner. The flow of information from wholesalers, retailers and consumers back to producers (from fork to farm) can inform farmers' choice on what crops to plant and when to plant them, amplifying the holistic benefits of using CCI. The demand aggregation model is similar to the programme for LED bulbs and electric vehicles run by Energy Efficiency Services Limited (EESL), which resulted in the reduction of upfront costs. Such a model could be part of existing government schemes like KUSUM, where excess power from SWP systems are utilised for productive-use applications.

5. Create behavioural change for farmers: There is a need to provide incentives for medium and smallholder farmers to start using CCI. Stakeholders report a lack of awareness around CCI among farmers, who see it as a luxury rather than a necessity. Enhanced understanding of cold chain technology should change this perception, driving CCI uptake and improving income generation opportunities for farmers. Awareness drives led by government, financing institutions like NABARD, and NGOs would demonstrate the benefits of using CCI, convincing farmers to adopt it. Such campaigns could educate farming communities on pre- and post-harvest cooling practices to better manage their produce, and on how cold chain can improve incomes. This could be done through targeted consumer campaigns such as mobile van displays, live demonstrations and goodwill ambassadors, all of which will help scale demand for CCI.

6. Provide incentives for demand and supply side CCI ecosystems: Currently, the government is providing various capital subsidies for CCI development. It is recommended that the government uses additional incentives to encourage the growth of both a demand side and a supply side CCI ecosystem. The supply can be boosted through grants, tax rebates and R&D funds, while providing fiscal incentives to CCI users would help grow demand.

The supply side ecosystem could also be developed through capacity building, creating a pool of service providers and technicians. This would not only grow the CCI industry, but would establish India as a leader in CCI for both domestic use and export.

7. Build capacity and raise awareness of CCI: A lack of awareness of how to operate CCI is one of the major barriers to unlocking its potential. Correct operation of a CCI asset directly impacts the quality of the stored commodity; improper usage can lead to food spoilage, denting consumer confidence in cold chain. The current skills gap can be addressed through extensive capacity building and training at all levels of the supply chain, including farmers, operators and technicians.

Such training should cover the economic impacts and benefits of using cold-chain, as well as innovative business models, technical know-how (such as the temperature requirements of produce), and how to monitor, install and maintain/repair systems. Emphasis should be placed on providing skill and capacity development training to rural women in order to foster women's empowerment and self-reliance. Skill enhancement programmes such as "Pradhan Mantri Kaushal Vikas Yojana" could be used to further develop these skills. Industry leaders, associations (such as ISHRAE), practitioners, construction professionals and academics could work together to develop relevant training programmes. NGOs and Civil Society Organisations (CSOs) will also be critical to such trainings, as they work at the grass-roots level and carry out assessments.

8. Drive energy efficiency in new and existing CCI: The government should promote retrofits and replacement of existing inefficient CCI technologies, and the efficiency of new installations should be driven by the S&L programme. This would significantly reduce operating costs of CCI, and these savings can be passed on to the end-user in the form of affordable storage rates. EESL ran a similar Demand Side Management (DSM) programme to replace inefficient motors and air conditioning units. India currently has the world's largest capacity of cold storage warehouses, but these are designed almost exclusively for the long-term storage of potatoes; this existing single-commodity CCI storage needs to be converted or retrofitted to store multiple commodities through preferred lending programmes.

For OEMs /CCI Owners /Operators:

1. Strengthen product development: OEMs should focus on product development to make their products more low-cost sustainable and farmer-centric. Using clean technology (refrigerants with low GWP) would make CCI solutions more climate friendly, which would be a better fit for the market.

2. Develop financing and servicing models: TOEMs and system integrators should leverage available government subsidies to provide end-to-end financing solutions for their customers; this includes exploring pay-as-you-store and Cooling-as-a-Service models. These models can be beneficial for smallholder farmers, who do not then need to own CCI themselves. OEMs should also focus on value-added features like warehouse financing products, after-sales support from trained personnel, and integration with reefer transport to improve market linkages.

For Financing Institutions (FIs):

1. Develop a long-term warehouse financing product: There is a need for a long term (10-15 years) financing product that de-risks farmers' production, de-risks the CCI business for operators, and benefits smallholder farmers without requiring them to own the asset. This could be developed based on the business model of the FPO, especially those using the CCI for their own consumption or to build a new business as aggregators. For FPOs in tribal communities where this business is still nascent, longer term financing is critical. In order to reach last mile FPOs, farmers and aggregators, FIs would need to create awareness of the credit linkages and subsidies available for this sort of infrastructure (through the AIF and MIDH, for example), and would have to assist with the process of applying for these schemes and financial products. This could be done through NABARD, SFAC and other FIs empanelled under schemes like AIF.

CONCLUSION

Although use cases vary across value chains, overall, CCI India is underdeveloped in the agricultural sector, and significant quantities of food are lost each year due to a lack of cold chain technology. The fruits and vegetables, dairy and fish value chains would all benefit from expanded cold chain solutions; currently only about 10% of agricultural produce in India passes through any cold chain at all. However, factors such as high costs, a lack of individual financing, unstable grid electricity, large informal markets and low levels of customer awareness all inhibit the uptake of CCI technologies among producers, distributors, aggregators, transporters and retailers. The potential market for CCI varies between value chains – the meat value chain's needs are largely met by existing CCI, for example, while fruits and vegetables require a significant cold chain expansion to reduce wastage. But across the country the growing popularity of formal-sector food retail is catalysing the development of supply chains that rely on a farm-to-fork cold chain model, presenting a tremendous opportunity for the CCI sector.

The Government of India has also recognized the importance of an integrated cold chain system to meeting its own goals. In recent years the government has established a number of incentive schemes, subsidies, tax breaks and investments funds for the promotion of CCI, with the intention of boosting exports, stimulating the food processing industry and providing higher prices to farmers. Still, further work needs to be done to decentralize CCI and bring it closer to the farmgate. Many smallholder farmers are still unaware of proper post-harvest handling procedures, and cannot access or afford the CCI they need to prevent losses. Business models like pay-as-you-store would help drive CCI uptake at the first mile level, as would farmer education and the development of more off-grid cold chain solutions that could reduce the risk of power cuts in areas with poor grid connectivity.

Conventional CCI technology relies on ozone-depleting refrigerants, and the environmental impact of these chemicals is substantial. There are considerable opportunities, however, to design CCI with cooling technologies that use climate-friendly refrigerants and maximise the efficient use of low-carbon energy. Cold chain development efforts should prioritise sustainable and energy-efficient technologies, which would lead to both lower operational costs and a reduced environmental footprint.

As the world's second largest food producer, India should be able to feed its population; instead, 190 million Indians are malnourished. Proper food preservation techniques could help change this by ensuring that a higher proportion of domestically produced food reaches the Indian population. Reducing food losses would also boost the incomes of smallholder farmers and others who earn their livelihoods at the first mile segment of the value chain, creating jobs and improving food security for rural populations. But solving this problem requires more than the proper technology; a system-wide approach combining education, financing and policy changes is needed for the potential of the cold chain market to be fully realized, and for Indians to finally revolutionise their agricultural sector.

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Annex 1: In-Depth Analysis of the Value Chains

Fresh Fruits and Vegetables

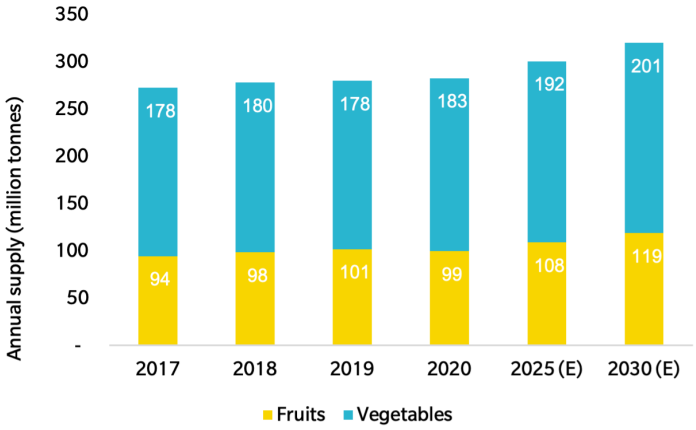
Market overview of the fresh fruits and vegetables value chain in India

With a tropical location and a total geographical area of 3,287,263 sq. km,[xxiv] India boasts a total of 127 agro-climatic zones[xxv] and is thus able to produce most of the fruits and vegetables consumed domestically. The horticulture sector's contribution to the Indian GDP is around 6%.[xxvi] A total of 98 million tonnes of fruits and 183 million tonnes of vegetables were produced in 2020, an annual production of around 204 kg of FFV per capita. India is the world's leading producer of bananas, papayas, mangoes,[7] okra and ginger,[xxvii] with production estimated to grow at a CAGR of ~2% for fruits and ~1% for vegetables till 2030.

Even though India's demand for fruits and vegetables is met by local production, the country does import a small volume of FFV not cultivated in the country, as well as supplements for emergency needs. **India imported approximately 1.2 million tonnes (1.22%) of fruits and 40,000 tonnes (0.02%) of vegetables in 2020.** In the last three years, these imports have grown at a CAGR of 4% for fruits and 23% for vegetables.

Figure 12 shows the total annual supply trend for fruits and vegetables in India:

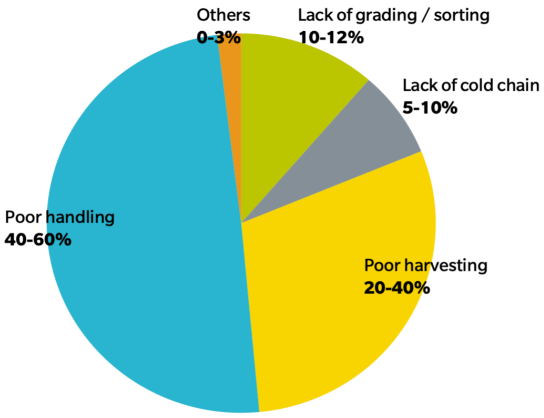
Figure 12: Annual Supply[8] of Fruits and Vegetables in India (2017-2030)



However, harvest and post-harvest losses of fruits and vegetables in India is a matter of concern. Each year 40%-45% of fruit and around 30% of vegetables produced are wasted, primarily due to poor harvesting techniques, poor handling of goods and a lack of cold chain infrastructure (see Figure 13).[xxviii]

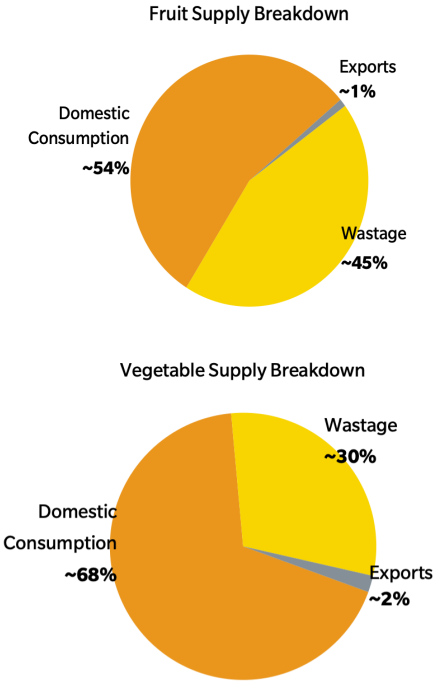
In 2020, annual per capita consumption was estimated to be 42.8 kgs of fruits and 92.9 kgs of vegetables.[9] This is equivalent to 372 grams of fruits and vegetables per person per day, which falls short of the WHO recommended daily minimum 400 grams.[10] Okra, potatoes, onions, mangos and bananas are the most consumed FFV in India.

Figure 13. Causes of Fruit and Vegetable Wastage



Currently, less than 2% of fruits and vegetables produced in the country are exported, leaving a huge untapped export market. Strengthening existing cold chain and developing new infrastructure can play a vital role in achieving the Government of India's goal of doubling farm exports in the next two years. Figure 14 breaks down supply estimates by domestic consumption, exports and wastage.

Figure 14: Breakdown of Annual Fruit and Vegetables Supply in India by Usage



7. Including mangosteens and guavas.
8. The supply includes both domestic production and imports (not exports).
9. Official estimates are not available for 2020 and there is data inconsistency across agencies. Hence, these numbers were arrived at by triangulating historical data trends using NSSO and FAO data.
10. Excluding potatoes and other starchy tubers.

90%-95% of the movement of fruits and vegetables from farm to customer takes place through the traditional value chain, without the use of cold chain.[xxix] The deployment of first mile cold chain solutions such as packhouses and reefer vehicles is key to reducing wastage, improving quality, increasing farmers' incomes and growing exports.

The value chain for fruits and vegetables in India is mapped out in Figure 15.

The value chain is different for each type of fruit and vegetable, depending on its characteristics. Certain FFV might skip some of these cold chain steps while moving from the farm to the consumer. Value chains for key fruits and vegetables are shown in Table 12.

Figure 15: Value Chain for Fruits and Vegetables in India[11]

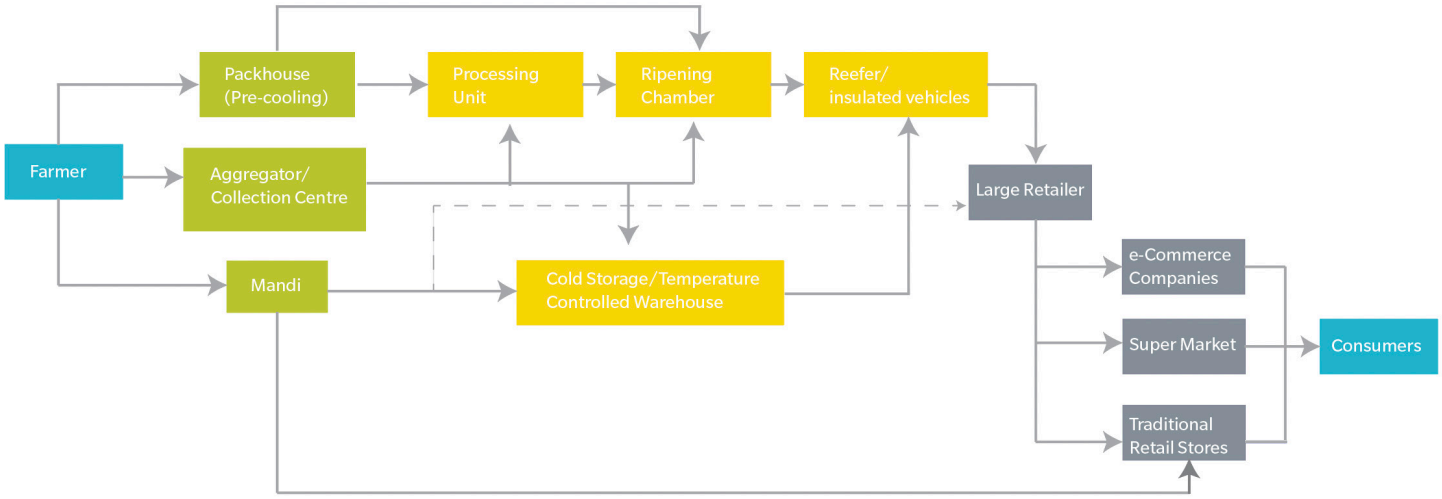


Table 12: Value Chain for Some Key Fruits and Vegetables

Product	Value Chain
Potatoes	Bulk cold storage[12] → Non-reefer transport → Wholesale/retail
Onions	Storage structure → Non-reefer transport → Wholesale/retail
Okra/Tomatoes	Packhouse → Reefer transport → Cold storage hub[13] → Last mile transport → Wholesale/retail
Mangos/Bananas	Packhouse → Reefer transport → Cold storage hub → Ripening chamber → Last mile transport → Wholesale/retail
Apples	Bulk cold storage → Packhouse → Reefer transport → Cold storage hub → Last mile transport → Wholesale/retail

Potatoes and onions are the most consumed fruits and vegetables in India. As illustrated in Table 12, potatoes go through just one cold chain element (bulk cold storage), and onions don't require any cold chain as they move from farm to customer. Fruits like mangoes, on the other hand, are placed in pack-houses for sorting, grading and pre-cooling before moving on through other steps in the cold chain. Cold storage is the most common CCI requirement for fruits and vegetables, with potatoes occupying 68% of all cold storage space in the country.[xxx] However, a significant gap exists in first mile CCI infrastructure like packhouses.

11. A mandi is a common marketplace for selling fruits and vegetables.
12. TBulk cold storage is generally constructed near production centres (farms) and is designed for long-term storage of perishable produce.
13. Cold storage hubs are generally constructed near consumption centres and are designed for short-term handling of products.

Table 13 illustrates the CCI requirements for FFV, and the gaps that remain:

Table 13: Estimated CCI Gap for FFV (by 2020)

	Created (Nos.)	Required (Nos.)	Gap (%)
Packhouses	675	83,041	99%
Cold Storage - Bulk	6,026	6,669	10%
Cold Storage - Hub	225	231	2%
Reefer Vehicles	11,000	70,035	84%
Ripening Chambers	1,232	12,654	90%

CCI Utilisation and Gaps Within the Fruits and Vegetables Value Chain

The last assessment of the overall status of CCI in India was published by NCCD in 2015.[xxxi] The study highlighted that only bulk cold storage units and cold storage hubs were numerous enough to meet India's requirements. Integrated packhouses were almost non-existent, whereas existing reefer vehicles and ripening chambers accounted for only 15% and 9% of the total required, respectively. Further research suggests that this gap still exists in 2020, pointing to a clear need to strengthen the network of packhouses, ripening chambers and reefer vehicles.

More than 75% of the total cold storage capacity is currently used to store FFV, with potatoes being a key commodity. In 2020 this capacity stood at 37.42 million MT, having grown at a CAGR of 2.7% from 2014-2020;[xxxii] according to FFV supply estimates, market volumes grew by only 1.2% during the same period. Assuming the trend continues, the capacity of bulk and hub cold storage should be sufficient to meet market demand in the coming years. However, around 16% of cold storage facilities do not appear to be functional.[14] Most cold storage users are traders and manufactures, with farmers generally preferring to encash their produce immediately rather than storing it. The average utilisation rate of a cold storage facility is around 70%, rising to 90-100% in peak season and falling to 40-60% in the off season.

There are several GoI initiatives intended to catalyse an agricultural revolution in the country. These include: 1) the Doubling Farmers' Income (DFI) initiative, with agri-logistics and cold chain identified as the backbone of agricultural market development; 2) Gramin Agricultural Markets (GrAMs) focusing on market linkages at the first mile; 3) the Agricultural Produce & Livestock Marketing (Promotion & Facilitation) Act (APLM), which legally permits cold storage facilities to function as agricultural markets; and 4) government exemptions and subsidies for CCI development.

Table 14 quantifies the expected deployment of various cold chain solutions for FFV in India.

Table 14: Estimated Required CCI Deployment for FFV CCI in India by 2030)[xxxiii]

Cold Chain	Units by 2030
Packhouses	Nos. 42,872
Bulk Cold Storage	Nos. 7,073
Cold Storage Hubs	Nos. 249
Reefer Vehicles	Nos. 15,000
Ripening Chambers	Nos. 16,416

The government sees CCI as key to achieving its goal of doubling farmers' income. As a result, the GoI has put in place several targets and incentives to encourage CCI development. The deployment of affordable packhouses at the first mile, ripening chambers at the last mile, and reefer vehicles connecting the two has the potential to reduce wastage by 15-20%. In the case of FFV, small-capacity solar cold rooms (<10MT) have great potential and can be installed close to the farmgate at the community level. About 500 solar cold rooms are already running in India; 50-60% are used for FFV and 30-35% for floriculture, with the rest being used for other commodities such as pharmaceuticals. The focus is expected to shift from the deployment of cold storage facilities to other critical CCI solutions like packhouses, reefer vehicles and ripening chambers. The estimated growth rate (2020-2030) for packhouses, reefer vehicles and ripening chambers is 50%, 34% and 30%, respectively, with growth being driven primarily by government programmes such as the DFI initiative and offers of capital subsidies.

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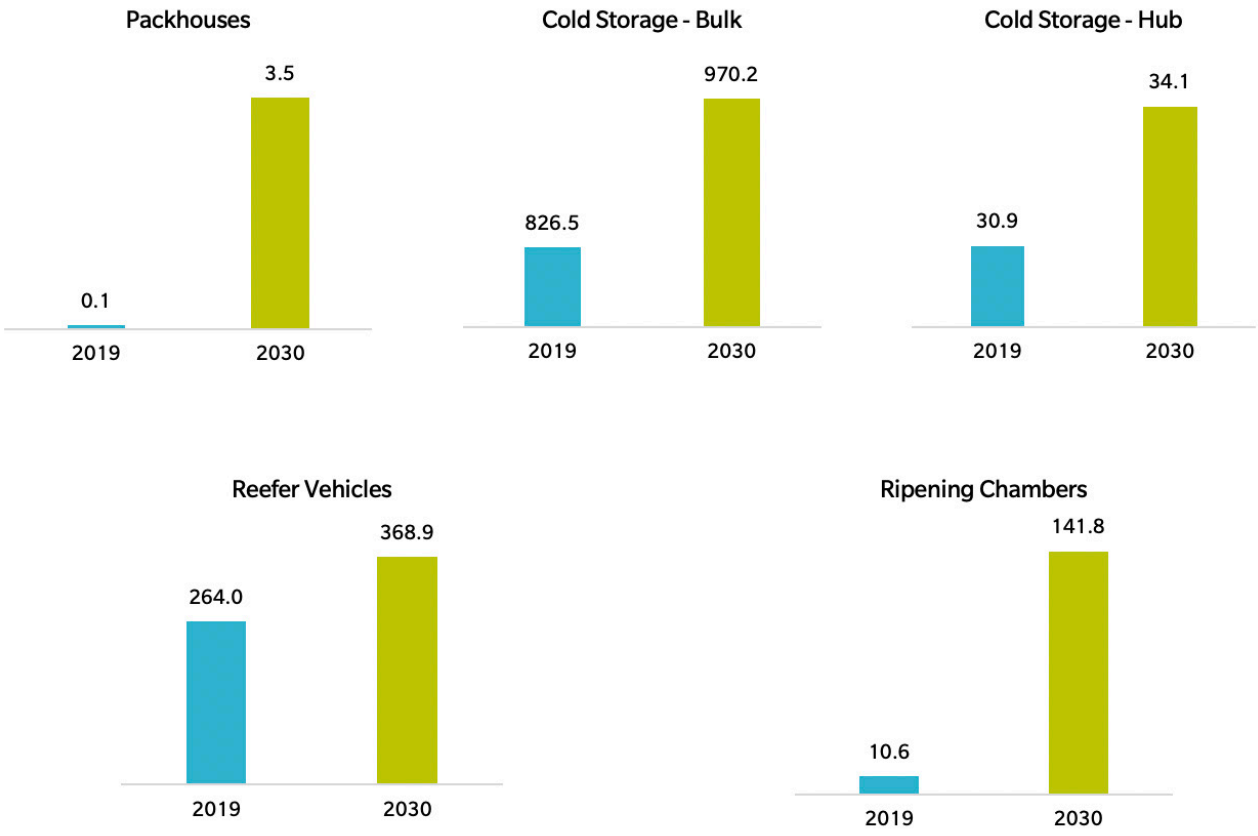
Based on these assumptions, the 2019 CCI market size (for a CaaS model) can be estimated at US$0.1 million for packhouses, US$826 million for bulk cold storage, US$30.9 million for cold storage hubs, US$264 million for reefer vehicles and US$10.6 million for ripening chambers. For upfront purchase of assets (CAPEX model), the 2019 market size can be estimated at US$47 million for packhouses, US$8.66 billion for bulk cold storage, US$324 million for cold storage hubs, US$294 million for reefer vehicles and US$13 million for ripening chambers, as illustrated below:

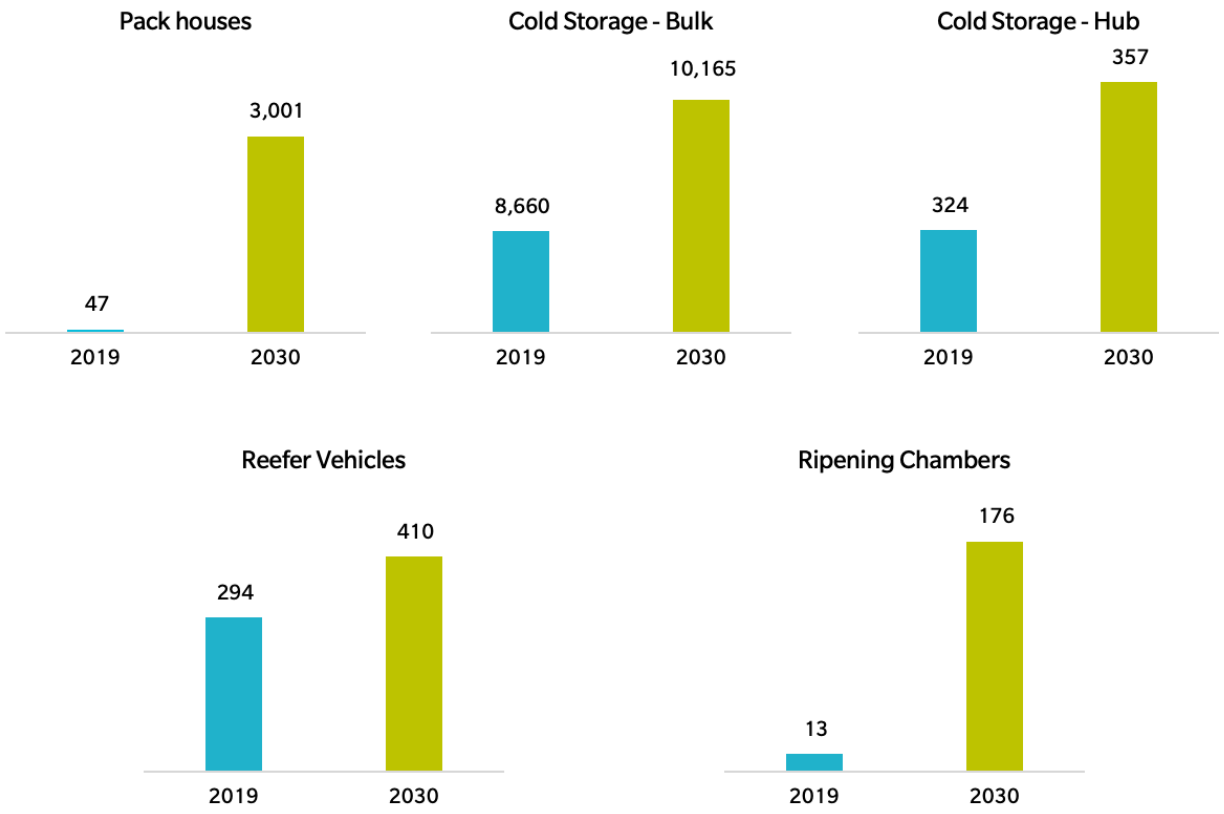
Figure 16: Current and Projected CCI Market Size in the FFV Value Chain Based on CaaS (USD million)[xxxiii]



Assuming the government's focus is on reducing wastage and developing CCI, the projected 2030 market size, based on a CaaS model (Figure 16) is estimated at US$ 1.52 billion - broken down as US$3.5 million for packhouses, US$970 million for bulk cold storage, US$34 million for cold storage hubs, US$368 million for reefer vehicles and US$141 million for ripening chambers.

For upfront purchase of assets based on the CAPEX model (Figure 17), the projected 2030 market size is estimated at US$14.11 billion - broken down as US$3 billion for packhouses, US$10.17 billion for bulk cold storage, US$357 million for cold storage hubs, US$410 million for reefer vehicles and US$176 million for ripening chambers, as illustrated above. Around 80% of CAPEX investment would go towards strengthening first mile and last mile cold chain infrastructure such as packhouses, reefer vehicles and ripening chambers.

Figure 17: Current and Projected CCI Market Size in the FFV Value Chain Based on CAPEX (USD million)[xxxiv]



Note: Average capacity considered for CCI components is: Packhouse=16 MT/day; Bulk cold storage=5,000 MT; Cold storage hubs=5,000 MT; Reefer vehicles=10 MT; Ripening chambers=8 MT.[xxxv]

Challenges of Utilisation of CCI in the Fruits and Vegetables Value Chain

The following are some of the barriers to CCI uptake in the fruits and vegetables value chain:

1. Affordability and holding capacity: The majority of farmers in India cannot afford CCI. Their holding capacity also tends to be quite low, compelling them to immediately sell their produce instead of storing it. High power tariffs and interest rates on loans make CCI even more unaffordable.

2. Subsidy disbursement: Delays in subsidy disbursement can prevent CCI from scaling up. Subsidies in India are also extended only to FPOs, not to individual farmers, which means farmers who are not part of an FPO fail to benefit from the scheme.

3. Post-harvest techniques: Stakeholders have limited knowledge of post-harvest techniques that can be used to preserve the quality of produce and extend its shelf life.

4. CCI exposure: Farmers are largely unaware of the benefits of CCI, and of how they can participate in helping the country achieve food security and reduce food wastage. This makes them less confident of the ROI of CCI assets.

5. Unreliable grid: To be effective, CCI requires electricity for almost the entire day. Unreliable grid power is a major problem in rural India, which hampers uptake of cold chain solutions. Decentralised renewable energy systems can address the problem of grid reliability, but are expensive due to high storage costs and little access to financing. Solar cold rooms can be a good alternative solution for FFV storage; with a temperature range of 40°C and above, they can be used for pre-cooling at the farmgate or at cold storage hubs closer to consumers. Currently, around 90% of cold storage hubs are used for products that need to be chilled (0-100°C) or mildly chilled (10-200°C). For bulk cold storage, however, off-grid systems may not be viable due to high storage costs.

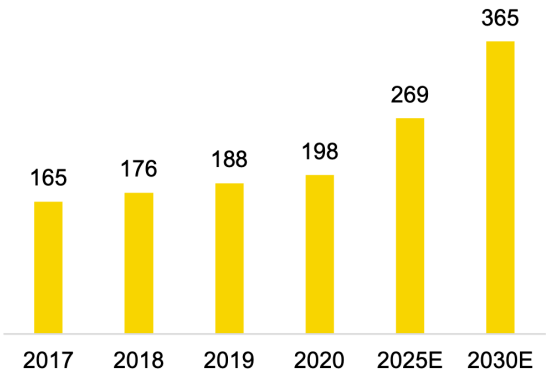
Dairy

Market overview of the dairy value chain in India

India is the world's largest producer of milk, accounting for 22% of the global supply.[xxxvi] Annual milk production per capita is estimated to be 144 kgs. Milk production grew at a CAGR of 6.3% from 2017-2020, reaching 198 million tonnes in 2020; Figure 18 illustrates this trend.

10%-15% of the milk produced in India is used to manufacture value-added products, with the rest directly consumed in liquid form. Milk imports are negligible (<0.1%) compared to the level of production. In 2020, the total number of dairy farms in India was estimated at around 75 million.[xxxvii]

Figure 18: Milk Production in Million Tonnes, India (2017-2030)



The formal sector, which includes Dairy Cooperative Societies (DCS) and other private players, makes up around 20% of the industry, while the informal sector comprises 80% (Figure 19). The DCS structure has strengthened the value chain and is one of the key contributors to the success of the dairy industry in India.

Between 2013 and 2019, DCS have grown at a CAGR of 3.4% to approximately 190,516 units, covering a total of 16.93 million dairy farmers. DCS members produce approximately 10% of the total milk in the country, accounting for around 50% of milk produced by the formal sector.[xxxviii]

The structure of the Indian dairy industry is outlined in Figure 19.[xxxix]

Most small dairy farmers are only involved in the value chain at the first mile, and have little to no exposure to the movement of milk beyond the level of the DCS or private players. However, dairy farmers in India receive up to 80% of the price paid by the consumer, whereas in Australia, New Zealand and most European countries farmers receive only 25%-40% of this price.[xl]

The annual per-capita consumption of liquid milk in India was estimated at 101.5 kgs in 2020, equivalent to 278 grams of milk per person per day. But 5-10% of the total milk supply is wasted every year, with up to 30% of this waste occurring during the summer. The primary causes of milk wastage in India include a lack of accessible cold chain facilities (especially in the first mile), and the absence of a reliable electricity supply.

Figure 19: Structure of the Indian Dairy Industry

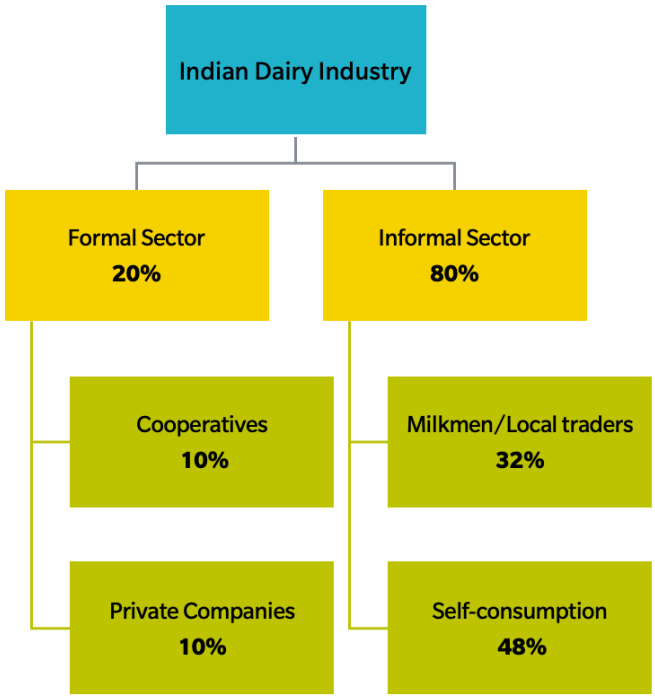
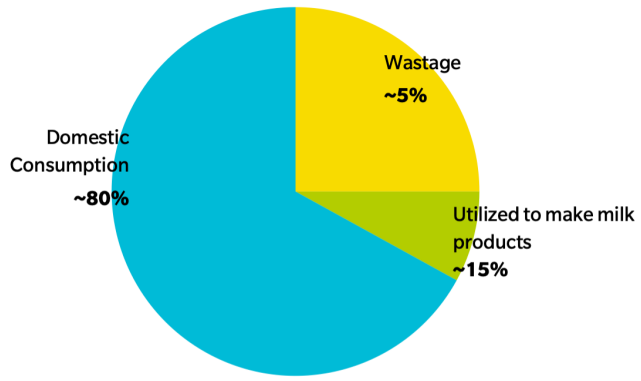


Figure 20 breaks down the total milk production by how it is used:

Figure 20: Breakdown of Annual Milk Production According to its Usage



Utilisation and Gaps Within the Dairy Chain

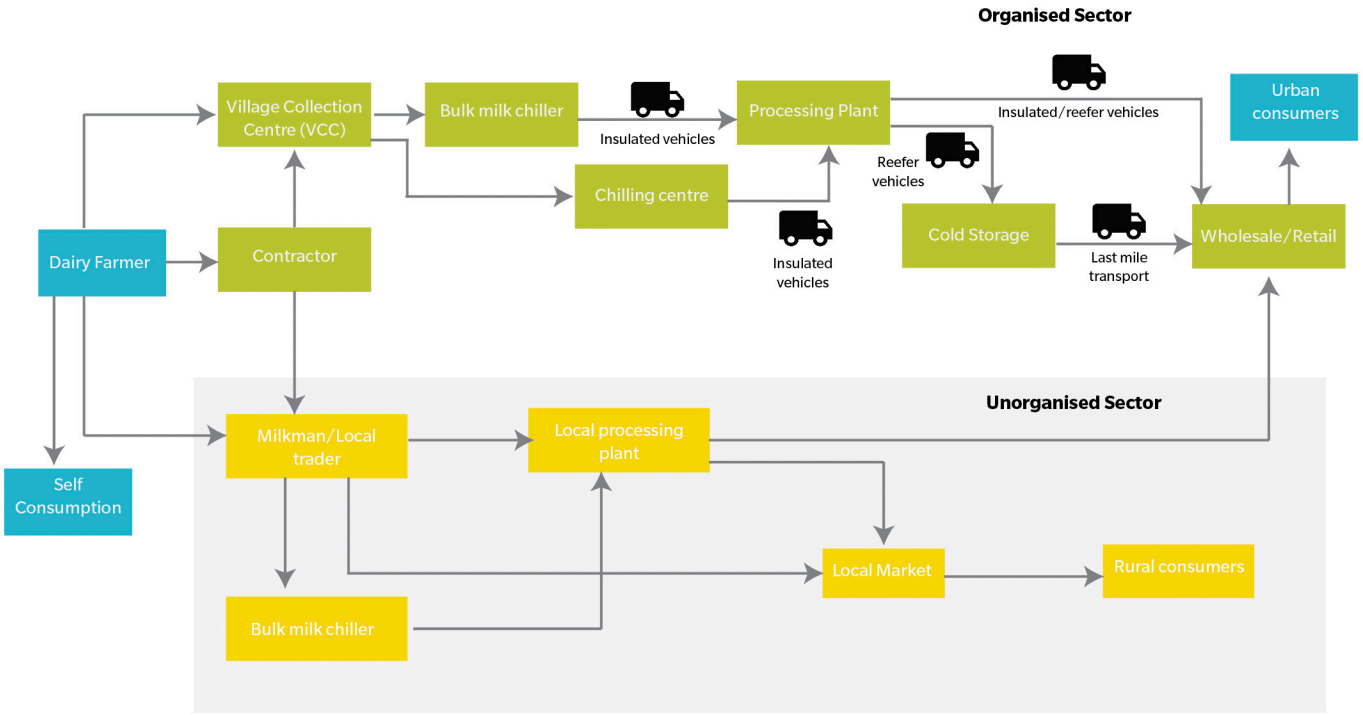
The temperature of fresh milk is around 38°C, but needs to be brought down to around 4°C within three to five hours to protect it from spoilage. Therefore, farmers need to either sell their milk immediately, or use cold chain to extend its shelf life. Milk from the informal sector tends to be used immediately and/or sold at the local level, with little to no exposure to cold chain. CCI is primarily used by the formal sector.

To avoid spoilage, the bulk milk chiller (BMC) is the most critical component of CCI for the first mile. At the village level, BMCs are generally deployed by the DCS and private dairies, and dairy farmers sell their milk to them. This milk is then stored and cooled to 4°C using either BMCs or chilling centres. The deployment of BMCs at each DCS saves transportation costs, reduces spoilage, preserves milk quality and ensures a better sale price.

After cooling, the milk is transported to a dairy processing plant in an insulated milk tanker; currently around 36,000 such tankers are operating in India. At the processing plant, milk is either pasteurised or converted into value-added products. Depending on the product, it is then transported via reefer vehicle or insulated vehicle to cold storage or to wholesale/retail stores. Around 80% of refrigerated vehicles (including insulated vehicles) in India are used to transport milk and milk products.[xli] Some products, such as ice-cream, require cold storage even at the wholesale/retail level; an estimated 70%-80% of the deep freezer market in India has been captured by the ice-cream industry. The annual market size for deep freezers is estimated to be around 500,000-600,000 units.

The different value chains in the dairy industry are illustrated in Figure 21.

Figure 21: Possible Value Chain Combinations for Milk and Milk Products in India



45%-50% of wastage in the formal sector occurs before milk reaches the Village Collection Centre (VCC), and the remaining 50% occurs at the BMC/chilling centre.[xlii] This highlights the need to strengthen first mile cold chain solutions like BMCs.

On average, each DCS deploys one BMC with an average capacity of 1,500-2,000 litres/day. As of March 2019, total BMC storage capacity in India was 41.447 million litres/day. Currently around 25,000 BMCs are deployed by DCS, with around 13% of DCS in India using at least one; the highest coverage is in Gujarat. It is assumed that private dairies deploy an additional 50% of this BMC capacity. Thus, the total number of BMCs deployed in India is around 37,500 units. This clearly indicates an untapped potential for first mile cold chain solutions (Table 15).

Figure 22: Number of BMCs in India (2018-2020)

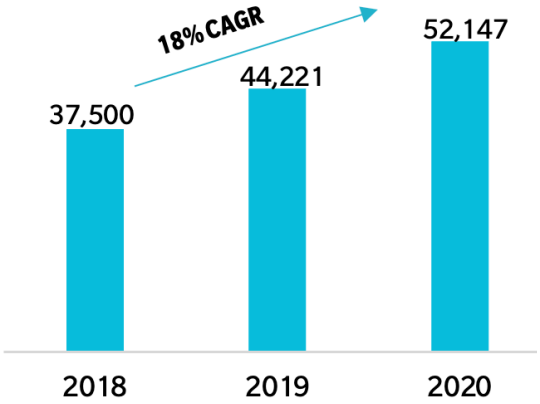


Table 15: CCI Deployment Gap for First Mile Cold-Storage

CCI Component	Created (Nos.)	Required (Nos.)	Gap (%)
Chilling Centres/Bulk Milk Chillers	52,147	260,737	80%
Reefer Trucks (excluding insulated tankers)	1,747	8,733	
Cold Storage	39	196	

Based on these assumptions, the 2019 CCI market size (based on a CaaS model) can be estimated at US$171 million for bulk milk chillers, US$37 million for reefer vehicles (excluding insulated tankers) and US$4 million for cold storage. For upfront purchase of assets (CAPEX model), the as is market size can be estimated at US$819 million for bulk milk chillers, US$47 million for reefer vehicles (excluding insulated tankers) and US$59 million for cold storage.

Figure 23: Current and Projected CCI Market Size in the Dairy Value Chain Based on CaaS (USD million)[xliii]

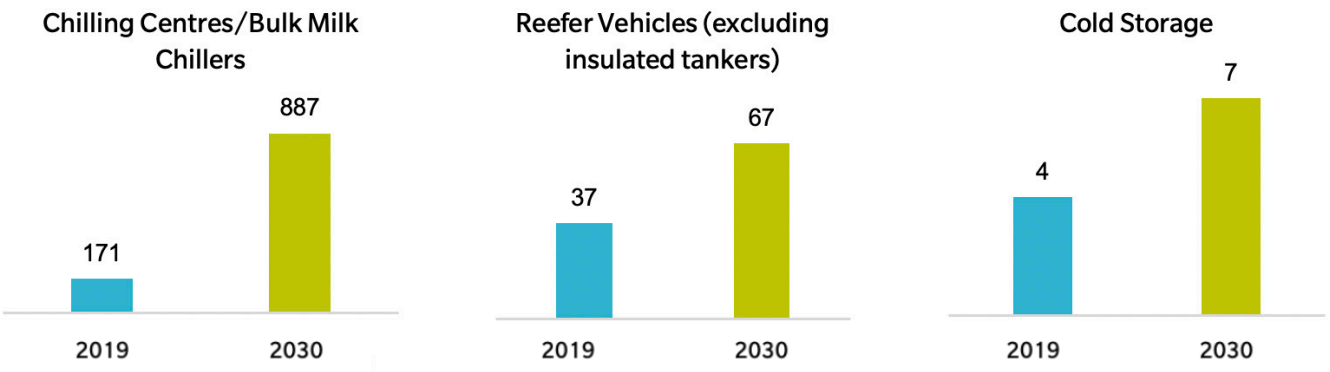
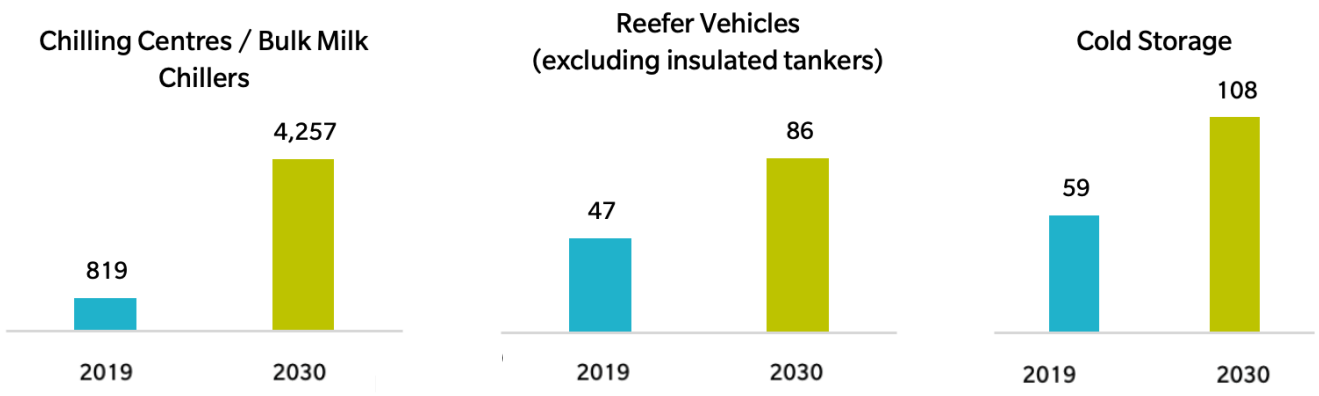


Figure 24: Current and Projected CCI Market Size in the Dairy Value Chain Based on CAPEX (USD million)[xliv]



In 2018, the Government of India announced its plan to install an additional 105,000 BMCs in the country by 2028 to strengthen the dairy value chain.[xlv] This is equivalent to an annual deployment target rate of around 10,000 units. If these targets are met, about 60-65% of DCS[15] in India will have installed BMCs by 2030.

Table 16 quantifies the estimated CCI deployment required for the dairy value chain:

Table 16: Estimated CCI Deployment Required for Dairy Value Chain in India by 2030

CCI Component	Units by 2030
Bulk Milk Chillers (BMCs)	Nos. 271,166
Cold Storage	Nos. 72
Reefer Vehicles	Nos. 3,210

Assuming the deployments mentioned above go forward, the total projected market size based on a CaaS model is estimated at US$961 million, broken down as; US$887 million for bulk milk chillers, US$67 million for reefer vehicles (excluding insulated tankers) and US$4 million for cold storage. For upfront purchase of assets based on the CAPEX model, the total projected market size is estimated at US$4.45 billion, broken down as: US$4.257 billion for bulk milk chillers, US$86 million for reefer vehicles (excluding insulated tankers) and US$108 million for cold storage. Around 95% of CAPEX investment would go towards strengthening first mile cold chain infrastructure like bulk milk chillers.

Challenges in Utilisation of CCI in the Dairy Value Chain

The following are some of the barriers to CCI uptake in the dairy value chain:

1. Limited participation of farmers across the value chain: Currently, farmers are not involved in the dairy value chain beyond the first mile. Their participation is negligible when it comes to value-added products. Shifting the cooling process from the village level to the farm level would ensure better quality milk with less spoilage, and would enable farmers to manufacture their own value-added products. This would allow them to receive higher prices for their milk.

2. Slow cooling: Instant cooling is not possible with BMCs, which take more than three hours to chill milk to 4°C. Instant milk chilling facilities chill milk in less than 30 minutes, thus ensuring that the quality of the milk doesn't deteriorate. However, the processing capacity of this technology is currently limited to 1,000 litres per day.

3. Maintenance issues: When BMCs are not properly maintained and cleaned it lowers their utilisation rate, and can also result in milk spoilage. In some cases, operators switch off their machines to save money, thereby reducing their effectiveness and benefits.

4. Unreliable grid: Due to unreliable grid power in villages most BMCs use diesel generators for backup power, thereby increasing costs. Solar power could be a good alternative. Initial capital costs would be higher, but subsidies could be made available through government grants. However, space constraints could be a problem for the installation of solar panels, and the performance of the off-grid system would depend on irradiation levels. On cloudy days, power back-up may be insufficient in case of long power cuts.

15. The estimated number of DCS by 2030 is ~ 285,000, assuming the 2013-2019 CAGR of 3.4%.

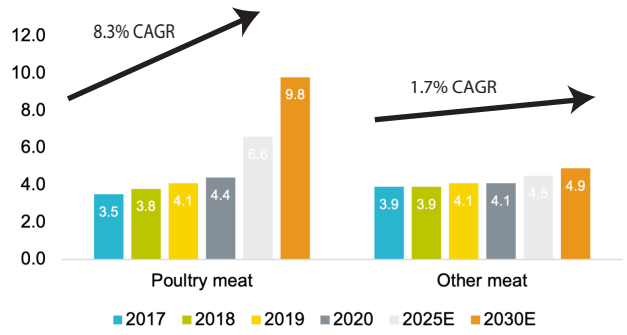
Meat

Market overview of the dairy value chain in India

The livestock sector contributes 25.6% to India's agriculture GDP, and 4.11% to the overall GDP.[xlvi] One of its key industries is meat, which can be divided into two categories: poultry meat and other meat. The "other meat" category includes buffalo, goat, sheep, pig and cattle meat. India is the world's largest producer of buffalo meat and the second largest producer of goat meat. In 2020 around 8.5 million tonnes of meat were produced and imported, ~52% of which was poultry meat; meat imports, however, are negligible, at <0.1% of the total. The annual per capita supply of meat is 6.17 kgs.[16]

Figure 25 illustrates total meat supply in India:

Figure 25: Supply of Meat in Million Tonnes in India (2017-2030)

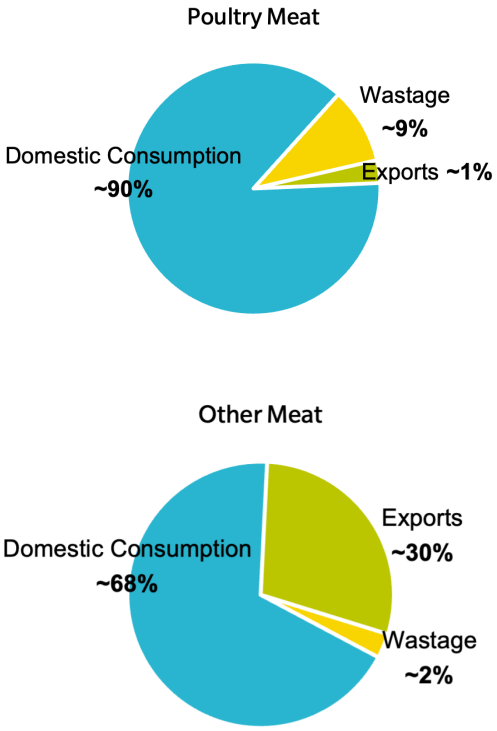


At 2.9 kgs of poultry meat and 2.1 kgs of other meat, **annual per-capita meat consumption in India is one of the lowest in the world.** This is mainly because of religious beliefs, personal dietary preferences and income levels. Poultry consumption is estimated to increase at a CAGR of 3.7%, while for other types of meat the estimated CAGR is 2.3%. Currently, poultry meat accounts for around 58% of total meat consumption in India, and its share is expected to increase in the coming years.

1.2 million tonnes of meat are exported from the country annually, 97% of which is buffalo meat.[xlvii] 7%-9% of poultry meat is wasted, as is 2%-4% of other meat.

Figure 26 breaks down the total meat production by domestic consumption, wastage and exports:

Figure 26: Breakdown of Annual Meat Supply According to its Usage



CCI Utilisation and Gaps Within the Meat Value Chain

Apart from buffalo meat, there is very little meat processing in India. One of the primary reasons for this is the Indian consumer's preference for fresh meat, which sometimes results in unhygienic poultry slaughtering at the retailer level.

Table 17 shows the extent to which different types of meat are processed, both for domestic consumption and for export.

Table 17: Processing Levels in India for Different Types of Meat

Type of Meat	% Share of Supply	Domestic Consumption		Export
		Fresh	Processed	Negligible
Poultry meat[xlviii]	~50%	~94%	~6%	~80%
Buffalo meat	~19%	~20%	Negligible[17]	~1%
Sheep and goat meat[xlix]	~21%	~96%	~3%	Negligible
Pig meat[l]	~6%	~95%	~5%	
Total	~97%			

16. Supply includes both production and imports.

17. The Indian buffalo meat industry for domestic consumption is based on the production of fresh meat, which is processed and sold daily. Retail outlets are generally not equipped with air conditioners, refrigerators or deep freezers.

Low processing volumes and negligible exports (except for buffalo meat) result in low utilisation and deployment of cold chain facilities for the meat value chain. CCI is primarily used to process poultry meat and to export buffalo meat. Other domestically consumed meats are generally stored, transported and sold without any cold chain involvement. This study has therefore focused on the two types of meat most important to the cold chain industry: buffalo meat and poultry meat.

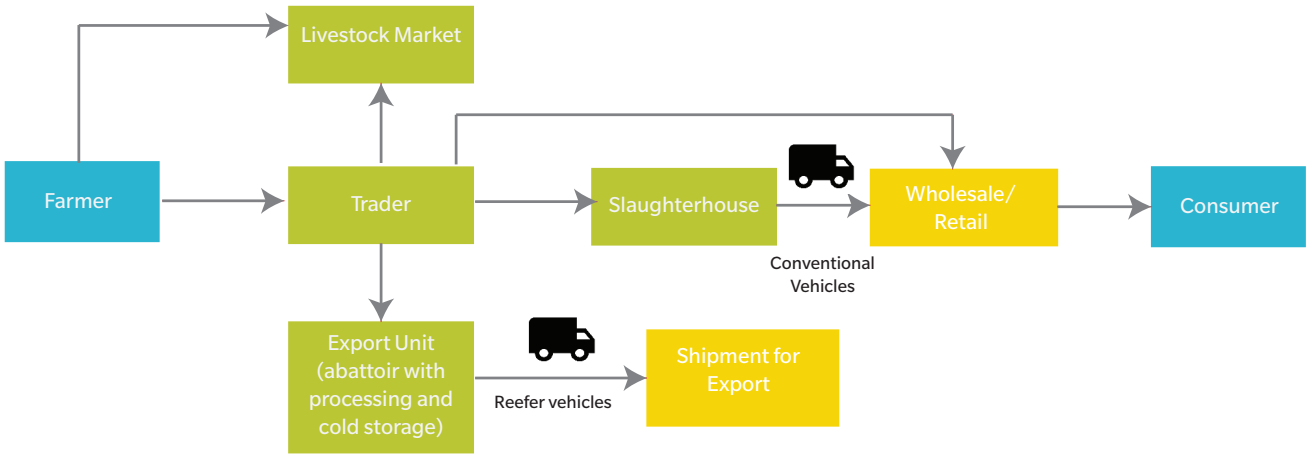
Buffalo Meat

Figure 27 maps out the buffalo meat value chain in India.

As buffalos age they become less productive. Once older animals are no longer considered useful, they are sold to a trader who sells them on to either a municipal slaughterhouse (for domestic consumption) or to an export unit abattoir. The price is based not on the weight of the buffalo but on the carcass yield, which is generally 45% of an animal's weight.[li] The domestic demand for buffalo meat is met by daily slaughtering and sales through wholesalers or retailers, and cold chain facilities are generally not used.[lii] Cold storage of buffalo meat at the wholesaler and retailer level is rare.[liii]

For the export market, slaughtering takes place at an export unit abattoir. The slaughtered carcass is washed and immediately chilled to -18°C for 24 hours (prior to deboning) at a chiller within the export unit. This is done to minimise spoilage and the development of microorganisms.[liv] After a day of chilling the meat is deboned, packaged, and frozen at -40°C in a blast freezer or cold storage facility for 12 hours. It is then transferred in cartons to a reefer vehicle, and sent for export. Only deboned buffalo meat is legally permitted for export in India. Currently, there are around 84 export units with chillers and blast freezer/ cold storage facilities catering to buffalo meat exports, the majority of which are in the state of Uttar Pradesh.

Figure 27: Buffalo Meat Value Chain in India



Poultry Meat

Poultry meat accounts for around 52% of the total meat supply in India, and is expected to increase to around 67% by 2030. Of the poultry meat, around 70% comes from broilers.[lv]

Figure 28 maps out the poultry meat value chain in India.

From the breeding farms, processors purchase day-old chicks and rear them for 3-6 weeks, the time it takes for them to grow into adult broilers.[lvi] **In the informal market, broilers are either sold live to retailers, or sent to slaughterhouses from where the meat is sold to wholesalers/retailers or directly to customers.** In the formal market, the broilers are sent to either registered slaughterhouses or registered abattoirs with integrated processing and cold storage facilities. The processed meat is stored at -18°C before being transferred by reefer vehicle to wholesalers, retailers or high-end customers such as restaurants and hotels. The average holding capacity of a reefer vehicle is 28 MT per trip.[lvii]

Considering the low processing volumes and negligible exports in the meat value chain, the estimated CCI available and required for meat in India (until 2020) is as follows:

Based on the numbers above, the 2019 CCI market size (based on a CaaS model) for the meat value chain is estimated at US$3.1 million for cold storage and US$19.1 million for reefer vehicles. For upfront purchase of assets (CAPEX model), the 2019 market size is estimated at US$29 million for cold storage and US$24 million for reefer vehicles.

Figure 28: Poultry Meat Value Chain in India

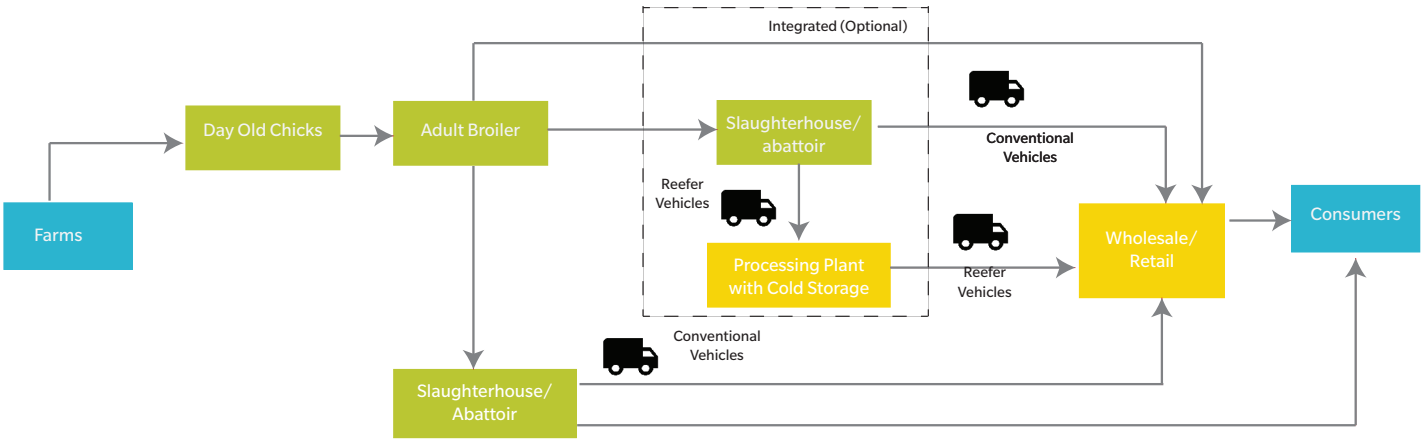


Figure 29: Current and Projected CCI Market Size in the Meat Value Chain Based on CaaS (USD million)[lviii]

Figure 30: Current and Projected CCI Market Size in the Meat Value Chain Based on CAPEX (USD million)[lix]

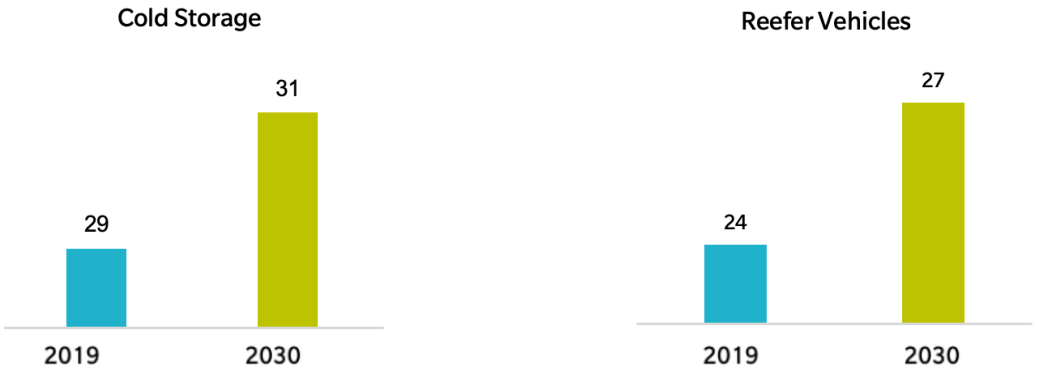


Table 18: Estimated CCI Deployment for the Meat Value Chain in India by 2030

CCI Component	Units by 2030
Cold Storage	Nos. 21
Reefer[18] vehicles	Nos. 1,000

Assuming the meat value chain becomes more formalised and the frozen meat industry grows, the total projected 2030 market size based on a CaaS model is estimated at US$24.3 million, broken down as US$3.4 million for cold storage and US$20.9 million for reefer vehicles. For upfront purchase of assets based on the CAPEX model, the total projected market size is estimated at US$58 million, broken down as US$31 million for cold storage and US$27 million for reefer vehicles. Around 50% of CAPEX investment would go towards strengthening cold storage infrastructure and cold chain logistics.

Challenges in Utilisation of CCI in the Meat Value Chain

1. Limited need for CCI in the first mile: The meat industry functions very differently than the FFV, dairy and fish industries; livestock can be stored and transported while still alive, which decreases the need for cold chain in the first mile. CCI is only required after slaughtering, and if this step only happens at the last mile (slaughtering at the retail level) then CCI requirements are lower still.

2. Informal market: Around 90% of the fresh meat in India is sold through the informal market, like butcher shops.[lx] Most unregistered slaughterhouses lack not only the required CCI, but also basic amenities like proper ventilation and minimum space for lairage. Transitioning fresh meat from the informal market to the formal market would not only drive CCI uptake, but would also ensure that more hygienic and high-quality meat is supplied to consumers.

3. Small export and import market: Apart from buffalo meat exports, India's contribution to the global meat trade is extremely low.

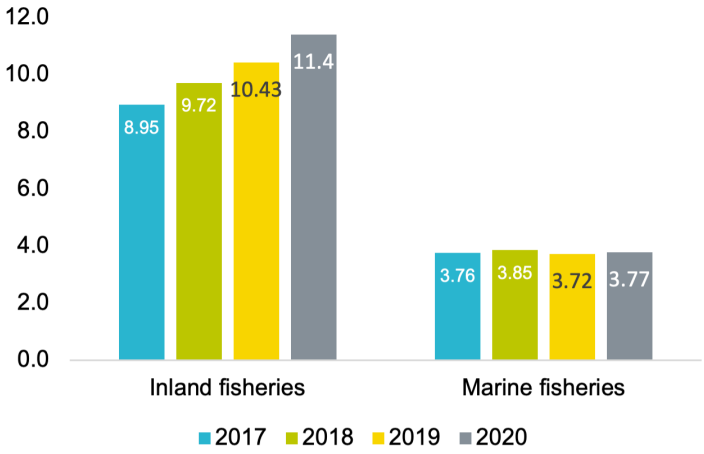
4. Consumer preference for fresh meat: Meat consumers in India prefer fresh meat over frozen or chilled meat, encouraging the practice of live slaughtering. This limits the need for CCI while storing and moving meat.

Fish

Market overview of the fish value chain in India

India is the world's second largest producer of fish,[19] accounting for 5.7% of global production. Fisheries contribute about 7.28% of India's agricultural GDP, with inland and marine fish production making up 74% and 26% respectively. In 2020 about 15.2 million tonnes of fish were produced in the country, assuming the 2013-2019 CAGR of 6.7%. During this period marine fishery production grew at a CAGR of 1.3%, while inland fishery production grew at 8.5%.

Figure 31: Production of Fish in Million Tonnes in India from 2017-2020



In 2020 Indians consumed about 10.4 million tonnes of fish, a per capita consumption of 7.5 kgs per year. Historical data (2007-2017) show a 2.9% annual growth in per capita consumption and a 4% annual growth in overall demand for fish in the country; the perception of fish as a healthy food and lifestyle change drive growth in fish consumption.[lxi] The five states and union territories with the highest per capita fish consumption are the A&N islands, Puducherry, Tripura, Kerala and Odisha.

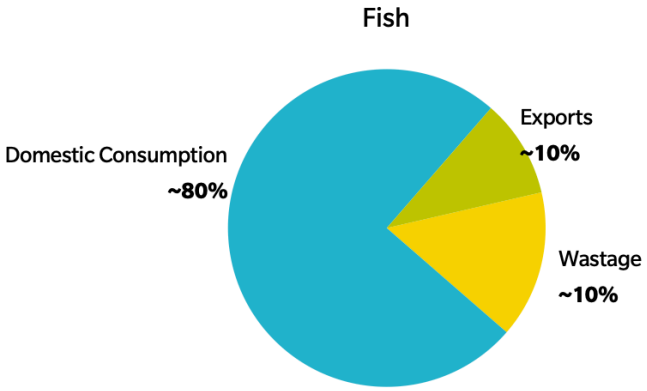
Fish is India's second largest export, accounting for about 29% of total export volumes and 11% of USD earnings.[lxii] 8-10% of total fish production is exported; in 2020 this amounted to about 1.14 million tonnes, worth USD 5.96 billion. Export volumes grew at a CAGR of 5% during the period 2013-2019.

According to ICAR's All India Coordinated Research Project on Post-Harvest Engineering & Technology, about 5.23% of all inland fish and 10.52% of all marine fish is lost to spoilage.[lxiii] 80% of this loss occurs at harvesting, post-harvest sorting/grading and during transport, while the remaining 20% occurs during storage at the wholesale level.

Fish is a highly perishable commodity. Once caught it must be immediately frozen, which is usually done by covering it in block, flake or slurry ice. A fish starts to freeze at -2°C and completely freezes at around -40°C. Once frozen, fish must be stored at a constant temperature of –23°C or below to maintain shelf life and ensure quality. Cold chain is therefore critical, especially during long-distance transport.

18. It is assumed that a) cold storage utilisation is 75%, b) the holding period is 30 days, and c) one round trip takes four days if the estimated distance from processing unit to port is greater than 1,500 km.
19. The term fish in current analysis includes all seafood.

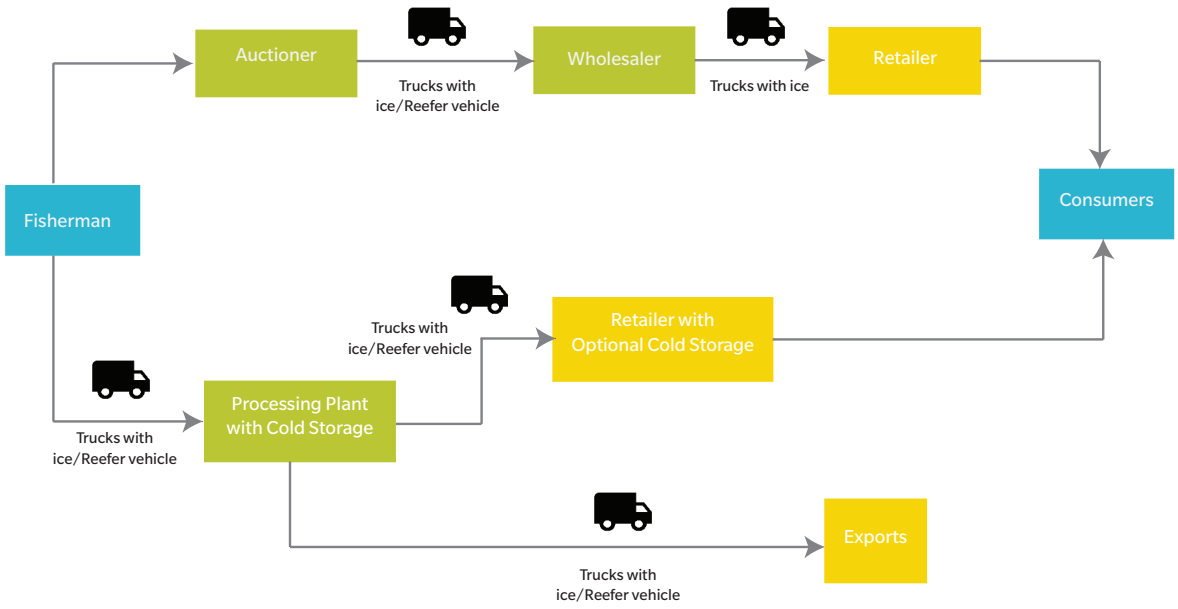
Figure 32: Breakdown of Annual Fish Supply According to its Usage



CGI Utilisation and Gaps Within the Fish Value Chain

70-80% of the total fish supply is consumed domestically. Of this, more than 85% is sold fresh in informal markets.[lxiv] Auctioneers or commissioning agents are the first point of contact for fisherman; these agents sell the bulk of the fish they collect to wholesalers. **The size of wholesale markets typically ranges from 1 to 100MT, with minimal or no cold chain facilities.** After some basic value addition in the form of sorting, grading and icing, wholesalers sell the produce to retailers, who add additional value by cleaning and ice packing. Small vendors associated with these retailers then perform door-to-door marketing to sell fresh fish. Typically, fish is sold within 1-2 days of harvesting. Stakeholders along the value chain have a strong preference for live or fresh fish due to its freshness, taste and nutritional value, so fish is generally processed not for domestic consumption but to cater to export markets. **Ice blocks and flakes are generally used for storage and transportation, making ice plants one of the most important CCI components for the fish value chain.**

Figure 33: Fish Value Chain



In order to improve fish quality and reduce losses, the GoI is trying to improve and develop post-harvest infrastructure through a programme called Blue Revolution. **Through this scheme, grants are provided to fishing cooperatives, NGOs, private players and government institutions to develop landing centres at harbours.** The government is looking to develop other post-harvest infrastructure as well, including icemaking plants, integrated cold storage facilities with ice plants, refrigerated/insulated trucks, modern retail marketing infrastructure, and other forms of icebox transport (two-wheelers, bicycles and three-wheelers).

The Blue Revolution scheme also provides financial assistance for installing "Hybrid Solar Wind Energy Generators" to promote the use of renewable energy in fisheries and aquaculture. These systems can be used for illumination, to power auxiliary units on board marine fishing boats, to operate small-scale ice plants, and to run pumps, aerators and filters.[lxv] Solar cold rooms have high energy requirements due to the very low temperatures needed to store fish (-23°C), which increases the upfront cost of these assets. They could also be promoted under this scheme through providing financial assistance.

Table 19 outlines the number of units sanctioned under the Blue Revolution scheme over the periods 2015-2016 and 2019-2020.

Table 19: Solar Wind Hybrid Power Support Utilisation in Fisheries

Cold Chain	Icemaking Plants	Cold Storage Facilities	Ice Plants with cold storage Facilities	Refrigerated/ Insulated Trucks	Solar Power Support Systems	Transport with Ice Boxes			
						Auto Rickshaws	Motorcycles	Bicyles	
Avg. Capacity	40 MT	40 MT	40 MT	10 MT	6 MT	-	-	-	-
Nos.	221	8	104	206	112	233	832	5, 614	3, 361

Cold and chilled storage plays a critical role in the export market for fish,[20] helping to maintain the quality of highly perishable products as per international standards. **According to the Marine Products Export Development Authority (MPEDA), a statutory body under the Ministry of Commerce & Industry, 430,000 MT capacity of cold and chilled storage has been deployed as of September 2021.**[lxvi] The total capacity of such storage grew at a CAGR of around 11% between 2014-2021. Since Pradhan Mantri Matsya SAMPADA Yojana (PMMSY)[21] envisages doubling the value of fish exports between 2020-2025,[lxvii] it is expected that cold storage capacity will continue to grow to support this growing market. In 2020, the cold storage capacity used for fish and fish products was estimated to be about 1.2% of the total.

Based on the below estimates, the 2019 CCI market size (based on a CaaS model) for the fish value chain can be calculated at US$34 million for ice plants, US$18 million for cold storage (mostly for exports) and US$13 million for reefer vehicles. For upfront purchase of assets (CAPEX model), the as is market size can be calculated at US$38 million for ice plants, US$134 million for cold storage (mostly for exports) and US$16 million for reefer vehicles.

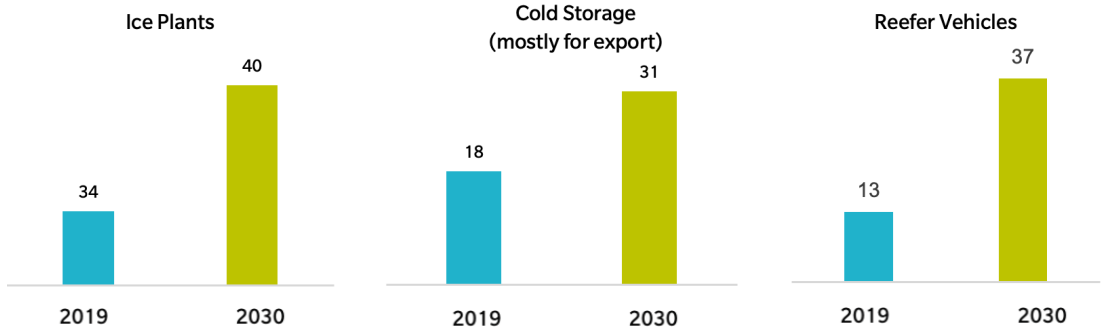
Table 20: Cold and Chilled Storage Deployment for Fish Export Value Chain

CCI Component	Cold Storage		Chilled Storage		Total	
	Nos.	Capacity (MT)	Nos.	Capacity (MT)	Nos.	Capacity (MT)
As of July 2014	479	193,464	29	11,376	508	204,840
As of Sept. 2021	653	409,993	42	23,267	695	433,260

Table 21. Estimated CCI Deployment and Requirement for the Fish Value Chain in India (until 2020)

CCI Component	Created (Nos.)	Required (Nos.)	Gap (%)
Ice Plants	272	1,017	74%
Cold Storage (mostly for export)	624	6,294	90%
Reefer Vehicles	606	6,104	90%

Figure 34: Current and Projected CCI Market Size in the Fish Value Chain Based on CaaS (USD million)[lxviii]



20. Almost all exports are frozen; volumes of dried and live fish are minimal.

21. Pradhan Mantri Matsya SAMPADA Yojana (PMMSY) is a scheme launched in 2020 by the Department of Fisheries to bring about a Blue Revolution through sustainable and responsible development.

Figure 35: Current and Projected CCI Market Size in the Fish Value Chain Based on CAPEX (USD million)[lxix]

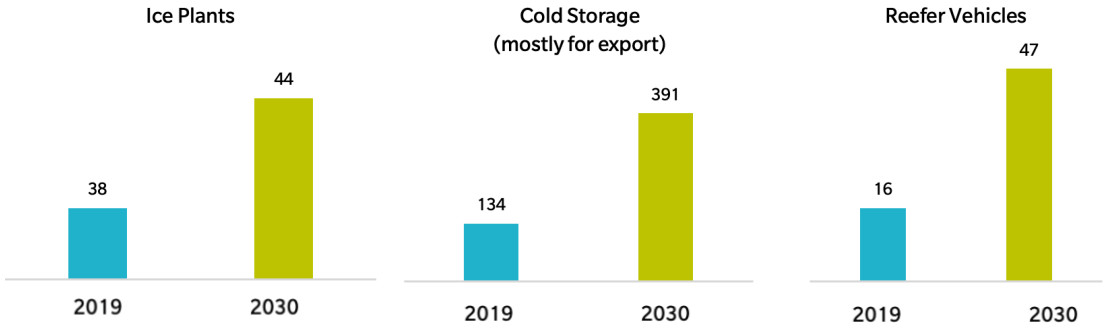


Table 22 estimates the CCI deployment required for the fish sector by 2030. Because cumulative deployment data for icemaking plants and refrigerated vehicles is not available, the units to be deployed under the Blue Revolution scheme were used to estimate the projected market size and CAPEX required.

Table 22: Estimated CCI Deployment Required for the Fish Value Chain in India by 2030

CCI Element	Units by 2030
Ice-making Plants[22]	Nos. 317
Cold & Chilled Storage	Nos. 1,821
Reefer Vehicles[23]	Nos. 1,766

Using the above estimates, the total projected 2030 market size based on a CaaS model for the fish value chain is estimated at US$108 million, broken down as: US$44 million for ice plants, US$391 million for cold storage and US$47 million for reefer vehicles. About 80% of total investment would go towards developing cold and chilled storage, while the remaining 20% would be needed for icemaking plants and reefer vehicles. On the other hand, the projection for the fish value chain based on a CAPEX model is US$482 million.

Challenges in Utilisation of CCI in the Fish Value Chain

1. Informal market: Around 85% of fresh fish in India is sold through the informal market. Most of these markets are poorly maintained, with minimal supervision and poor hygiene. Leftover fish is stored in unhygienic plastic containers. Transitioning fresh fish from the informal to the formal market would both drive CCI uptake and ensure that more hygienic, higher-quality fish is supplied to consumers.

2. Consumer preference for fresh fish: Consumers in India prefer fresh fish over frozen or chilled fish. As a result, apart from ice blocks, limited CCI is used to store and transport fish.

3. Unaffordability of CCI: Because fish is highly perishable, it requires integrated CCI at all stages of the value chain to maintain optimal temperatures (-20°C to -15°C) once frozen. This requirement increases both upfront investment and operational costs for CCI. The upfront cost of a solar-powered cold storage facility also increases since it requires a larger solar PV system to power it. The unaffordability of CCI affects stakeholders across the fish value chain, hindering the uptake of cold chain solutions.

22. It is assumed that the average processing capacity of an icemaking plant is 40 MT. The average annual utilisation rate of icemaking plants is 30-35%, assuming 300 working days. 1 MT of fish requires 0.34 MT of ice. 23. It is assumed that: a) the average holding period of fish in cold storage is 90 days, b) cold storage utilisation is 75%, and c) the average time a reefer vehicle takes to complete a round trip is two days.

Annex 2: List of Stakeholders Interviewed

Sr. No.	Organisation	Category
1.	Gubba Cold Storage	Cold Storage Operator
2.	ColdEX Logistics	Cold Chain Logistics Operator
3.	New Leaf Dynamic Pvt. Ltd	Milk Chiller OEM
4.	Danfoss Industries	Cold Chain Sub-Component Manufacturer
5.	Inficold	Milk Chiller OEM (Solar Integrated)
6.	Pluss Advance Technologies	Technology Provider
7.	Farmico	Cold Storage Operator
8.	Bhavin Chotaj	Cold Storage Operator
9.	Alliance for an Energy Efficient Economy (AEEE)	Cold Chain Expert
10.	Ecozen	Cold Storage Manufacturer
11.	SELCO	Institution (Cold Chain Expert)
12.	EESL	Demand Aggregator
13.	Promethean Power	Cold Storage OEM
14.	Snowman	Cold Chain Logistics Operator
15.	Cold Star	Cold Chain Logistics Operator
16.	Blue Star	Cold Storage Operator
17.	BEE	Standards Body
18.	NABARD	Financing Institute
19.	Amazon Fresh	Retailer
20.	Adani Agri Fresh	Retailer

ANNEX

Annex 3: Bibliography

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Annex-4: List of Government Schemes Providing Financial Assistance for CCI Development

Entity	Scheme	CCI Elements Covered	Pattern of Finance Assistance
Mission for Integrated Development of Horticulture MIDH	Sub-schemes of the National Horticulture Mission (NMH) & the Horticulture Mission for North East and Himalayan States (HMNEH) under MIDH	Packhouses / on-farm collection & storage units	50% of capital cost of project, INR 4.00 lakhs per 9m x 6m unit
		Integrated packhouses with facilities for grading, sorting, etc.	35% of capital cost of project, or 50% in hilly and Scheduled Areas, as credit-linked back-ended subsidy of up to INR17.50 lakhs per 9m x 18m unit
		Pre-cooling units	35% of capital cost of project, or 50% in hilly and Scheduled Areas, as credit-linked back-ended subsidy of up to INR 8.75 lakhs per 5 MT unit
		Setup (construction/ expansion and modernization) of new cold storage units (maximum 5,000 MT)	35% of capital cost or project, or 50% in hilly and Scheduled Areas, as credit-linked back-ended subsidy
	Sub-scheme of the National Horticulture Board (NHB) under MIDH	Ripening chambers (maximum 300 MT)	35% of capital cost of project, or 50% in hilly and Scheduled Areas, of up to INR 50.75 lakhs per project
		Cold storage units for commercial horticulture (capacity from 5,000 MT to 10,000 MT)	35% of capital cost of project, or 50% in hilly and Scheduled Areas, for capacity above 5,000 MT, as credit-linked back-ended subsidy
	Agriculture Infrastructure Fund	Cold storage units, warehousing, silos, assaying, grading and packaging units, e-marketing points linked to e-trading platforms and ripening chambers. Also PPP projects for crop aggregation sponsored by central/state/ local bodies	INR. 1 Lakh Crore will be provided by banks and financial institutions as loans to Primary Agricultural Credit Societies (PACS), Marketing Cooperative Societies, Farmers Producers Organizations (FPOs), Self Help Group (SHG), farmers, Joint Liability Groups (JLG), Multipurpose Cooperative Societies, agri-entrepreneurs and central/state agencies or local bodies sponsored by PPP projects.
Small Farmer Agri-Business Consortium (SFAC)	Integrated Scheme for Agricultural Marketing (ISAM): Operational Guidelines	Cold storage	75% of Total Financial Outlay (TFO); subsidy to projects is at 25% of capital cost with maximum ceiling of INR 2.25, or 33.33% with a ceiling up to INR 4 crores in North East States, hilly areas and Scheduled Areas
Ministry of Food Processing Industry (MoFPI)		Packhouses and pre-cooling units, ripening chambers and transport infrastructure	Grants-in-aid of 35%, or 50% for North East States, Himalayan States, Integrated Tribal Development Project (ITDP) Areas and islands, of the total cost of plants, machinery and technical civil works
		Value addition and processing infrastructure, including frozen storage and deep freezers integral to processing	50%, or 75% for North East States, Himalayan States, ITDP Areas and islands
Agricultural and Procesed Food Products Export Development Authority (APEDA), under the Ministry of Commerce and Industry	Scheme for Infrastructure Development	Intermediate storage and grading/storage/cleaning of produce	25% of the cost of equipment subject to a ceiling of INR 5.00 lakh per beneficiary
		Mechanized handling facilities including sorting, grading, washing, waxing, ripening, packaging adn palletisation	25% of the cost of equipment subject to a ceiling of INR 10.00 lakh per beneficiary
		Pre-cooling facilities with proper handling systems and cold storage	25% of the cost of equipment subject to a ceiling of INR 10.00 lakh per beneficiary
		Specialized storage facilities such as high humidity cold storage deep freezers, controlled atmosphere (CA) storage and modified atmosphere (MA) storage	25% of the cost subject to a ceiling of INR 10 lakh per beneficiary

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