सत्यमेव जयते
Government of India






Study on
SUSTAINABLE E-COMMERCE COLD CHAIN INFRASTRUCTURE

OZONE CELL
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA

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मंत्री
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सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

भूपेन्द्र यादव
BHUPENDER YADAV

आज़ादी का अमृत महोत्सव

MESSAGE

The rising urbanization has led to the need for a robust cold-chain infrastructure, spurring both growth and innovation, to impart storage and distribution services for produce and products that must be maintained at a given temperature. Sustainable food cold chains are key for improving human well-being, boosting economic growth and reducing greenhouse gas emissions. Establishing robust food cold chains continues to play an essential role in addressing many of the United Nations Sustainable Development Goals (SDGs) while balancing environmental, social and economic benefits.

The Kigali Amendment to the Montreal Protocol will result in global technological conversion efforts towards low Global Warming Potential alternatives including the cold chain sector, which relies on refrigerant gases. The role of the cold chain in realizing the 2030 Agenda for Sustainable Development and the achievement of the SDGs related to ending hunger and poverty, food security, improved nutrition, climate action, sustainable agriculture and fisheries, and health and well-being is very critical.

Cold Chain has also been identified as one of the thematic areas of the India Cooling Actin Plan (ICAP) with the focus on promoting sustainable cooling technology options, focusing on energy efficient, non-ozone depleting substances and low global warming potential technologies, to be adopted in different components of cold chain, which would be a major driver in supporting the Government's priority areas of reducing food loss, ensuring food security and doubling farmers income.

The study on Sustainable E-commerce Cold Storage Infrastructure aims to capture and promote good management practices for developing e-commerce infrastructure for cold chain.

I congratulate all those who are involved in the preparation of this report.

Date: 14 **.09.2023**

(Bhupender Yadav)

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CONSUMER AFFAIRS, FOOD & PUBLIC DISTRIBUTION
GOVERNMENT OF INDIA

सत्यमेव जयते

आहारशुद्धौ सत्त्वशुद्धिः

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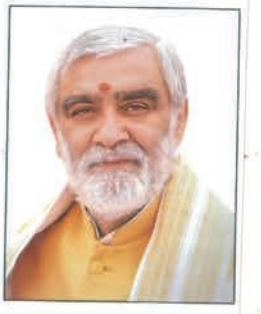

संदेश

ई-कॉमर्स द्वारा भेजी जाने वाली वस्तुओं की नाजुक प्रकृति को देखते हुए एक सस्ती और प्रभावी कोल्ड चेन की आवश्यकता होती है, जिसमें तापमान नियंत्रक सुविधाएं जैसे पैक हाउस, वितरण केंद्र और प्रशीतित वाहन आते हैं।

ई-कॉमर्स के क्षेत्र में हुई महत्वपूर्ण वृद्धि के कारण शीतलन और प्रशीतन सुविधाओं की मांग बढ़ गई है। तदनुसार, कोल्ड चेन को इंडिया कूलिंग एक्शन प्लान (आईसीएपी) में एक प्रमुख क्षेत्र के रूप में चिन्हित किया गया है। अत: शीत भंडारणों के लिए अच्छे प्रबंधन पद्धतियों को विकसित करने और बढ़ावा देने के साथ-साथ शीतलन प्रणालियों के लिए जलवायु अनुकूल रेफ्रिजरेंट का उपयोग करके शीत भंडारण अवसंरचना की परिचालन दक्षता में सुधार करना भी आवश्यक है।

एक सतत ई-कॉमर्स कोल्ड स्टोरेज बुनियादी ढांचे को बढ़ावा देने की दिशा में कुशल प्रबंधनपरक तरीकों में थर्मल इन्सुलेशन में सुधार करके निष्क्रिय शीतलन तकनीकों को शामिल करना चाहिए, जिससे न केवल शीतलन की मांग को कम किया जा सके, बल्कि शीतलन प्रणालियों में उपयोग किए जाने वाले रेफ्रिजरेंट के लिए ऊर्जा की मांग और सुरक्षा संबंधी उपायों को भी शामिल किया जा सकेगा।

"सतत ई-कॉमर्स कोल्ड स्टोरेज इन्फ्रास्ट्रक्चर" पर अध्ययन रिपोर्ट का प्रकाशन एक महत्वपूर्ण संसाधन सामग्री के उद्देश्य की पूर्ति करेगा और इसका सभी संबंधित हितधारकों के बीच व्यापक रूप से प्रसारण किया जाना चाहिए। इसके अलावा, इस अध्ययन की प्रस्तावित सिफारिशों को लागू करने के लिए भी प्रयास किए जाने चाहिए।

(अश्विनी कुमार चौबे)

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SECRETARY
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MINISTRY OF ENVIRONMENT, FOREST
& CLIMATE CHANGE

Message

Cold chain infrastructure is an important aspect of modern life. Improving and expanding the cold chain would have a significant impact on enhancing the shelf life of products and various types of produce and thereby contributing to economic activities. While it is important to develop robust and sustainable cold chains, it is also necessary to ensure that the cold chains minimise direct and indirect GHG emissions. The India Cooling Action Plan (ICAP), with cold chain as one of the thematic areas, has proposed specific actions towards promoting a sustainable cold chain infrastructure.

In recent years with the increase in e-commerce business, especially for fast-moving consumer goods including perishable items, there has been an increase in investment at the backend, for cold chain Infrastructure. Developing sustainable cold chains with climate friendly cooling systems supports a circular economy and is critical for climate and food security. Towards this end, there is a need to focus on efficient design of the cold storage infrastructure through adopting passive cooling techniques as well as operation and maintenance of the infrastructure by adequate training and capacity building of the associated personnel.

This study report proposes actions for achieving sustainable cooling while developing and promoting cold chain e-commerce infrastructure. I compliment the team associated with the preparation of this report for their in-depth analysis and invaluable recommendations.

(Leena Nandan)

New Delhi,
September 12, 2023.

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1. Introduction

1.1. E-commerce in India

A marketplace is an area where merchants congregate to sell their goods and services to customers—either in a physical enclosure or online using the internet or any electronic medium. All buying and selling is considered commerce, and when this happens on an electronic network, it's called e-commerce. E-commerce is not limited to a store selling goods online to customers (business-to-consumer or B2C). It's also e-commerce when one business transacts with another (B2B) or even when one consumer transacts with another consumer or a consumer transacts with a business. But largely, when we talk of e-commerce, we are generally talking of B2C and B2B transactions.

E-commerce has changed the way people shop and consume products and services. More and more people are turning to their computers and smart devices to order goods that are delivered to their homes. E-commerce has helped businesses (especially small businesses with a narrow reach) gain access to and establish a wider market presence by providing cheaper and more efficient distribution channels for their products or services.

India's e-commerce market was valued at USD 74.8 billion in 2022 and is expected to reach USD 350 billion in the year 2030. Retail accounts for the bulk of this and the key drivers of growth are expected to be groceries and fashion/apparel[1]. In 2022, perishables accounted for 15% of retail sale value in e-commerce with a value of USD 7.5 billion.

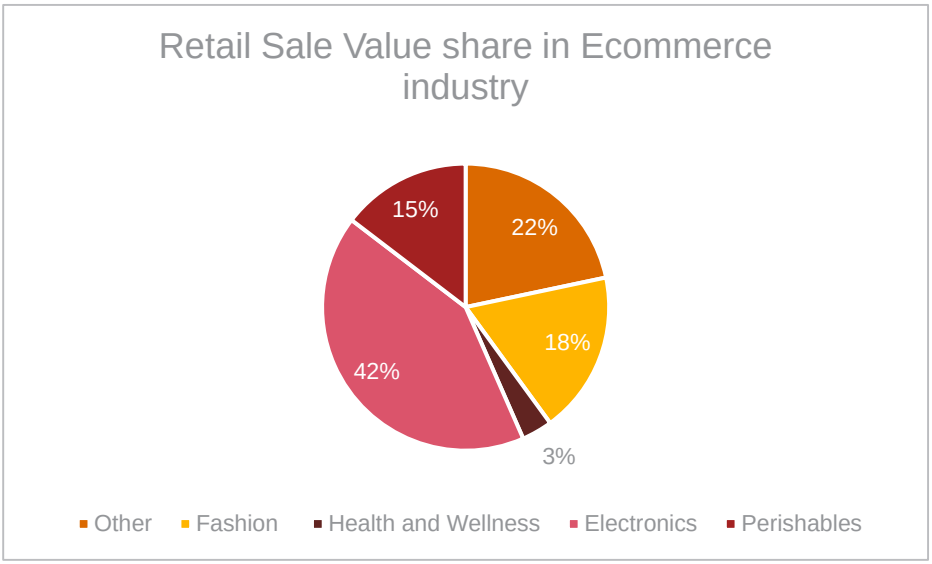


Figure 1 Retail sale value share in e-commerce sector

1.2. Significance of cold chain in e-commerce

India is one of the world's largest producers of fruits, vegetables, milk, meat and fish[2] (Refer to Table 1). Because the country's agro-climatic zones are so diverse, it produces a vast variety of agro-commodities. However, much of this does not find its way to consumers or even businesses because there's a high level of wastage across the value chain of key perishables. The annual post-harvest loss of major agricultural

[1]https://www.ibef.org/download/1682314986_E-Commerce-February-2023.pdf
[2]https://www.fao.org/india/fao-in-india/india-at-a-glance/en/

produce is worth about USD 13.16 billion. Despite large perishable produce, the cold chain potential in India remains largely untapped. High share of **single commodity cold storage** coupled with high initial investment in land and refrigerator units characterize India's cold chain. Lack of enabling infrastructure like power and roads and lack of awareness for handling perishable produce and lapses on part of storage provider or transporter further lead to spoilage of produce.

Table 1 India's cold chain commodity output as of 2021[3,4,5,6,7,8,9,10]

Commodity	India's Output (million metric ton)	World Output (million metric ton)	Global Share	Post-harvest loss
Fruit	102.48	909.64	11%	6.02% - 15.05%
Vegetable	200.45	1154	17%	4.87% - 11.61%
Milk	209.96	6170.48	23%	0.87%
Meat	8.80	329.28	3%	2.34%

With increasing urbanization and the growth of organized retail (largely from e-commerce), there's a greater focus on the problems dogging the perishables sector and therefore an increased interest in the cold chain industry. This is now a global phenomenon with an increasing number of organized retail stores in emerging economies leading to increased demand for cold chain solutions. Moreover, trade liberalization, government efforts to reduce food waste, and expansion of retail chains by multinational companies are all expected to boost industry growth over the forecast period (2021–2028).

1.2.1. What is a cold chain?

Cold chain is a controlled environment logistics chain, that ensures uninterrupted care from source-to-user. A typical cold chain consists of storage and distribution related activities in which the inventory is maintained within predetermined ambient parameters. Cold chain does not alter the essential characteristics of the produce[11]. The cold chain ensures that perishable products are safe and of high quality at the point of consumption. Cold chain is particularly deployed for perishable products such as:

- Horticulture produces (fruits, vegetables, flowers)
- Dairy products
- Meat
- Vaccines

The cold chain is a science, a technology, and a process. It is a **science** since it requires an understanding of the chemical and biological processes linked with perishability. It is a **technology** since it relies on

[3]https://apeda.gov.in/apedawebsite/six_head_product/FFV.htm

[4]https://www.indiabudget.gov.in/economicsurvey/ebook_es2022/files/basic-html/page277.html#:~:text=India%20is%20ranked%201st%20in,%2D15%20(Figure%2021).

[5]https://knoema.com/atlas/World/topics/Agriculture/Crops-Production-Quantity-tonnes/Vegetables-primary-production#:~:text=In%202021%2C%20vegetables%20primary%20production,decreased%20to%201.39%25%20in%202021.

[6]https://ourworldindata.org/grapher/milk-production-tonnes?tab=table

[7]https://www.pashudhanpraharee.com/recent-status-of-indian-meat-industry-an-overview/#:~:text=In%20terms%20of%20total%20meat,tonnes%20(BAHS%2C%202021).

[8]https://www.statista.com/statistics/237644/global-meat-production-since-1990/

[9]https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1885038

[10]https://www.mofpi.gov.in/sites/default/files/study_report_of_post_harvest_losses.pdf

[11]All India Cold-Chain Infrastructure capacity 2015 – National Centre for Cold-Chain Development (NCCD)

physical means to ensure appropriate temperature conditions along the supply chain. It is a **process** since a series of tasks must be performed to prepare, store, transport, and monitor temperature-sensitive products. The main elements of a cold chain involve:

Cooling system: Bringing commodities such as food to the appropriate temperature for processing, storage, and transportation.

Cold storage: Providing facilities for the storage of goods over a period of time, either waiting to be transported to a distant market, at an intermediary location for processing and distribution, and close to the market for distribution.

Cold transport: Having conveyances available to move goods while maintaining stable temperature and humidity conditions as well as protecting their integrity.

Cold processing and distribution: Providing facilities for the transformation and processing of goods as well as ensuring sanitary conditions, consolidating, and de-consolidating loads (crates, boxes, pallets) for distribution.

The major components of cold chain include:

- Modern pack houses with precoolers and a small cold room;
- Transportation (refrigerated / normal trucks depending on product);
- Cold storage (bulk) at farm gates for long term inventory; and
- Cold storage (hub) near consumption centers as a distribution platform.

Pack Houses: Part of the first mile of the cold chain where the incoming material undergoes selection and preconditioning like trimming, sorting, grading and precooling. Small cold rooms (staging) are set up near farm gates, in preparation for the produce to be moved to the cold storage (hub) / consumption centres.

Refrigerated Transport / Reefer Vehicles: It is important to transport perishables in a controlled atmosphere (temperature and humidity conditions) in order to maintain the quality of packaged goods and products e.g., fruits and vegetables, frozen goods, among others. So, refrigerated or containers on trailers can transport the produce to cold storage bulks or directly to cold storages hubs or distribution centers.

Cold storage (Bulk): This is where single commodities e.g., potatoes, apples, spices, are stored near the farm-gate. These commodities can be purchased outright by the owner for trading or on rent for 6 months to a year.

Cold storage (Hub): These are near markets/consumption centers for short-term transitory storage of incoming produce to distribute on demand. These front-end cold stores are distribution centers or hubs, which receive and dispatch produce frequently, are critical connecting infrastructure.

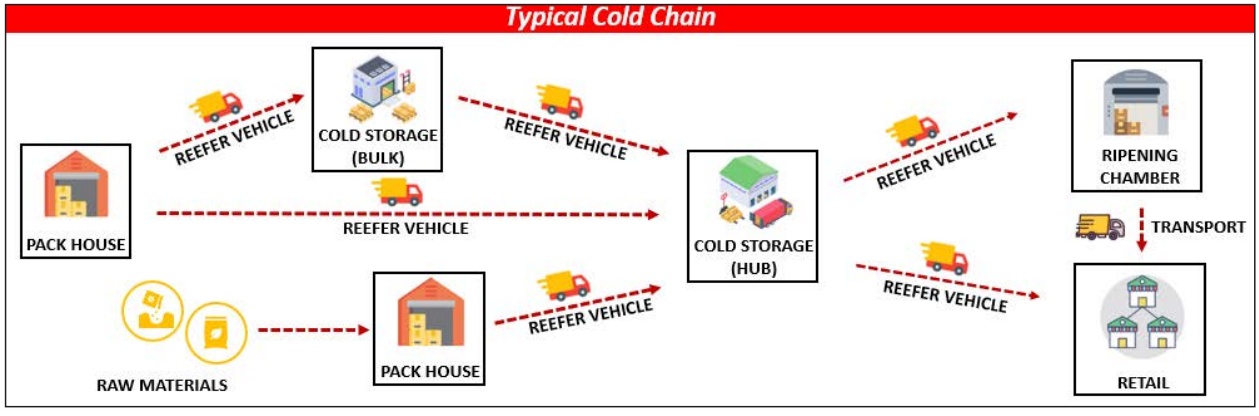


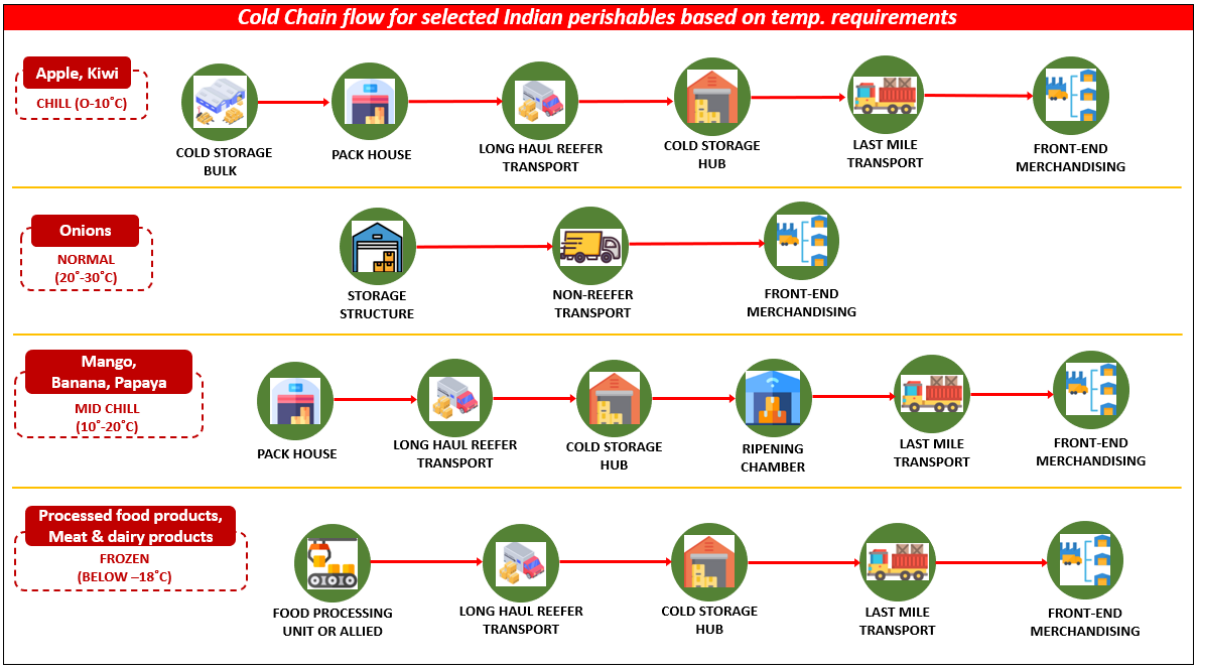
Figure 2 Typical cold chain

Ripening Units/Chambers: These units near markets/consumption centers, are mainly used for bananas, mangoes, and papayas. They can be used as a private label or provided as a service to other retailers.

The entire cold chain can be represented by the following flow diagram for easy understanding.

Infographic shows the cold chain flow for selected Indian perishables, such as, onions, mangoes, bananas, papayas, apples, among others.

Figure 3 Cold chain flow for selected perishables



Different commodities demand different temperatures and relative humidity for storage. These two parameters determine the shelf life of the commodity. The following table shows some perishables with their temperature and humidity requirements.

Table 2 Temperature and RH requirement for different commodities[12,13,14]

Commodity	Temperature (°C)	Relative Humidity (%)	Storage Life (Days)
Apple	-5	90-95	30-180
Onion	0	65-70	30-240
Mango	13	90-95	14-21
Banana	13-15	90-95	7-28
Papaya	7-13	85-90	7-21
Potato (early)	7-16	90-95	10-14
Potato (late)	4.5-13	90-95	150-300
Meat	0-2	90-95	0-42
Milk Powder	20-30	<-50	-
Chilled Dairy	26	<-60	-

[12]https://www.fao.org/3/y4893e/y4893e06.htm#TopOfPage

[13]https://www.researchgate.net/publication/320051361_Cold_chain_management_in_meat_storage_distribution_and_retail_A_review

[14]https://www.fssai.gov.in/upload/uploadfiles/files/Guidance_Document_Milk_14_03_2019.pdf

1.2.2. Footprint on the cold chain sector

India is predominantly an agriculture-based economy with ~55% of the population still rural agrarian based. The agriculture sector forms a substantive part of the Indian economy, contributing up to 20.2% of Gross Domestic Product (GDP)[15] and 45.5% of employment[16] in 2021. India achieved a record food grain and horticultural production of 315.7 and 333.2 million metric tons (MMT) in 2021-22 according to the Ministry Agriculture and Farmer Welfare. India has seen a phenomenal growth in production of fresh food, dairy, and meat products over the last decade. India leads in the production of perishable commodities[17]:

- Fruits and vegetables – second largest producer in the world with a production of 303 MMT;
- Milk and dairy products – largest producer in the world with 23% share in global milk production;
- Fish – second largest producing nation in the world valued at around 12.6 billion Euros / 93 thousand crore INR; and
- Buffalo meat - leading exporter in the world[18].

Despite the abundant production of a wide variety of perishables, India's present share in global farm trade is still very small. A key deterrent to this is the high level of fresh food wastage across the value chain due inadequate cold-chain infrastructure. The International Institute of Refrigeration (IIR) states that 23% of perishable foods in developing countries are lost due to the lack of cold-chain infrastructure.

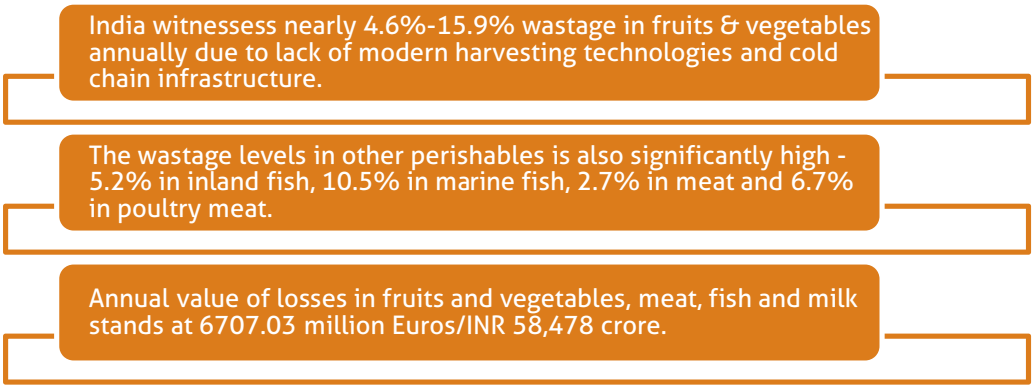


Figure 4 Losses in perishable food in India (YES Bank-Dutch Embassy collaborative study)

Apart from the food losses, the inadequacy of cold-chain infrastructure also results in:

- Reduced availability and inflated prices in lean season;
- Reduced food quality;
- Lower income for farmers; and
- Global warming - 'Each tonne of fruits and vegetables spoiled decomposes into approximately 1.5 tonnes of CO_2 equivalent in greenhouse gases' (GHG) (Kohli, Stop Food Loss to Stop Climate Change, 2016).

Food loss also has an impact on socio-economic development as food loss also represents a waste of the labour, water, energy, land, and other inputs that go into producing food. A seamless cold chain will ensure following benefits:

[15]https://www.pib.gov.in/PressReleasePage.aspx?PRID=1741942
[16]https://thewire.in/economy/share-of-agriculture-in-employment-rose-manufacturing-declined-in-2021-22-plfs
[17]Cold-chain opportunities in India: The Perishables sector perspective, 2018
[18]Indian meat industry: Red Meat Manual-APEDA,2020

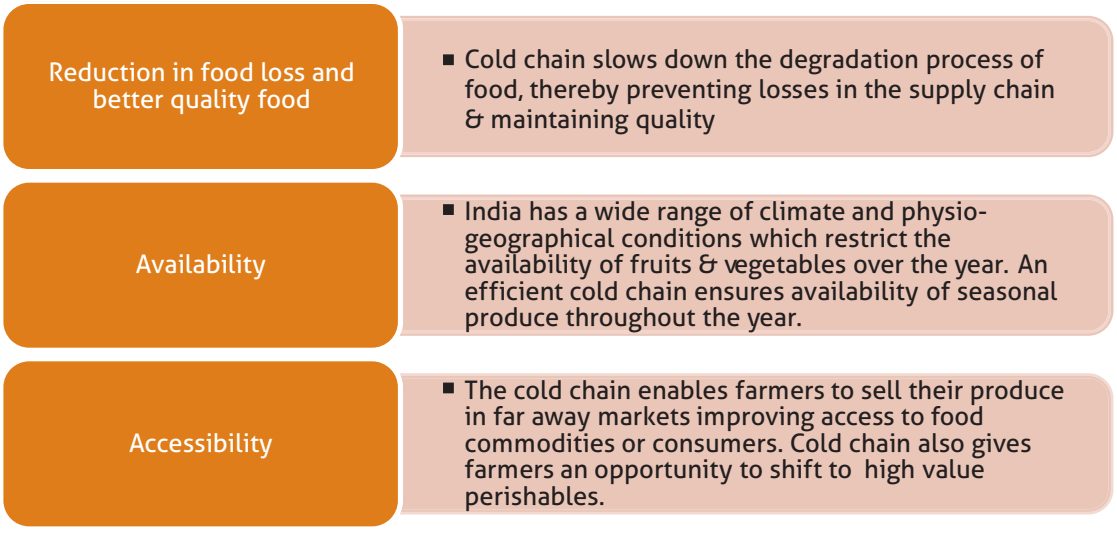


Figure 5 Benefits of cold chain

E-commerce is transforming the way business is done in India. The Indian online grocery market size has been projected to grow from USD 4,540.0 million in 2022 to USD 76,761.0 million by 2032, at a CAGR of 32.7% through 2032[19]. The growth of organized **third-party logistics (3PLs)**, **quick service restaurant (QSR, retail), e-commerce**, and food service industries due to changing consumption patterns have brought the **cold storage** segment in focus. Consumers demand a large variety of fresh fruits and vegetables, dairy products, meat and poultry products and other temperature-sensitive commodities that require **cold storage infrastructure**. Over the last decade, the culture of e-commerce or online buying has gained immense popularity in India. With rapid digitization, the food and grocery buying is now just a click away. The online demand for buying of food and groceries has been catalyzed by the Covid-19 pandemic and the need for need social distancing. The rise of multiple retail outlets and restaurants has created the demand for foods with improved shelf life and packaged cold foods.

The trend is now shifting towards establishing **multipurpose cold storage** and providing **end-to-end services** across the value chain. The segment is expected to become more organized and attract more institutional fundings. Future trends in this sector may include built-to-suit assets with superior building specifications, diversity in cold storage offerings catering to higher-value commodities and use of sustainable solutions for reducing operational costs.

In India, the past five years have been significant where private players like Amul, Haldiram, Flipkart and Amazon have made significant investment to enhance the capability to cater to the huge demand for processed food, groceries and FMCG products, particularly the frozen food and perishable goods. To cater to the demand and following business models like hyper local delivery models, many turnkey projects have got investments, giving rise to CAPEX and OPEX in the cold chain sector. Here are some of these projects:

- Ninjacart, a B2C company shifted to a B2B model to provide a supply chain for fresh produce (mainly cold chain infrastructure). The company specializes in fast delivery to retailers, restaurants, and other service provider. Ninjacart raised USD 145 million from Walmart and Flipkart in 2021 to expand its technology and infrastructure[20].
- Amazon Web Services (AWS) in collaboration with Carrier is innovating and developing a Lynx program which will provide artificial intelligence in lowercase support to the fragmented cold-chain sector in India. The idea is to help the spoil rate of fresh produce or perishables due to breakdown in operation and maintenance[21].

[19]https://www.futuremarketinsights.com/reports/india-online-grocery-market
[20]https://www.zeebiz.com/small-business/news-flipkart-walmart-invest-145-million-in-produce-supply-chain-ninjacart-173303
[21]https://aws.amazon.com/blogs/industries/carrier-and-aws-collaborate-to-reduce-food-spoilage-across-the-cold-chain/

- Big Basket, an e-commerce giant that specializes in online grocery delivery raised USD 300 million in February 2018 to acquire companies in spaces like milk delivery and instant delivery of perishables. In 2019, Big Basket received USD 150 million to further expand their first mile delivery and scale up their supply chain. In 2022, Big Basket raised USD 200 million to further infuse capital in expanding their online grocery business from 55 cities to 75 cities[22].

Asset management companies like Colliers reckon that the increased adoption of online platforms for grocery and essential goods' delivery has led to the mushrooming of startups in the hyperlocal delivery space. Companies like Dunzo, Swiggy and Big Basket witnessed steady growth during the Covid-19 outbreak, catering to the surging demand for essentials, food & grocery and medicines[23].

In 2017, the government approved 101 cold chain projects with an estimated capacity of 2.76 lakh tonnes. These projects were put forth by companies like Amul, Big Basket and Haldiram. This illustrates the trends of e-commerce companies and FMCG industry infusing capital to increase their foothold in the cold chain sector.

Given that grocery is a key driver of the cold chain sector, it may be useful to understand the business models in the online grocery market:

- Inventory-based model: Companies usually have their own inventory, which they manage according to demand. Time-based delivery is done as soon as a customer's order is placed. This model is being used by Big Basket.
- Hyperlocal model: Companies do not own their own warehousing facilities but partner with local fulfillment centers or local shops to cater to the demand. This type of model is currently being implemented by companies like Blinkit.
- Mixed model: Here, companies do operate with some inventory, but to maintain costs, this is generally low[24]. The hyperlocal model makes up for the low inventory.

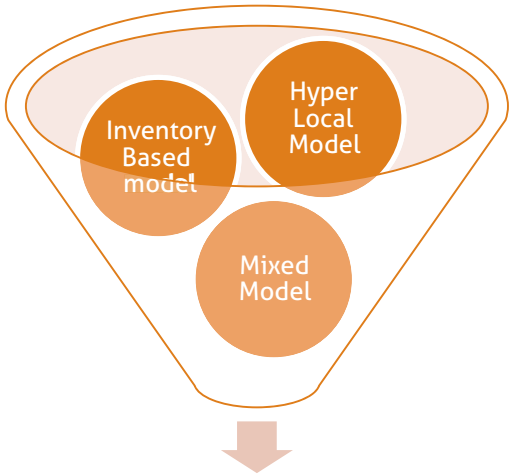


Figure 6 Online grocery business model

Big chains like Big Basket and Blinkit[25] collaborate with local fulfillment centres to serve customers with perishable products in as short a timeframe as possible. Here are some of the other strategies these companies have adopted.

- Minimizing risk of perishability: Procurement of lower shelf-life product is done on an order basis to bring down the loss of stock;
- Own logistics: Big Basket operates their own fleet and warehouses which helps them mange the demand better;
- Hyper local delivery model for efficient and fast delivery of items with a short shelf life such as milk, fruits, and vegetables;

[22]https://startup.outlookindia.com/sector/e-commerce/bigbasket-raises-200-million-from-tata-capital-report-news-6953

[23]https://www.colliers.com/en-in/news/how-is-the-warehousing-sector-shaping-up-in-india

[24]http://ijariie.com/AdminUploadPdf/ONLINE_GROCERY_RETAIL_BUSINESS_MODEL__SUPPLY_CHAIN_STRATEGIES_AND_GROWTH_DRIVERS_FOR_ONLINE_GROCERIES__CATERING_TO_BIG__BASKET__ijariie10837.pdf

[25]https://blinkit.com/blog/things-we-do-save-food

- Storage of perishables in inventory for as shorter a period as possible; and
- Sales through methods like flash sales or seasonal sales regularly to reduce losses in perishable stocks.

The Government of India (GoI), understanding the importance of cold storage, is extending support to create infrastructure. This is being done through various agencies like the Ministry of Food Processing Industries (MoFPI), National Horticulture Board (NHB), and Agricultural and Processed Food Export Development Authority (APEDA) etc. Given the government push in this sector, India is looking at a substantial capacity addition in cold storage in the coming years.

What all this means is that the sector is looking at a huge upsurge in cooling energy requirement, refrigerant demand and consequently greenhouse gas emissions. The emissions occur primarily on account of these three activities:

- The use of primitive compression-based cooling equipment which have very low operational efficiency when compared to the modern active, passive, and renewable technologies available globally;
- Most refrigerants used have high GWP (Global Warming Potential) and/or ODP (Ozone Depletion Potential); and
- Loss of food due to lack of proper post-harvest storage / transportation facilities. Decomposition of produce releases methane which is more than 25 times potent than CO_2 in terms of GHG emissions[26].

1.3. About this study report

In India, more than 90% of the cold chain facilities are owned by private sector entities. The sector is in a nascent stage but, as we have seen, has the potential to grow exponentially in the coming decade. This is also a very fragmented sector, so there's the need for a single document that acts as a one-stop shop for gathering information on sustainable and good management practices with proper standards and best practices for green cooling. The document will provide complementing suggestions to enhance the skills of the technical personnel including service technicians involved in operation and maintenance. This would assist the government/policy makers in educating the stakeholders involved in this sector on the use of sustainable cooling technologies and support the HPMP initiative of phasing out HCFC from the cold chain sector. Already, the 3PL companies working for big e-commerce clients are becoming sensitive towards issues relating to climate change and environment and run their operations with an aim to improve the energy efficiency of their systems and facilities.

This study is undertaken by the implementing agencies, Ozone Cell, MOEF&CC and United Nation Environment Programme (UNEP) under India's HCFCs Phase-out Management Stage-II. The study covers the related activities in the cold chain sector intervention and inter alia related to the good management practices for cold storage (warehouse) infrastructure used by e-commerce businesses and applications of non-HCFC and low Global Warming Potentials (GWP) refrigerants-based energy efficient cooling systems. This study has been conducted by collection, collation, and analysis of information through desk research, field visits and covers the following aspects of the cold storage (warehouses) related to e-commerce sector:

- ➢ Survey of existing infrastructure, mapping of policies and relevant standards;
- ➢ Status of existing cold storage (warehouse) infrastructure used in e-commerce business and estimation of growth scenarios in the sector;

[26]https://www.epa.gov/gmi/importance-methane

- Information on cold storage infrastructure in use comprising of typical cooling equipment and their cooling capacities, energy-efficiencies, type of refrigerants (including HCFCs) in use, operation, and end-of-life refrigerant management;
- Mapping of the Government policies in terms of development of infrastructure;
- Information related to opportunities for reducing cooling, refrigerant requirement and energy consumption through improved designs including proper insulation and use of energy efficiency cooling equipment in cold storages;
- Requirement of regulatory permissions from the various authorities including State Pollution Control Boards (SPCBs) / Pollution Control Committee (PCC) for setting up of cold storages (warehouse infrastructure). Details of environmental condition prescribed by the SPCBs, if any;
- Skills of the technical personnel including service technicians involved in operation and maintenance;
- Available best practices for reducing cooling demand in the sector and information on the use of efficient Refrigeration and air-conditioning (RAC) equipment based on non HCFC and low GWP refrigerants; and
- Collate and analyze the information collected and make recommendations in terms of good management practices.

2. Overview of Cold storage in India

2.1. Current infrastructure and growth estimation of cold storages

Cold storage comprises of a highly insulated and refrigerated warehouse designed to store perishable products to essentially maintain the temperature and humidity parameters, which were initiated at the pack-house or during manufacturing. They serve as an important link between farm produce and the final consumer. Fresh produce cold stores are designed to control respiration and prevent discoloration, sprouting, dehydration and decay, thus maintaining the quality and extending shelf life of the perishables.

The main advantages of using cold storages are:

- Fresh and better quality of produce available to customers;
- Off-season farm products available at affordable rates;
- By reducing wastage, great saving in cost can be achieved;
- It helps in providing remunerative price to farmers; and
- Packaged or processed food are available to customers.

The capacity of most cold storages varies between 1000 MT to 10000 MT. The average size of cold storage in India is 5003 MT[27]. A cold storage facility can enable various temperature-controlled environments based on the products stored as highlighted below:

Table 3 Temperature ranges in a CS facility

Name	Temperature range	Indicative products
Frozen	Below -18 °C	Meat, Seafood
Chilled	0°C to 10 °C	Dairy products, Fruits, Meat
Mildly chilled	10°C to 20°C	Fruits, Vegetables

Significant facts about the cold storages:

- Uttar Pradesh, West Bengal, Gujarat, Punjab, and Andhra Pradesh are the top 5 states in terms of installed capacity;
- Majority of bulk cold stores are for potatoes and chilies. Potato cold stores are mostly located in Uttar Pradesh, Gujarat, Punjab, and West Bengal; chilies are largely stored in Andhra Pradesh; and
- Currently, about 95% of the cold storages are owned and operated by private entities, 3% by cooperatives and the remaining 2% by public sector undertakings (like Balmer Lawrie & Co Ltd).

[27]All India Cold-chain Infrastructure Capacity Assessment of Status & Gap NCCD report 2015

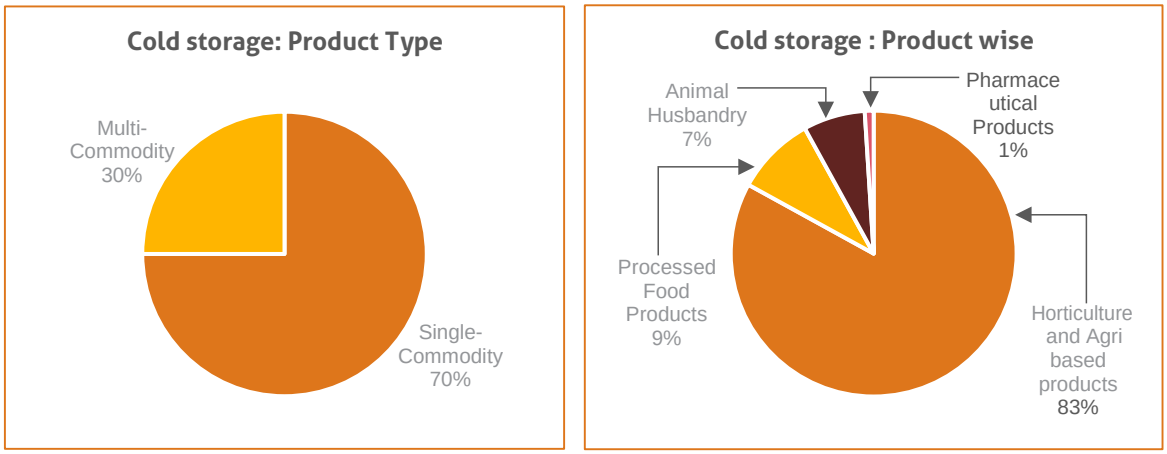


Figure 7 Cold storage distribution by type and product

The total number of cold storages in India is 8,361 with a capacity of 38.1 million tons[28] as of 2022, out of which 75% are single commodity cold storages (storing mainly potatoes) and 25% are multi-commodity cold storage.

The table shows the cold storage distribution by state.

Table 4 State wise distribution of cold storages as on 18.07.2022[29]

S.no	*Name of the state*	*Total*	
		No.	Capacity (MT)
1	Andaman and Nicobar Islands (UT)	4	2,210
2	Andhra Pradesh and Telangana	442	1,703,321
3	Arunachal Pradesh	2	6,000
4	Assam	41	197,096
5	Bihar	312	1,475,667
6	Chandigarh (UT)	7	12,462
7	Chhattisgarh	99	487,263
8	Delhi	97	129,857
9	Goa	29	7,705
10	Gujarat	985	386,9543
11	Haryana	370	846,588
12	Himachal Pradesh	81	167,312
13	Jammu and Kashmir	72	263,853
14	Jharkhand	58	236,680
15	Karnataka	229	694,991
16	Kerala	201	96,405
17	Lakshadweep (UT)	1	15
18	Madhya Pradesh	309	133,1532
19	Maharashtra	627	1,043,182
20	Manipur	2	4,500

[28]https://ap.data.gov.in/resource/stateuts-wise-distribution-cold-storage-country-18072022

[29]https://ap.data.gov.in/resource/stateuts-wise-distribution-cold-storage-country-18072022

21	Meghalaya	4	8,200
22	Mizoram	3	4,071
23	Nagaland	5	8,150
24	Orissa	181	576,688
25	Pondicherry (UT)	3	85
26	Punjab	726	2,451,501
27	Rajasthan	187	631,569
28	Sikkim	2	2,100
29	Tamil Nadu	187	395,940
30	Telangana	74	411,518
31	Tripura	17	51,140
32	Uttar Pradesh	2429	14,836,735
33	Uttarakhand	60	206,621
34	West Bengal	515	5,948,316

The cold storage capacity in India might look enough, but most of the development has happened in single commodity cold storages. However, rising demand for prompt deliveries, especially for food and grocery items, has led to a spurt in demand for multi-commodity cold storage facilities and refrigerated warehouses. **In terms of revenue, the storage segment accounted for the largest revenue share of more than 58% in 2020** and will retain its dominance in the coming years owing to an increasing preference for packaged foods and frozen foods.

As per consultations with the relevant stakeholders, **15% of the total cold storage capacity is being utilized by e-commerce companies i.e., around 6 million metric tonnes**. The estimated growth in the sector is of the order of 13-16% CAGR from 2022–27 and the capacity of cold storages in the e-commerce sector is expected to reach 12 million MT by 2027.

As the e-commerce industry primarily uses the Hyper-local grocery delivery model, it will also be one of the major factors for driving the growth in the cold storage capacity in the country.

The following developments by the major e-commerce companies over the recent years further establish the potential rise in demand for cold storages:

- Amazon had set up 60 fulfillment centers by 2021, occupying a total of 32 million cubic feet of warehousing space spread over 15 states. The cold storage or temperature-controlled zones within these warehouses handle items like vegetables, fruits, dairy products, and frozen products;
- Indian dairy giant Amul and online grocery player Big Basket are among the companies that have got central government approval to set up 101 integrated cold-chain projects;
- In 2021, Flipkart ramped up its fulfillment capacity by setting up 66 fulfillment centers hosting around 20 million cubic feet of storage space across 12 states; and
- Blinkit (formerly Grofers) has increased its storage capacity from 2.1 million sq. ft. in 2019 to about 3.5 million sq. ft. in 2020.

Table 5 Present and future drivers of cold storage segments in India[30]

	Key market drivers	2019	2028	Impact
	Population (bn)	1.37	1.45	Online food delivery likely to grow by 60%
CONSUMER BASE	Revenue from Online Food delivery services ($ bn)	7.7 (12.14 in 2022)	20.9 (considering a CAGR of 10.8% projected between	Growing preference for doorstep delivery given the impact of Covid-19
	Value of Cloud kitchen industry ($ bn)		2.5	Emergence of cloud kitchens and healthier
INDUSTRIAL BASE	Value of online F&G Retail ($ bn)	2.1	34.6[31]	Industry likely to more than double
COLD STORAGE (CS) SEGMENT	CS capacity (mn tons)	x 32[32]	60.4	Government initiatives coupled with growth in OFD industry to boost CS capacity and value

The above-mentioned drivers are expected to fuel the growth of the cold storage segment over the next few years. In this age of digitization and improved internet access, the demand for e-commerce services in both tier 1 and tier 2 cities will grow.

The market value of online grocery in 2022 was USD 4.54 billion and is expected to grow to USD 76.76 billion by 2032 with a CAGR of 32.7%. In 2022, the market size of the cold chain sector in India was USD 22.41 billion[33] and is expected to grow to USD 46.89 billion in 2028 and USD 71.49 in 2032 with CAGR of 12.3%[34]. This shows the exponential rise in gross merchandise value (GMV) share of ecommerce companies in the cold chain sector from 2022-2032.

Due to non-availability of primary and secondary data on cold storage capacity used by e-commerce industry, the above projections on the GMV share of the e-commerce industry in the cold chain sector have been taken from the numbers provided from the third-party research done in online grocery sector, which is the key driver of cold chain sector in e-commerce.

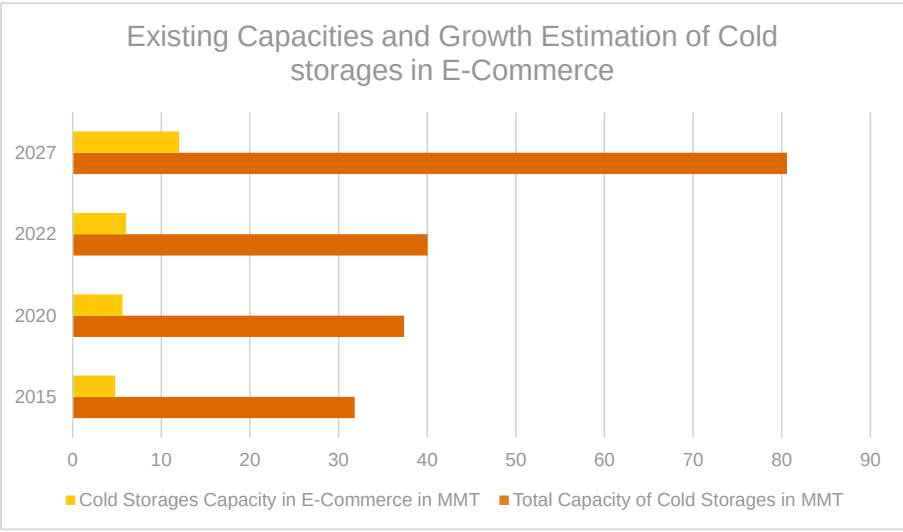


Figure 8 Cold storages in e-commerce

[30]https://www.cbre.com/-/media/project/cbre/shared-site/insights/articles/apac/india/2022/cold-storage-in-india-all-the-way-from-farm-to-fork/india_major-report---cold-storage-in-india---all-the-way-from-farm-to-fork_october-2020.pdf/ap.data.gov.in/resource/stateuts-wise-distribution-cold-storage-country-18072022
[31]https://www.blueweaveconsulting.com/report/india-online-grocery-market
[32]2020 value as per foodinfotech
[33]https://www.imarcgroup.com/indian-cold-chain-market
[34]https://www.imarcgroup.com/indian-cold-chain-market

The entire cold chain network consists of various types of cold storages depending upon the products stored, its usage in terms of whether the requirement is in the first mile or towards the last mile distribution of the cold supply chain.

Cold storages in e-commerce can broadly be classified in two categories:

1. **Refrigerated cold storages**- these are designed for preserving the quality and shelf life of products that don't need to be frozen like fruits and vegetables. They are generally between 0.5°C to 20°C.
2. **Frozen cold storages** - these are designed for preserving the quality and shelf life of products that must be frozen like meat and fish. They are generally maintaining temperatures less than 0°C.

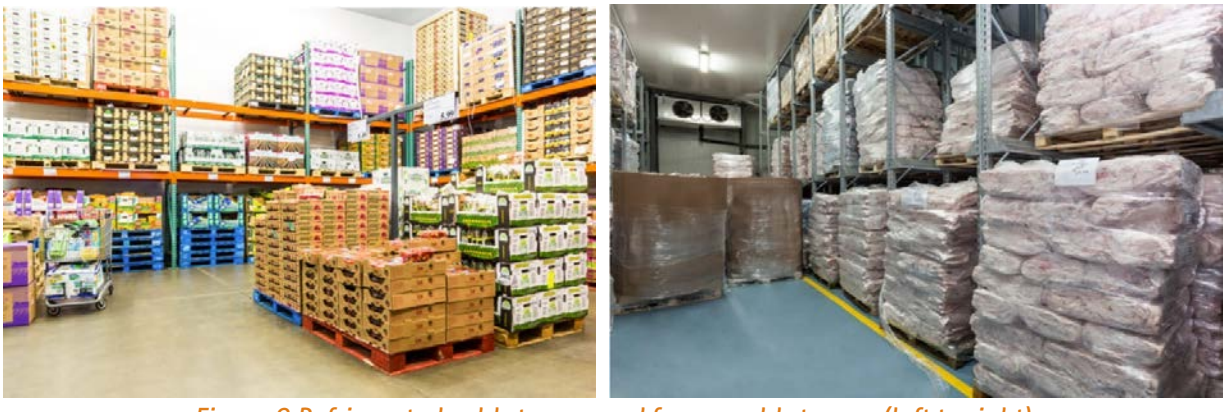


Figure 9 Refrigerated cold storage and frozen cold storage (left to right)

Following are the main types of cold storages in an e-commerce cold supply chain

1. **Bulk Cold Stores:** Environment controlled warehousing space intended for the bulk storage of perishable produce are known as bulk cold stores. It is designed for long duration storage of produce so as to build an inventory buffer which will serve to smoothen the episodic production by stabilizing and sustaining the supply lines. These are normally constructed in areas close to producing areas (farm-gate) to facilitate quick access to producers for a selective set of crops only. Such stores are generally used for a single commodity, such as potatoes, chilies and apples among others.
2. **Multipurpose Cold Stores / Cold storage (Hub):** These are warehousing spaces with multiple temperature zones for functioning as a distribution hub. It is designed for short-term handling of products to serve as a distribution logistics platform for market ready packaged produce and ready-to-retail products. They are designed for storage of a variety of commodities including seasonal fruits, vegetables, dry fruits, spices, pulses and milk products. Cold storage (hubs) are key to effective distribution of perishable foods and are essentially at the front end of the cold chain, constructed close to consuming centers.
3. **Small cold stores** with pre-cooling facilities for fresh fruits and vegetables, mainly, for export-oriented items like grapes. The major concentration of these units is in Maharashtra, but the trend is now picking up in other states like Karnataka, Andhra, and Gujarat.
4. **Frozen food stores** with or without processing and freezing facilities for fish, meat, poultry, dairy products and processed fruits and vegetables. These units have helped the promotion and growth of the frozen foods sector, both in the domestic and the export markets.
5. **Controlled Atmosphere (CA) Stores:** These are cold stores fitted with technology that can alter the atmospheric gaseous contents, in addition to controlling the temperature, for certain fruits/ vegetables like apples, pears, cherries.

6. **Walk-in cold rooms/ Walk-in cold freezers:** These are refrigerated enclosures accessible by at least one door and large enough for a person to walk into, housed within existing buildings. Located in hotels, restaurants, malls, etc.

7. **Refrigerated Display Cabinets:** Not only do they keep products chilled or frozen, but they also allow employees and customers to see the products within the cabinet. Refrigerated display cabinets are the perfect cold storage solution when it comes to food and drink retail stores, in supermarkets etc. Such cabinets used in a retail environment for access by consumers, account for about half of the global commercial refrigeration equipment market by market value or revenue (United4Efficiency, 2021).

2.2. Operating business models in cold storages in Indian e-commerce

With the rise in demand for cold storages, several players have come into the market. Some are private cold storages which are owned and operated by the same enterprise that uses or produces the goods stored in the facility. There's also public cold storage that is usually owned and operated by 3rd-party logistics (3PL) companies. These are more common because owning and running a cold storage facility is a massive, expensive, and complex undertaking. Unlike private cold storage warehouses, public ones also receive and ship goods on behalf of client companies in addition to storing them.

The common business model followed by major e-commerce companies is in partnership with 3PL partners such as Snowman, Coldman, Crystal Logistics, TCI Cold Chain Solutions among others, who own these cold storage facilities and have the technical know-how to run the cold storage.

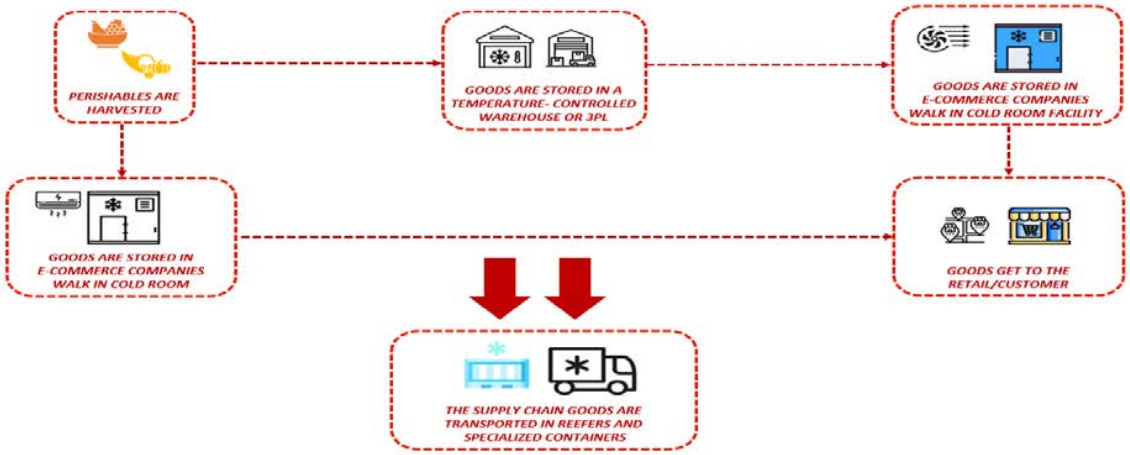
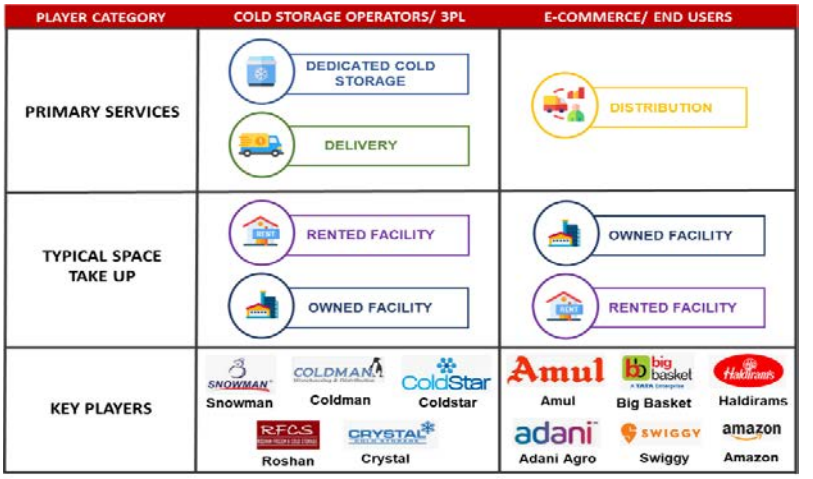


Figure 10 Value supply chain in e-commerce companies

E-commerce companies outsource their requirements to these 3PL companies who do the stock management and also, in some cases, provide logistics support to them. Depending on the partnership, e-commerce companies procure perishables from different vendors to store them in the 3PL cold storages and, depending on the need or per contract, the produce is shifted to the central location of e-commerce companies for further distribution at their end. Retail chains/ restaurants procure perishables from different vendors and then store them in their cold rooms at the site.

Table 6 Business model of cold storages in e-commerce companies



2.3. Guidelines and standards for cold storage construction

2.3.1. National Building Code of India (NBC 2016)

The National Building Code of India (NBC 2016) provides guidelines for regulating building construction activities across the country. It serves as a model code for adoption by all agencies involved in building construction. The code contains administrative regulations, development control rules, and general building requirements (including fire safety and facility management). While no benchmarks or threshold values have been specified for energy efficiency related aspects for cold storages, Clause 9 'Refrigeration of cold stores' of Part 8 of NBC 2016 provides general guidelines on following:

1. Refrigeration heat load considerations

For calculation of heat load, the NBC 2016 specifies taking into consideration thermal transmission or U-values as prescribed in international standards such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers standards ASHRAE 90.1, and inclusion of the following loads for arriving at the total cooling load and sizing of the refrigeration system.

- Transmission load: Heat transmitted into the refrigerated space through its surface;
- Product load: Heat removed to bring products to the storage temperature and heat generated by products in storage;
- Internal load: Heat produced by internal sources;
- Infiltration air load: Heat gain associated with air entering the refrigerated space; and
- Equipment related load: Heat gain by refrigeration equipment.

2. Temperature sensing and monitoring

Accurate and constant temperature monitoring is paramount for a cold storage since the food products are adversely affected by temperature fluctuations. Temperature monitoring is dependent on factors such as placement, resolution, and accuracy of measuring instruments. The NBC 2016 specifies the following for temperature monitoring:

- Temperature sensors and thermometers should be placed at multiple locations in cold storage and their values should be displayed accordingly at the central control location;
- Products having considerably different temp. requirements should be zoned separately; and
- The accuracy of the probe inserted in the food should be at least 0.5° C.

3. Installation and maintenance of cold room

NBC 2016 recommends the use of polyurethane foam (PUF) Panels as insulation material between two sheet metal skins compared to conventional insulation materials such as fiberglass, mineral wool on walls and ceilings. NBC 2016 refers to IS 661:2000 'Code of practice for thermal insulation for cold storage (third revision)' for selection and design of panels for thermal insulation.

4. Cold room safety

The NBC 2016 specifies safety guidelines for firefighting equipment, safe handling of refrigerant leaks, safety device, controls and alarm systems, emergency lighting in the cold chambers, first aid kit, emergency assembly points and water shower in ammonia plants.

2.3.2. "Guidelines & Minimum System Standards for Implementation in Cold – Chain Components"

"Guidelines & Minimum System Standards for Implementation in Cold-chain Components" (published by NCCD, 2015) provides standard definitions and description of cold storage components supported under the Mission for Integrated Development of Horticulture (MIDH) and allied agencies. The document incorporates the minimum norms as per the MIDH guidelines that enable users to leverage financial and other assistance available under government schemes and programs.

For both new and old projects, the document provides standard templates and technical data sheets for various equipment and components. These must be included in the Detailed Project Report (DPR) and compiled for the purpose of availing loan, subsidies, and other forms of financial assistance.

For new installations, this specifies compliance with standards such as BIS, ISO and EN as specified in tables 5, 6 and 7 which indirectly drives equipment level energy efficiency.

For old and existing installations, this specifies three broad areas for improving energy efficiency. These are:

1. Modernization of refrigeration systems in cold storage

This component refers to modernizing the refrigeration system in existing cold storages to reduce the carbon footprint, power consumption and enhance safety for existing cold storages. The components may include:

- Upgradation of evaporators;
- Upgradation of compressors;
- Replacement of refrigeration valves including electronic expansion valves; and
- Automation with PLC/ microprocessor-based monitoring and controls.

To qualify for subsidy and other financial assistance under this, the reference data sheets of old and new equipment must substantiate reduction in energy consumption by 5%. In addition, the refrigerant GWP and ODP must be in compliance with the **Montreal Protocol on Substances that Deplete the Ozone Layer**. The cost norm applicable is 50% of incurred cost with maximum admissible cost of INR 100 lakh but not more than INR 2,500 per MT of the cold store capacity.

This will typically manifest into upgradation of open tube evaporators to more energy efficient evaporators and low efficiency compressors to higher energy efficiency compressors with the capability of full and partial operating load. The modern refrigeration systems must comply with important standards mentioned in Table 7.

Table 7 Reference standards for modernization of refrigeration equipment [35]

Code and Reference	
IS 660	Safety Code for Mechanical Refrigeration
ARI/EU	Manufacturing and Testing standards for refrigeration compressors
ASME Sec VIII Div. 1	Code of Pressure vales
Eurovent	European Standards for Evaporators / Air Coolers
IS 11132	Ammonia Valves
IS 4544	Code of Safety for Ammonia
IS 3233	Code for Safety and Relief Valves

2. Non-ODS blowing agents for insulation:

This applies to utilizing an insulating medium resulting in superior thermal barrier which in turn results in reduction in energy loss. **The insulation should result in reduction of energy consumption by at least 5%.** The reference data sheet to substantiate old versus new performance includes details of insulating material and thickness, U-value, density, thermal diffusivity density, and thermal diffusivit. The cost norm applicable is 50% of incurred cost with maximum admissible cost of INR 100 Lakhs but not more than INR 1,500 per MT of the cold store capacity.

The insulation must comply with important standards mentioned in table 8.

Table 8 Standards for modernization of insulation [36]

Code and Reference	
IS 661	Code of practice for thermal insulation of Cold storages
IS 12436-1988	Specification for Preformed Rigid Polyurethane (PUR) and Polyisocyanurate (PIR) foams for thermal insulation
DIN 55928	Specifications for galvanized steed cladding
ASTM D 1622	Density
ASTM C 177-97	Thermal Conductivity
The National Building Regulations and Building Standards Amendment Act No. 103 of 1977	Building Standards
AISC-2005	Design Code
IBC-2006	Building Code

3. Alternate energy options:

This includes various alternate energy options such as renewable energy sources, thermal energy banks or other non-conventional technologies that can be used to operate the equipment or serve as an energy buffer at a cold chain facility. Under MIDH norms, a beneficiary may apply for a maximum cost of **INR 35 Lakhs for listed items and combination thereof**. The items under the subsidy component include:

- Solar PV systems;
- Solar thermal systems;
- Thermal banks; and
- Vapor absorption refrigeration.

[35]Guidelines and Minimum System Standards for Implementation in Cold - chain Components - NCCD report 2015

[36]Guidelines and Minimum System Standards for Implementation in Cold - chain Components - NCCD report 2015

The compliance requirements for the above-mentioned alternate energy options have been specified in the guidelines. Some of the key standards applicable for use of alternate energy options are mentioned in table 9.

Table 9 Standards for alternate energy options[37]

	Code and Reference
IEC 61215/ IS14286/IEC 61646	Thin film/ crystalline silicon terrestrial PV modules
IEC 62108	Concentrator PV modules & Assemblies
IEC 61730	Part 1: requirements for construction & part 2: requirements for testing, for safety qualification or equivalent IS.
IP 54	General requirements for junction boxes/ enclosures for inverters/ Charge Controllers/Luminaries
Flat plate collector	ISI mark
Outer cladding & Frames	Al/SS/FRP or GI powder coated. MS may also be used with special anti-corrosive protective offering.
Thermal insulation of tanks & Hot water piping	Minimum 50 mm thick with CFC free PUF having density tanks & hot water piping of 28-32 kg per cum.
Valves, cold water tank	ISI mark or standard make
IEC 60947 part I, II, III	General requirements, connector safety, A.C/D.C (switches, circuit breakers, connectors)

2.3.3. Walk in cold rooms- IS 2370: 2014

Bureau of Indian Standards (BIS) is the National Standard Body of India, responsible for the standardization, marking and quality certification of various appliances. BIS published standard no. IS 2370 in 2014 for walk in cold rooms, which prescribes the constructional and performance requirements of walk-in cold rooms of 5 to 20 kiloliter gross volume capacity that are operated by an electrically driven refrigerating machine of the vapor compression type. The document prescribes guidelines pertaining to materials, sound level, safety features and rating of motors.

While no benchmarks or threshold values has been specified for energy efficiency related aspects, the standard illustrates various methods of testing the cooling capacity and the test conditions such as indoor and outdoor temperature and RH%. The standard also mandates the following tests for compliance requirements:

Production routine tests (Conducted at manufacturer works)	Type tests (conducted at accreditated Labs)	Acceptance tests
• Pressure Running Test • Vaccum Test • Electrical Test • General Running Test	• Door seal test • Thermal Insulation • Measurement of Air flow • Capacity rating test • Power Consumption test • Maximum operating condition test	• On request of purchaser, production routine tests can be repeated))

Figure 11 Mandatory compliance tests

[37]Guidelines & Minimum System Standards for Implementation in Cold - chain Components - NCCD report 2015)

2.3.4. Other general design guidelines

Below listed are a few general but practical design considerations in construction of cold storages[38]:

1. Doors of the unit should be insulated in an adequate manner so that it is airtight.
2. Storage racks should be constructed in such a way that they never harm the workers working under it.
3. For the proper distribution and circulation of air, the passage
    - between the rows of racks should not be less than 0.76mt whereas the racks should be placed 20cm apart from the walls of the floor in the unit.
4. A gap of at least 30-40cm should be maintained between the top level and the ceiling of the topmost shelf of every rack.
5. The distance between the succeeding shelf should be at least 7.5cm.

2.4. Guidelines for storing perishables in cold storages

The FSSAI handbook for "Safe Storage, Distribution and Transportation of Food Products" mentions several guidelines for Refrigerated storage and Freezer storage for food.

Refrigerated Storage

Potential hazards that must be controlled in refrigerated storage include bacterial growth, cross contamination, and food beyond date marking.

Table 10 Guidelines for storage in refrigerators

Hot food must not be placed directly into the refrigerator as it will raise the temperature of the refrigerator above acceptable limits and may cause condensation leading to cross-contamination of food already inside.
Refrigerators must not be overloaded as this prevents cool air circulating. Double stacking must be avoided.
Raw food should be stored below cooked/ready-to-eat food
Refrigerated stores must be kept clean and defrosted regularly
The doors of all stores should be kept closed except when they are being filled, emptied, or cleaned.
A thermometer and indicating gauges should be provided to check the temperatures of refrigerators, freezers, cold rooms, and chilled cabinets on a daily basis. These readings should be recorded
Frozen meat, fish and poultry should be defrosted slowly in the refrigerator. Always follow manufacturers' 'use by' dates
Since processed food have very little shelf life, one of the critical requirements for storing processed food is maintaining FEFO (First Expired First Out). Hence receiving the stock as well as delivery can be done in FEFO manner.

[38]https://www.agrifarming.in/cold-storage-license-permission-guidelines-in-india#:~:text=The%20criteria%20for%20registration%20or,obtain%20only%20the%20FSSAI%20certificate.

Freezer Storage

It is vital that foods are in good condition before freezer storage because freezing greatly retards bacterial growth but will not necessarily kill them.

Table 11 Guidelines for storage in freezers

It is vital that foods are in good condition before freezer storage because freezing greatly retards bacterial growth but will not necessarily kill them.
All deliveries of frozen food must be placed in a freezer without delay.
A blast freezer should preferably be used to freeze foods.
Storage freezers are designed to store food that is already frozen.
Freezers must not be overloaded, and the door must not remain open longer than is absolutely necessary.
Deep freezers should ideally be fitted with a high temperature audio alarm and/or a high temperature indicator light.
Raw and cooked foods should ideally be stored in separate freezers and all foods placed in freezers should be properly sealed/wrapped in order to prevent cross-contamination.
Freezers must be maintained at or below –18°C.

2.5. Regulatory permissions for setting up cold storages

The following regulatory requirements are required for setting up cold storages in India as per our desk research and site visits :

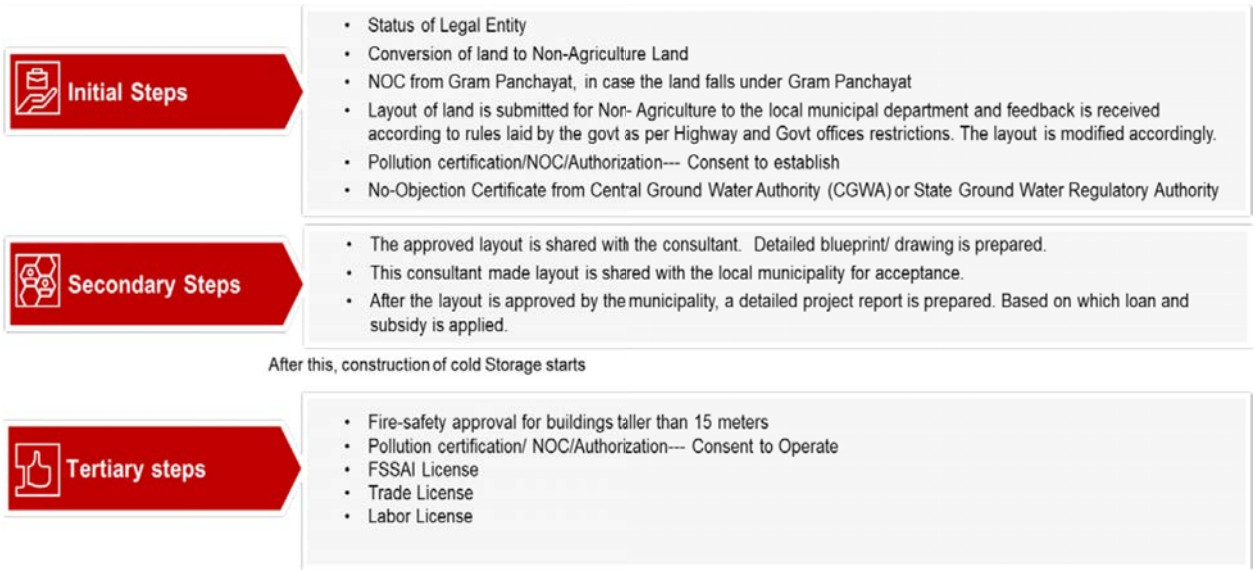


Figure 12 Requirements for setting up a cold storage

2.6. Government policies for cold storage development

Given the benefits, the Government of India has introduced various policies and programs to boost the cold storage sector. The following table provides an overview of the major central and state government initiatives that have contributed to improving the state of post-harvest management in the country.

Table 12: Policies for cold storage development

Ministry/ Implementing Agency	Concerned body / Scheme	Cold-chain Component	Incentive/ Subsidy
National Bank for Agriculture and Rural Development	NABARD Warehouse/ Cold storage Scheme	Cold storages	Under this scheme, loans are provided for projects involving:[39] • Creation of storage infrastructure, with a minimum capacity of 5,000 MT, for agricultural and allied produce, including the construction of Warehouses, Silos, Cold storage, Controlled Atmosphere (CA) stores, other cold-chain activities like reefer vans, and bulk coolers • Modernization/improvement of the existing storage infrastructure projects
National Cooperative Development Corporation	Cold storage and Fruits & Vegetables Development Program	Cold storages	Under this scheme, NCDC: • Provides financial assistance to the extent of 90% of the block cost to the State Governments for setting up/modernization/ expansion/ rehabilitation of cold storage
Ministry of Agriculture and Farmers' Welfare	National Horticulture Board (NHB) NHB is a sub-scheme of Mission for Integrated Development of Horticulture (MIDH). MIDH is a Centrally Sponsored Scheme for the holistic growth of the horticulture sector covering fruits and vegetables)	Cold storage – 5001 Metric tonne (MT) to 10000 MT	Credit linked back ended subsidy at 35% of project in general areas. 50% per project in NE and hilly areas[40].
	National Horticulture Mission (NHM) NHM is a sub-scheme of MIDH	Cold storage (long term storage and distribution hubs) – up to 5000 MT capacity	Credit linked back ended subsidy at 35% of project in general areas 50% per project in NE and hilly areas[41].
Ministry of Commerce and Industry	Agricultural and Processed Food Products Export Development Authority (APEDA)	Cold storages	Up to 40% of the total cost subject to a ceiling of INR100 lakhs[42].
Ministry of Food Processing Industry	Pradhan Mantri Sampada Kisan Yojana	Mega Food Park Scheme: facilitate establishment of a	50% grant in aid of the project cost for general areas.

[39]https://www.indiafilings.com/learn/nabard-loan-for-warehouse-and-cold-storage/

[40]http://nhb.gov.in/guideline/12.pdf

[41]https://midh.gov.in/PDF/Annexure-V.pdf

[42]https://apeda.gov.in/apedawebsite/Announcements/SchemeGuidelinesMTEF27042018.pdf

		strong food processing industry backed by an efficient supply chain • Collection Centers, Primary Processing Centers (PPC), Central Processing Center (CPC) and Cold-chain infrastructure	75% of the project cost for difficult area subject to a maximum of INR 50 crore per project[43].

[43]https://mofpi.nic.in/Schemes/mega-food-parks/pattern-assistance

3. Practices in Cold storages in the E-Commerce Sector

3.1. Current cooling technologies and refrigerants in use

A variety of different technologies are available to meet the cooling needs of cold storages. The cooling technologies are classified into 2 main categories basis refrigerant use:

- Ammonia based chillers
- Vapor compression refrigeration systems

There are two broad temperature ranges for which the cooling technologies are designed: medium temperature and low temperature applications. Although there are no standards which clearly demarcate these temperature ranges, -30° C to -5° C is considered low temperature and -5° C to 10° C is medium temperature.

1. Ammonia based chillers

Ammonia based chillers mostly find application in bulk cold storages. Ammonia based chillers have different type of condenser and evaporators depending on the application. For instance, Individually Quick Frozen (IQF) type evaporators are used for smaller fruits and vegetables such as peas, berries. Blast freezers are used for sea food and meat. The choice of condensers usually depends on the ambient conditions.

Table 13 Ammonia based chillers sub-components

Ammonia based chillers	Condensers	Ammonia atmospheric condensers
		Ammonia Plate Heat Exchanger
		Ammonia Shell and Tube condensers
		Ammonia Evaporative condensers
	Evaporators	Ammonia air cooling units/Blast freezers
		Ammonia diffusers
		Ammonia IQF

For bulk cold storage facilities, ammonia has become the refrigerant of choice since it produces the greatest net refrigerating effect (Btu/lb).

- Ammonia-based refrigeration systems cost 10-20% less compared to CFCs because narrower diameter piping is used and are 3-10% more efficient and thus require less electricity, resulting in lower operating costs[44].
- Ammonia as a refrigerant is best suited for meat, dairy, and potatoes. However, ammonia is poisonous at high concentrations and therefore ammonia-based cold storages are located outside the city limits; and
- Ammonia-based systems are dominated by the unorganized sector where different components of the systems such as compressor, evaporators, condenser are sourced from different vendors and assembled at site.

[44]Consultation with technology providers

2. Vapor Compression

The vapor compression refrigeration cycle is the most widely applied method in commercial refrigeration and air-conditioning technologies. Vapor compression cooling relies on an electricity driven, mechanical compressor. It is also known as mechanical refrigeration. A liquid refrigerant is circulated and exposed to low and high pressures successively. In a low-pressure environment, the refrigerant evaporates while absorbing heat from its environment, thus providing a cooling effect. Subsequently, the gaseous refrigerant is compressed and condensed, and so returns to its liquid state, while rejecting the previously absorbed heat to its environment. Vapor compression-based systems mostly find application in small and modular cold storages/ walk in cold rooms. These are split type systems and mostly catered to by India's leading HVAC companies such as Blue Star, Danfoss, Voltas and Carrier among others. These fall into two broad categories as shown in the figure below:

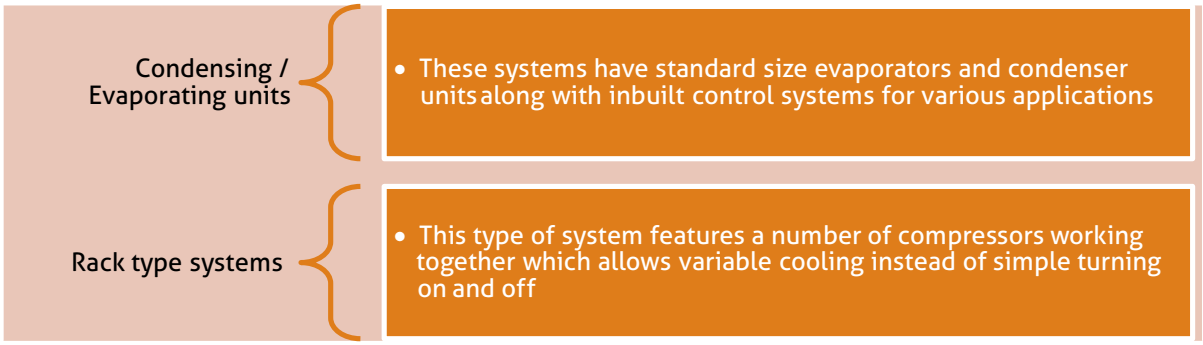


Figure 13 Vapor compression systems

The finer details of the vapor compression-based systems are presented in the table below -

Table 14 Vapor compression based systems

Type	Capacity	Compressor	Refrigerant	Application
Low Temperature Condensing Units	2 to 20 kW	Hermetic Reciprocating/ Scroll/ Semi-Hermetic/ Rotary/Scroll	R-404A/ R-410A	Ice-Cream, Fisheries, Vaccines, Frozen Food, Restaurants with small cold storage, supermarket
Medium Temperature Condensing Units	3 to 70 kW	Hermetic Reciprocating/ Scroll	R-404A/ R-410A	Dairy, Pharma, Fruits & Vegetables, Horticulture, Convenience stores
Medium Temperature Parallel Racks	100 to 1200 kW	Screw Compressor	R-404A	Vegetables, fruits, meat, fish
Low Temperature Parallel Racks	50 to 700 kW	Screw Compressor	R-404A	Seafood, meat, ice cream

The dominant refrigerants in this system based in India are R-22, R-410A and R-404A, R-134a and R-407C which have very high GWP as illustrated in the table below.

Table 15 GWP and ODP values of refrigerants

Refrigerant	Category	Global Warming Potential (GWP)	Ozone Depletion Potential (ODP)
R-410A	HFC	1924	0
R-404A	HFC	3922	0
R-134a	HFC	1300	0
R-407C	HFC	1774	0

3.2. Current practices in cold storage facilities

In India, cold storage facilities have served certain types of products. Typically crops like potatoes, onions and tomatoes are stored in cold storage facilities. However, as the market has expanded and as there's been more internet penetration into rural areas, there has been a significant rise in the online sale of perishables. To meet this surging demand, it has become a priority to scale up cold storage facilities near customers. Here are the criteria to be followed when setting up cold storage facilities:

- Design
- Operation and Maintenance, skill and capacity building

3.2.1. Design

Proper design of infrastructure and the refrigeration system of a cold storage is important. In general, e-commerce companies like Swiggy, Big Basket, Amazon, and Amul among others, tie up with 3PL companies to manage their stock requirements. These 3PL companies either own cold storage facilities designed and constructed for them, or tie up with some private cold storage owners.

Some e-commerce companies also own the cold storage, where they hire consultants to design and construct these facilities. These consultants / technology providers undertake the calculations and design the cold storages which are then constructed by the contractors based on the finalized design provided to them. The design of refrigeration system of cold storages requires information on the following aspects:

- Location of the cold storage;
- Size of the cold storage;
- Products to be stored;
- Incoming temperature of the product;
- Storage temperature;
- Ambient temperature;
- Air change load; and
- Number of persons working in the cold storage.

3.2.2. Location

The location of cold storage is important in terms of ease of product movement as well as operating and construction cost of the cold storage. The cold storage room is preferably located on the cold side of the plant. In case of multiple cold storages, all the cold storages should be located side by side to reduce the cost of insulation in the common wall of adjacent cold stores. It should be located in such a way that finished products can be transferred to the cold stores easily and finished products can be dispatched conveniently.

3.2.3. Size

The dimension of the cold storage is estimated based on the capacity requirement for the storage of the product. The dimensions of the cold storage depend on factors like the method of storage, working space, and air circulation. Considering number of milk pouch crates which can be stacked, working space etc.; the capacity of storage per m^2 area of the cold room is worked out. Similarly for potatoes, apples, and butter, the dimensions of the cold storage can be calculated e.g., 600kg butter/m^2 area, 500 liters ice-cream/m^2 etc. The storage period is one of the basic requirements to decide the size of cold storage to store the product. The capacity and number of cold storage units required for storage of cheddar cheese will be more as the cheese is stored in the cold storage for 4-5 months for ripening. This may not be the

requirement for milk, which is dispatched twice a day. In addition to exact space required for storage of product, 30-40% of the space is kept for movement.

3.2.4. Construction

The basic construction of cold storage is just like any other room — except for the insulation required. The room is constructed by using masonry work and it is plastered with at least 25 mm thick plaster material (mortar). After cutting the plaster, the walls, ceiling and floor are insulated. The cold storage should be constructed as per approved drawings and dimensions indicated. These facilities can be completely civil construction or steel construction / pre-engineered construction conforming to relevant BIS Codes for live load as per IS 875 Part-II, wind load as per IS 875 Part-III, seismic load as per IS 1893 and other codes and standards if applicable. Strip curtains are quite common for reducing air infiltration during loading and unloading.

In case of conventional civil construction, the general specifications are as under:

- Walls: 230 mm Brick walls / solid concrete blocks with sand- cement plaster. However, in RCC structure or prefabricated structure, insulated panel boards may also be provided in place of masonry walls; and
- Roof: RCC slabs or Truss Roof with G.S / Pre-coated G.S. Sheet cover. RCC slab to have proper water proofing with reflective colour paint / China mosaic finish.

3.2.5. Insulation

Materials with extremely low thermal conductivities are called insulating materials. It is necessary to insulate the cold storage to prevent the entry of heat through the walls, ceilings/roofs and floor. Insulation of cold storage is important to reduce the operating cost of the refrigeration plant by reducing heat gain. If insulation does not perform effectively, there will be cold loss and the load on refrigeration will increase.

Thermocol, expanded polystyrene etc. were widely used for insulation earlier. Today, PUF panels are available to insulate the cold storage. The material for insulation depends on the construction material and the thickness/ level of insulation required.

Recommendations for insulation

- Holes prepared in PUF panels for inserting support for evaporator, cables, pipes etc. should be sealed perfectly to prevent water vapor inside the insulation;
- A better alternative to PUF is polyisocyanurate (PIR) foam, which is an advanced fire safe insulation material. As per international practice, sandwich panels are made of PIR insulation, foamed between 2 metal skins with precoated or other desired finishes. The panels have the advantage of lower wall thickness due to elimination of brick walls and a better insulation value;
- It is recommended that appropriate BIS standards are adopted for selection of design parameters (IS 661:2000) and method of application of thermal insulation (IS 661 & 13205). For fresh fruits and vegetables stored at + 0° C, it is recommended to design thermal insulation for (-4° C to + 2° C) temperature condition to have lower heat load;
- Sheet metal flashing to be provided on all concrete / wall ceiling joints internally & externally. PVC coving or concrete curbing to be provided on wall - floor joints; and
- Insulated doors shall be suitable for panel mounting.

3.2.6. Vapor barriers

Vapor barriers are materials which are placed on the hot side of the cold storage to prevent moisture migration and to protect the insulation from moisture condensation. There are various types of vapor barriers such as structural sheets of aluminum and stainless steel, thin aluminum foils, plastic film hot melt type bitumen, special types of paints etc. are used to prevent moisture transfer through the insulating material. Bitumen and aluminum foil are widely used in insulation as permeance is very low. Vapor penetration into the insulation will occur as vapor pressures are lower at lower temperature and warm air will condense which in turn will form ice which may damage the panels. Panel and electrical services are carefully designed to ensure long-term vapor sealing. Penetrations are required for evaporator supports, electrical wiring and refrigeration pipes. In such cases, make a hole in the panel and use a PVC sleeve for the required penetration; sealing materials such as silicon may be used to make it airtight.

Recommendation for vapor barriers

Water vapor penetration into cold rooms increases the refrigeration load as cooling air is easier, requiring less energy, compared to cooling water vapor. That's why a vapor barrier is very important in cold insulation. Together with the vapor barrier, it's important to use proper adhesive for fixing insulation within a holding framework so that it remains in place for a longer period of time and performs effectively.

Total refrigeration load

Procedures laid out by ASHRAE Fundamentals and Refrigeration handbooks are followed. The current method prescribed by ASHRAE Fundamentals is RTS (radiant time series) method in which room by room analysis for each hour is carried out. However, the assumptions used for the building envelope and the loads are very crucial. Designers also tend to take a safety factor of 5-10% on the estimated loads. The following considerations need to be captured while calculating the refrigeration load:

Product incoming temperature: It varies with location and harvesting time. The initial product temperature and the final product temperature along with the temperature pull down period has to be considered for estimating the refrigeration requirement.

Capacity during loading, pull down, holding and lean periods: Refrigeration capacities should be calculated at various operating conditions and necessary arrangements for capacity control are included in the equipment to be provided.

3.3. Operation & maintenance, skills and capacity building

The operation of cold storage requires knowledge and skills in several areas, including knowledge of the effects of temperature on food products, product specific storage requirements, good practices in the handling & packaging of food products and cold storage management, as well as skills in operating cooling technologies, supply chain management, and logistics.

When these skills and knowledge are lacking, it hinders the use of cold storage; lack of knowledge and skills about cooling equipment operation and maintenance means that when equipment is available, it is often not used as effectively or efficiently as it should be. Upon the site visits conducted and brief conversation with the AMC companies who provide technicians and periodic maintenance to the cold storages, we have evaluated the skills and manpower required to run cold chain infrastructure on a regular basis.

Considering the rapid expansion of cold storages in the country, lack of adequate and relevant trained manpower to manage and operate these cold chain systems will pose a big challenge. Some tasks on the cold room maintenance checklist should be carried out daily, while some cold storage cleaning chores can be completed on a weekly, bi-weekly, or even monthly basis.

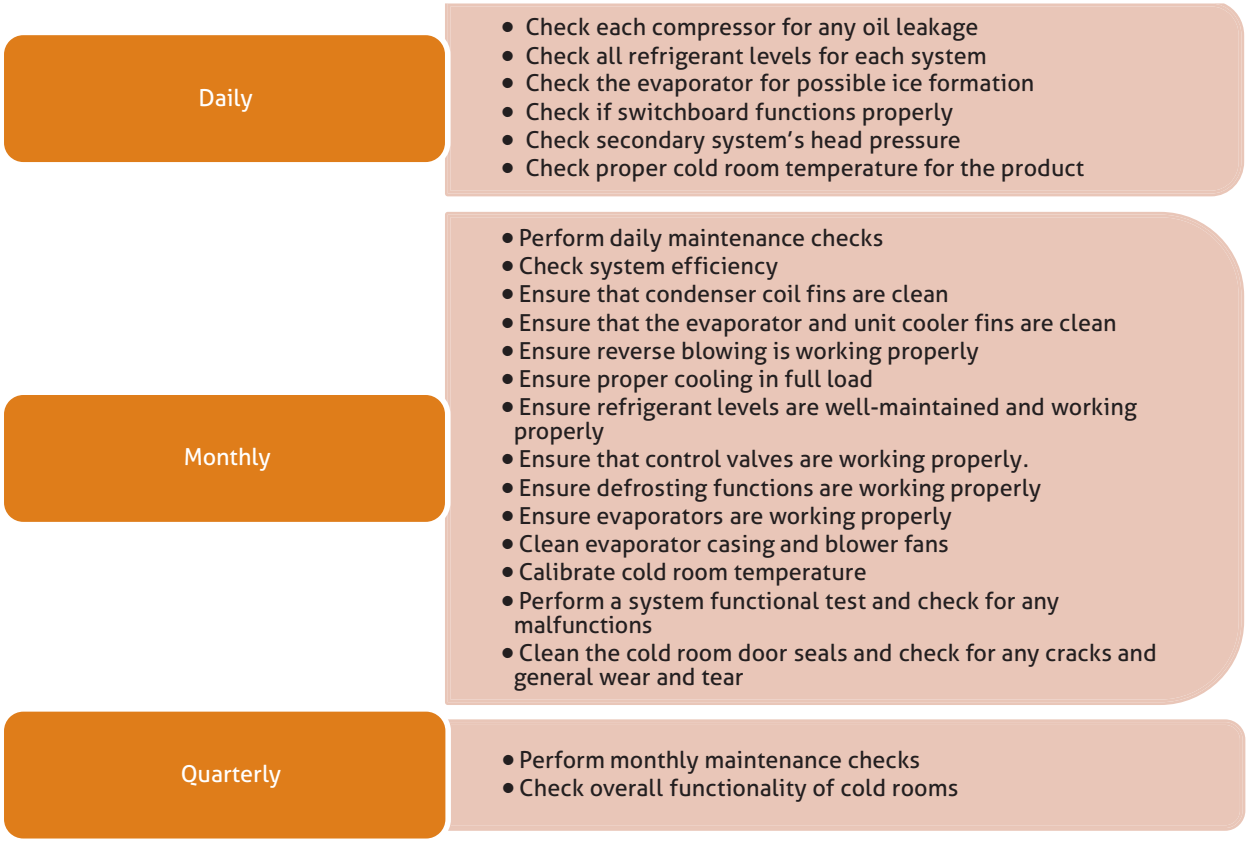


Figure 14 Good O&M practices

The skill level achieved through extensive capacity building and training is necessary to promote the proper functioning of cold chains. The skilled manpower requirement is important in the two major areas:

- Handling and post-harvest care of fresh produce including appropriate temperature & humidity control; and
- Cold storage equipment related - Technicians for installation, maintenance etc.

For the handling and post-harvest care, the training should focus on:

- Identifying the causes and sources of losses;
- Processes along the cold chain (like postharvest handling, precooling, cold storage, cold transport, food processing etc.);
- Basic practices for reducing losses for perishable foods intended for cold storage and logistic;
- Food safety issues due to poor post-harvest practices; and
- Energy efficiency.

Traders, middlemen, and transporters have a large impact on temperature management during handling and transport, and therefore on the final quality of foods. Hence, they should also be trained on the importance of temperature maintenance.

For technicians, the training should focus on:

- Practices for reducing losses for perishable foods intended for cold storage;
- Engineering including design, repairs, maintenance of cold technologies;
- Energy efficiency;

- Technical training is required for the proper handling of the refrigerants and other environmental issues; and
- Food safety.

Capacity building in food safety modules

Even though the actors in the supply chain, particularly in the logistics and retail end, are aware of various technicalities in maintaining the cold chain, there is a serious lack of knowledge pertaining to the food safety aspects of the frozen/ chilled/ temperature sensitive foods. In order to bridge this gap, there is a need to develop simplified modules of training to address the following:

- Criticality of temperature in food safety;
- Probable food safety risks of cold chain failure; and
- Risk mitigation and corrective actions during cold chain failure.

Training on these aspects will help in effective decision making by the stakeholders during crisis times and ensure food safety to the consumers.

Cold storage employment outlook

The cold chain sector has tremendous employment generation potential, from skilled workers, technicians to handle cold storage facilities to skilled drivers and handlers for reefer trucks.

In a traditional cold chain, employees learn on the job to run and maintain cold storages. These employees do not have relevant training credentials but learn from watching senior employees and follow similar practices. They take care of day-to-day maintenance of the cold chain infrastructure. If a problem is not solved, then they call the proper technicians. This is where capacity building will play a vital role.

Currently, technicians are hired by the AMC companies who come on call or are given contracts to visit the storages on a periodic basis. In the newer cold storages, the day-to-day activities are taken care of by facility management companies who take care of the day-to-day breakdown and have technicians on-site who are capable of dealing with the breakdowns.

Workers with diplomas or degrees are hired by AMC companies or facility management companies and are then trained for 4 months to become complete technicians where they are provided with 3 months of in-house training and 1 month of deployment with a senior professional before deploying them individually.

Any average cold storage employs around 75 direct and indirect workers[45]. Creation of new facilities to meet the deficit of cold storages across the country will create 25,000 jobs. Since the cold chain is at a nascent stage in India, this sector has the potential to provide employment to many people. Over the years, there would be high demand for labor to work in industries manufacturing infrastructure for cold chains. Technology providers will also play a crucial role in the sector.

3.4. Available best practices, technology, and refrigerants in the cold storage sector

3.4.1. Opportunities for reducing cooling demand, refrigerant requirement (Non HCFC & low GWP)

Considering the government's priority on cold storage development, a capacity addition is envisaged in terms of storage. In the coming years, this capacity addition will result in additional energy demand for the sector. This presents an opportunity to build an energy efficient cold-storage infrastructure and use

[45]https://www.sathguru.com/news/wp-content/uploads/2017/05/Cold-Chain-Report.pdf

of renewables to reduce indirect greenhouse gas emissions. The sector also presents an opportunity to reduce direct emissions and save the ozone layer with the use of zero ozone depleting potential (ODP) and low-GWP refrigerant based cooling solutions. According to the India Cooling Action Plan (ICAP), the growth projections over the next 2 decades are depicted in the figure below.

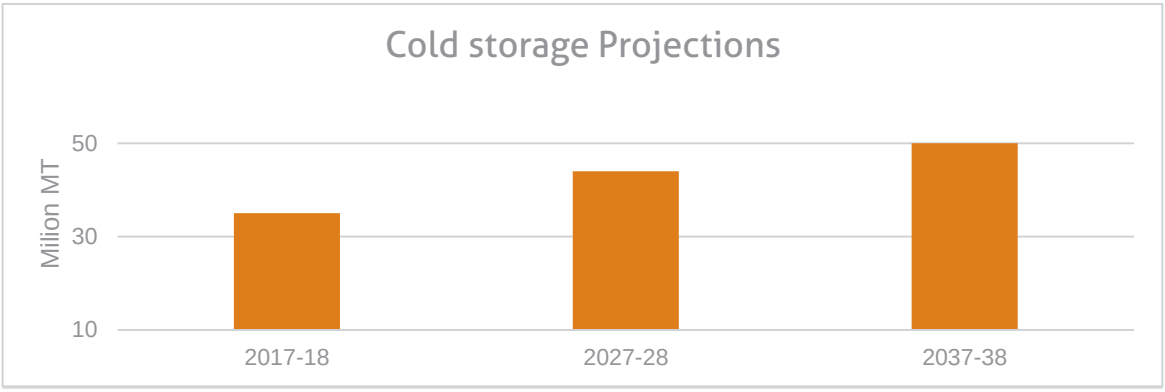


Figure 15 Cold storage projections

The effect on the energy consumption of this sector is expected to increase as well. The addition of cold storage capacity will be responsible for the increased energy demand. The annual energy consumption is expected to increase from 4 TWh in 2017-18 to 5.2 TWh in 2037-38. Upcoming and innovative technologies in cold storage technologies are mainly related to alternative sources of energy for cooling. Either renewable energy sources can be tapped into or closed loop systems such as waste heat recovery within the cold storage itself can be identified. Technologies such as Variable Frequency Drive (VFD), etc. and controls, as well as Internet of Things (IoT), are being looked upon as a replacement to existing technologies due to the energy efficiency they offer. The use of clean and energy-efficient technologies in the cold storage is expected to reduce the carbon impact throughout the supply chain directly by using cleaner refrigerants, and indirectly by using alternative technologies such as waste heat recovery, concentrated solar thermal, etc. This study has found that clean and energy efficient technologies for cold-chain deployments in India are available. However, apart from a small number, they are still at the early adoption stage and localization through adaptation to in-country and regional cultures, skills, and practices, is required.

3.4.2. Available best technology practices

Low Charge Ammonia System

Though ammonia is one of the better refrigerants as far as Ozone depleting potential is concerned, its toxicity and large volumes being handled and stored resulted into limitations in use of this refrigerant. However, now low-charge ammonia systems are available, due to which, handling of smaller quantities and use of sensors to detect leaks, help in reducing the hazards of handling large volumes of ammonia.

Cascade System

CO_2 is used in conjunction with NH_3 as a cascade system, where larger quantities of NH_3 can't be used due to its toxic properties. Typically, NH_3 is used for high stage compression and temperatures up to -10^{0}C are generated. Using cascade heat exchangers, low stage CO_2 compressors are used for generating lower temperatures upto-40^{0}C. In some cases, it is also used as secondary coolant.

Solar based Cooling

Solar panels are expected to increase in importance for the global energy supply and are expected to be the leading renewable energy source in the future. The price of solar panels is decreasing and the TCOE (Total Cost of Energy) is now in many instances cheaper than fossil-based alternatives. Solar panels can

provide electricity that can power well-known cooling compressors to supply cooling to a small cold storage unit. Solar panels can also be deployed in rural areas with no or weak access to the electricity grid, and could be especially suitable for pack houses and other storage facilities close to the producer. A disadvantage of solar panels is of course the intermittent nature of the power, which can then be complemented by alternative power sources in the form of grid connection or diesel generator or be combined with thermal energy storage.

Figure 16 Solar cold storages

The deployment of thousands of standardized huts based on solar power combined with battery backup or phase changing cooling storage could be a key product in clusters for e-commerce companies.

Combined power and cooling

In a more advanced setup, but still realistic in rural India is the Concentrated Solar Power (CSP) mentioned above combined with Organic Rankine Cycle (ORC) power production and absorption chiller for cooling. In this way, the local cold storage can get both power and cooling from sunlight. An advantage of this setup in comparison to solar panels and battery packs is that the CSP/ORC combination can store the sunlight as heat in buffer tanks for later use in the ORC loop, which is much cheaper than large scale electrical batteries.

Ground Source condensing based Geothermal Cooling

Ground source condensing based geothermal cooling systems use the ground as a heat sink, as the earth's temperature at a certain depth is lower than atmospheric temperatures. With lower ground temperature available to the cooling systems, their efficiency increases significantly. Where feasible, such systems can replace or augment existing refrigeration systems, leading to significant energy savings[46].

Two remote off-grid villages on the tiny Fijian island of Vanua Levu in the South Pacific are looking forward to their first reliable source of refrigeration. The plan for this pilot project is to pipe the Waikatakata Hot Spring at Vusasivo, which is coming out of the ground at 70°C, into an absorption chilling facility at Natewa Bay. This centralized cold storage facility will then be available for villagers to preserve their goods.

There are two agri-food geothermal direct-use projects near Amatitlan geothermal field. The San Michkael Geothermal Mini-Industrial Park pilot demonstration project produces hot water and steam from shallow wells, which is used to dehydrate food, grains, fruits and vegetables, to produce handmade candles and to provide hot and cold-water production for multiple industrial uses. Cold storage and other cascaded applications are being evaluated (Paiz, 2021).

The application of geothermal cooling in the cold chain has been so far limited. However, GEG Power, an Iceland-based geothermal development company with strong experience in delivering turn-key geothermal power plant solutions, recently received final permission from the Himachal Pradesh state government to begin conducting survey and exploration studies for GEG Cooling project on cold-storage solutions for local apple farmers.

Thermally driven cooling

Cooling can be produced from heat sources through absorption chillers using only relatively small amounts of electricity compared to conventional compressor cooling. The absorption process is viable where industrial processes already produce waste heat. However, it is also possible to use local waste streams

[46]Cold Chain Technologies: Transforming Food Supply Chains

to produce heat. This could be a furnace for burning nut shells, plant fibers from coconut or any other excess dry biomass from the processing of food, which would otherwise be wasted. The installation of an absorption chiller based on burning of biomass would require a certain size and considerable investment to be feasible but would be able to produce cheap cooling.

Another possible heat source is high temperature solar heat collectors in the form of parabolic collectors such as CPC (Compound Parabolic Collectors) or CSP (Concentrated Solar Power). These technologies can supply heat above 90°C, which can be used directly in an absorption chiller to produce cooling. Examples of thermally driven cooling systems:

- CPC installed on Indian Gandhinagar Thermal Power Station's office buildings[47];
- Thermal hybrid (solar and biomass) cold storage demonstration plant from Thermax at the Solar Energy Centre in northern India[48]; and
- Example of CSP installation in India: Godavari 50+MWe concentrated solar power plant[49].

3.4.3. Use of low GWP refrigerants

Condensing units with HFO/HFC-HFO blends based refrigerants

These systems work same as HCFC/HFC based refrigeration systems but use HFO / HFC-HFO blends which have low GWP. However, their use is limited due to high costs. HFO-1234yf, HFO-1234ze can be utilized in cold storages as an alternative to high GWP refrigerants. Blends such as R-455A which is a blend of an HFO (R-1234yf), HFC (R-32) and CO_2 having a GWP of 146 is also a good alternative to HFCs[50].

Table 16 Best Refrigerants practice in cold chain sector

Application type	Typical Refrigerants used	New agerefrigerant (Short term replacement)- Lower GWP	Long term replacement (Lowest GWP)
Pack House	R134A / R404A	R448A / R449A / R513A	R1234yf, R1234ze Natural: R290
Reefer Vehicles	R22, R-134A, R404A, R-507	R-448A, R-449A, R-513A, R452A	R1234yf
Cold storages	R22 / R134A / R404A / R507	R-448A, R-449A, R-513A, R1234ze, R744, R717	R515B, R1234yf, R1234ze Natural: R744, R717
Ripening Chambers	R22, R134A	R134A	R513A
Domestic Refrigeration	R134A	Natural: R600A	Natural: R600A
Commercial Refrigerant (Last Mile)	R22, R404A	R507, R448A / R449A, Natural: R744	R1234yf, R1234ze Natural: R744, R290

Source: Expert Guidance

Intarcon, a company based out of Spain has developed a new range of equipment called Waterloop Evaporators, which can replace traditional condensing unit connected to one or two direct expansion evaporators with HFC (R449A or R134a) using R290 (Propane) in the refrigeration circuit. It is a hermetically

[47]https://www.solarthermalworld.org/news/first-cooling-installation-indian-government-building

[48]https://www.solarthermalworld.org/news/india-new-solar-biomass-cold-storage-and-power-generation-system

[49]https://www.aalborgcsp.com/projects/50-mwe-steam-generator-system-for-godawari-india/

[50]Study on cold chain sector in India for promoting Non-ODS and low GWP refrigerants

sealed compact system for installation inside small cold rooms. They are pre charged with a small charge of natural refrigerant R290.

A German Retailer, Secon has installed three of its propane (R290) chillers with a large food retailer near Berlin for a total of 900kW (255.9TR) cooling capacity at -2^{0}C. The three R290 units are all air-cooled liquid chillers with the liquid in this case being brine. They cool the cold rooms of the central warehouse of the food retailer.

In India, Embraco, has broad portfolio of compressors and condensing units. It includes options with natural refrigerants R-290 and R-600a (propane and Isobutane) which are an environmentally friendly solutions that help to protect the ozone layer and prevent global warming. However, the sizes of the same are small and not on large scale. Shifting to large scale implementation of these natural refrigerants is important and these should soon be introduced into the Indian cold chain market for its sustainable development. Incentivizing the homegrown companies can help them to easily switch from higher GWP refrigerants to lower/greener options.

3.4.4. End of life management practice

Refrigeration and air conditioning systems have become an inherent part of life, touching everything from food security to health security to financial security and human comfort. Due to heavy usage of refrigerants, there is a need for refrigerant management throughout its life cycle and at the end of life as the refrigerant gases currently used in India are environmentally damaging in nature and must always be recovered at the end of appliance life cycle.

Earth's ozone layer extends from 7-30 miles into the stratosphere and is essential to block lethal ultraviolet rays. Depletion of the ozone layer is partly caused by chlorofluorocarbons (CFCs) and hydrofluorocarbons (HCFCs) which are found in older refrigerants. When CFCs and HCFCs are released into the atmosphere, ultraviolet rays from the sun destroy these molecules, setting free chlorine and bromine atoms which can damage the integrity of the ozone layer.

Currently, when an asset is taken out of service, gases like CFC / HCFC are not destroyed but are cleaned and reused, which leads to providing these gases an opportunity to harm the environment due to the probability of high leakage from the old cooling system. It is highly essential to provide proper assistance to contain these gases and have proper guidelines to dispose them.

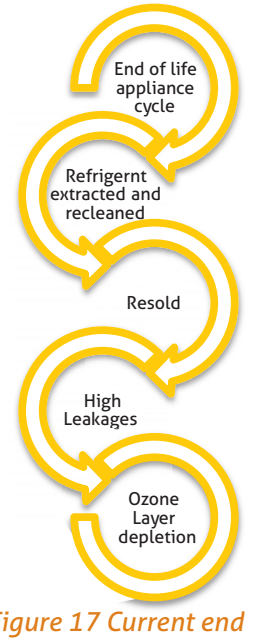


Figure 17 Current end of life cycle of refrigerants

As per India's commitment, the country has completely phased out CFC refrigerant gas from its cooling ecosystem and is in the process of phasing out HCFCs by 2030. According to the latest Kigali Amendment to the Montreal Protocol, nations have been called upon to phase down HFCs. It is vital to have proper guidelines in place for end-of-life refrigerant management.

The benefit of having end of life refrigerant management practices in place will lead to:

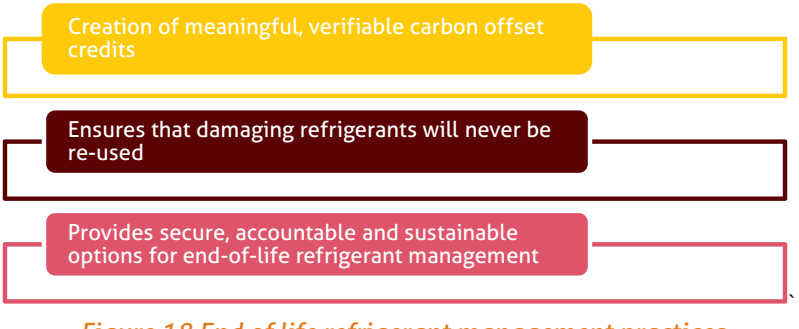


Figure 18 End of life refrigerant management practices

Current of end-of-life refrigerant management practices in India

India has been at forefront in phasing down ODS related High GWP gases like CFC and is in the process of phasing down the HCFC gases. However, while we address this, it is essential to explore better ways to manage refrigerants throughout their lifecycle. Currently, India is not equipped to dispose off refrigerants. The barriers from regulatory framework to human behavior are listed below.

- Recovering refrigerants from cooling systems;
- Decommissioning of large cooling systems, vacuum pumps and tanks will require significant investment for site and time to pump down refrigerant. Then the old refrigerant will be taken for disposal which will require separate fees;
- Consumer awareness regarding the harmful nature of refrigerants to the environment and proper precautions to dispose them;
- Proper available information about the appliance disposal and respective responsible organization; and
- Recycling service charges to consumers which lead to abandoning of cooling systems or disposal in local landfills.

Best market practices for disposing refrigerants

Currently there is no framework for end-of-life refrigerant management in India. To reach commitments to phase out all CFCs and HCFCs three essential tasks are mentioned below:

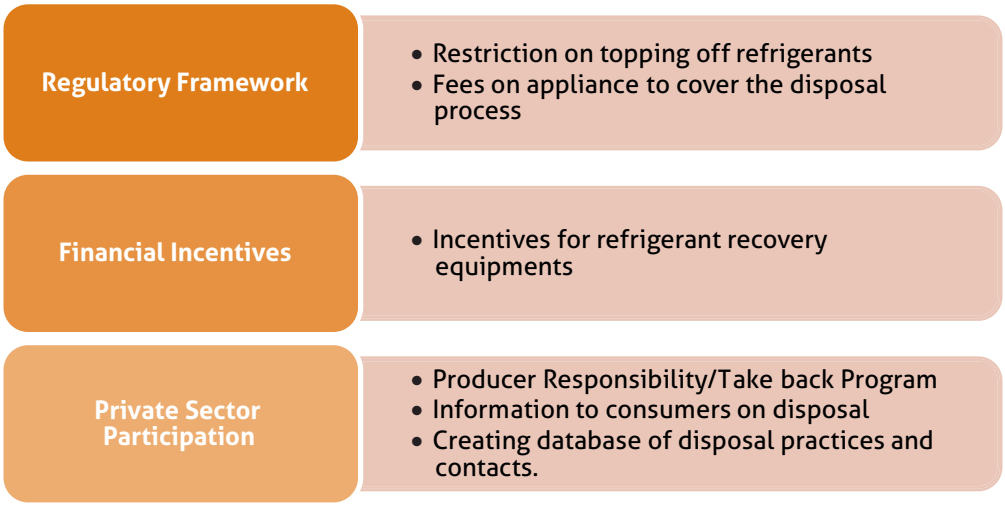


Figure 19 Tasks to fulfill commitment of phasing out CFCs and HCFCs

Best practice for end-of-life refrigerant management around the globe

To assess the practices for the end-of-life refrigerant management, it is essential to look at global best practices. Countries like Japan, South Korea, and the EU have introduced multiple mechanisms that need to be followed by all the concerned parties including users as well as providers.

Reverse logistics is one kind of mechanism which has been looked upon by the above-mentioned countries, thus the typical model of reverse logistics followed by the abovementioned countries to recover the gases at the end-of-life of the product that they have been used in is described in the below figure[51].

[51]https://www.ceew.in/sites/default/files/global-best-practices-lifecycle-refrigerant-management-emissions.pdf

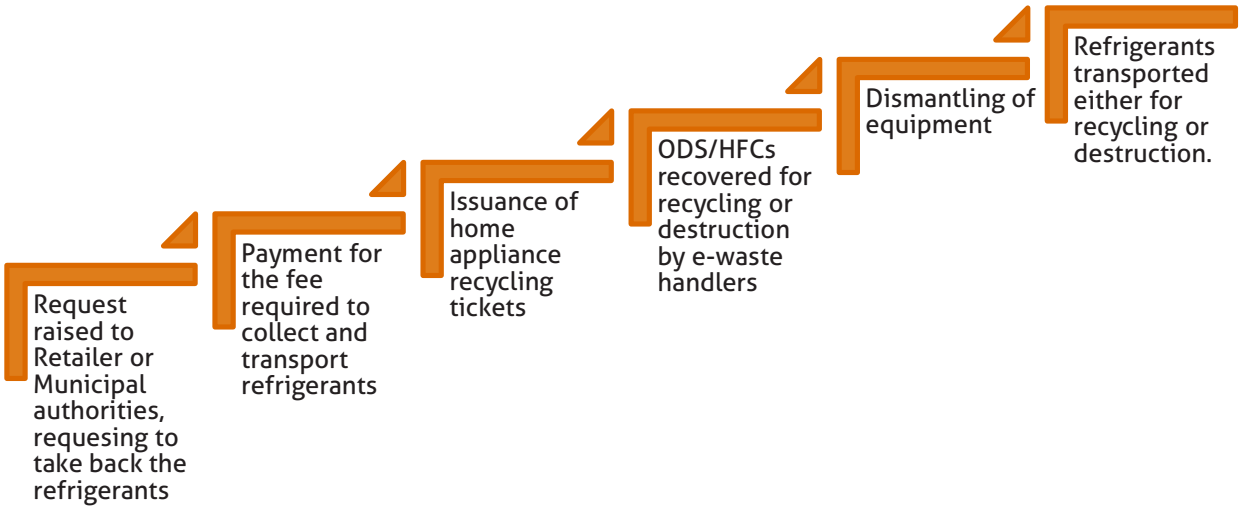


Figure 20 Refrigerants end-of-life management practice in Japan

3.5. Cold storages site visits

Site Visit

Site visit 1: Ajanta Cold storage, Ghaziabad

- About the unit
  - Ajanta Cold Storage is a cold storage facility located in Ghaziabad, UP.
  - It is a privately held business with an estimated aggregate cold storage capacity of 5 to 6,000 tons. It is multi-commodity CS facility with 25-30 chambers with traditional racks of 14-to-16-meter height which are mostly non-pelletized and horizontally constructed.
  - The products stored are mostly potatoes, spices (red chilies, turmeric, coriander), dairy products and ice cream and clients such as Amul, Mother Dairy, Britannia and Kwality walls among others.
- Cooling technology
  - The CS facility used a controlled atmosphere (CA) conventional ammonia-based VC refrigeration system with positive temperature range of 10 to 14°C and a negative temperature range of -18 to 22°C.
  - There is also a provision of 1-2 chambers using refrigerant based vapor compression system.
  - The refrigerants used are ammonia and R-410A. PUF panels are used for insulation, and the cold storage design is usually self-made with dedicated in-house experts.
- Business model
  - The business model of the CS facility is that the clients handle inbound logistics and procurement to the CS facility, there is a CFA on-site that handles the incoming and outgoing flow of products in a first-in first-out (FIFO) structure and also checks the products and handles the dispatch, and the CS facility handles and maintains critical parameters such as temperature, humidity among others.

- O&M
  - The operation and maintenance practices in the CS facility were mostly manual and ad-hoc in nature with no major capacity building activities.
- Remarks
  - There was no real-time technical monitoring of parameters, and the facility depends mostly on manual interventions in the event of any fault or any such incidents. There was no standardized training and operational standards that were followed in the CS facility.

Figure 21 Outdoor unit at site 1

Figure 22 Indoor unit inside cold storage at site 1

Site visit 2: Transport Corporation of India (TCI), Manesar

- About the unit
  - Transport Corporation of India is a Cold Storage facility located in Manesar and they have multiple cold storage facilities located in Delhi NCR, Pune, Bangalore, Chennai, Hyderabad, and other cities.
  - TCI Manesar is a multi-commodity cold storage facility with positive temperature range of -1 to 10°C and negative temperature range of -40 to -18°C.
  - The client portfolio includes companies such as Amul, Swiggy, Mother Dairy, Mars, Snickers among others and products stored includes fruits and vegetables, dairy, chocolates, ice cream, marine and meat.
  - Clients utilize the CS facility as an extended warehouse, wherein they take the storage facility on rent to store products for a short period of time before dispatching it.
  - Vendors handle the incoming transportation and dispatch, and TCI handles the storage and outgoing dispatch in a few cases.
- Cooling technology
  - The refrigerants used are mostly ammonia and R-404A. PUF or Polyurethane foam insulated panels are used in reefer trucks for distribution and Frick India compressors are used.
- O&M
  - The best O&M practices observed in the CS facility are that they have a dedicated in-house O&M team, and in emergencies they contact external teams. They have 24*7 monitoring using SCADA and dedicated teams.

- Remarks
    - The facility has multiple areas such as staging area (outward), docking area, CS room and they also have 24*7 monitoring of critical parameters with a dedicated in-house maintenance and servicing team.
    - They have KYT - Training and drills for safety every day for 10-15 minutes for all employees onsite, they conduct mock training to deal with instances such as ammonia leakage.

Figure 23 Outdoor unit at site 2

Figure 24 Palletized cold storage at site 2

Site visit 3: NSSPL, Ahmedabad

- About the unit
    - The CS facility had stacked in multiple chambers with 5-6 floors and a total cold storage capacity of 5,000 MT and a refrigeration capacity of 550 kW.
    - The facility consists of a controlled atmosphere (CA) cold storage with humidity and oxygen level controls and a modified atmosphere cold storage.
    - The temperature controlled cold storage is used for storage of spices, jaggery, cumin and related products with temperature, humidity and oxygen level control to main quality and increase shelf life.
- Cooling technology
    - The modified atmosphere cold storage has temperature, CO_2, and RH (relative humidity) control.
    - In addition, the CS facility also had IQF (Individual Quick Freeze) used for frozen products and humidifiers.
    - The technologies used are PUF or Polyurethane foam insulated panels with 50mm to 120 mm thickness, GI sheets, flashing method used, flooring covered with RCC, evaporators and condensers, PVC scripts, water sprinkler systems and dual safety valves among others.
    - The main refrigerants used are ammonia, freon and R-404A. The best O&M practices recorded were that the facility maintains checks for ammonia leakage including shower area, double safety valves, water sprinkler system and PVC scripts.
- O&M
    - Fully automated plant with a comprehensive data acquisition and monitoring system.
- Remarks
    - The facility does electronic monitoring and control, and multiple sensors are placed in every CS room to measure critical parameters such as temperature, pressure, ethylene, CO_2, RH values.

Also, capacity building trainings are undertaken and there are mandates for training for all employees.

Figure 25 Ammonia safety norms at site 3

Figure 26 Safety norms at site 3

Site Visit 4: Retail Outlets (Delhi NCR)

- Multiple ecommerce retail outlet across Delhi NCR.
- Outlets included 24 Seven, Smart Point, Smart Bazaar and Yess were observed in these visits.
- Multiple Refrigerated Display Cabinet units like Open-chilled vertical multi-deck remote (0° C to 8° C), Vertical freezer with doors (closed) (-8° C to -32° C), Chilled Horizontal frozen island (-8° C to -16° C), Chilled Open Wall Site (1° C to 5° C), Chilled serve-over counter closed service access (1° C to 5° C), and Pastry Cabinets (1°c to 5° C),

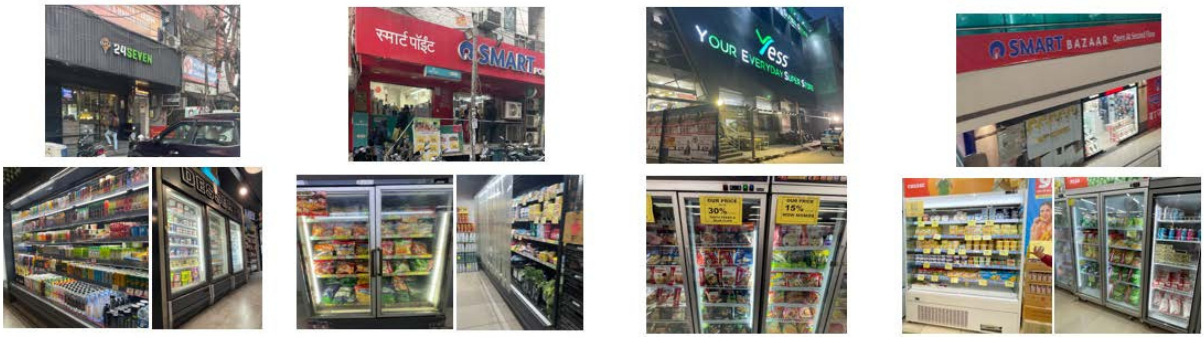


Figure 27 Refrigerated display cabinets at retail outlets in Delhi-NCR

Table 17 Multiple e-commerce outlets

Outlet: 24 Seven	Outlet: Smart Point	Outlet: Yess	Outlet: Smart Bazaar
Online Store: https://www.24seven.in/grocery-home-delivery	Online Store: https://reliancesmartpoint.com/reliance-smart-app/	Online Store: https://www.yess.co.in/category/Offer/Happy%20Monsoon/Happy%20Monsoon	Online Store: https://relianceretail.com/reliance-jiomart.html
Freezer Temperature: -24° to -8° C Refrigerator Temperature: 0° to 8° C	Freezer Temperature: -32° to -11° C Refrigerator Temperature: 0° to 6° C	Freezer Temperature: -16° to -6° C Refrigerator Temperature: 0° to 8° C	Freezer Temperature: -18° to -3° C Refrigerator Temperature: 0° to 8° C

4. Recommendations for Good Management Practices

The global demand for cold chain products is growing rapidly. As the worldwide market for perishable products expands, efficient and effective cold storage management becomes more and more critical. Cold storages offer a myriad of advantages, some of which include cost savings, prolonged product life, customizable temperature settings, more storage space, etc. But to derive such benefits, proper management of cold storage is imperative. Following are the eight best practices that one can employ to manage cold storage units efficiently:

1. Maintain temperature range

A single cold storage warehouse does not usually hold just one type of product. Instead, it simultaneously stores different products that require different temperatures. For example, vegetables are stored below 12°C, milk and other dairy products are kept just above the freezing point at 1°C, meat products are held just below the freezing point at -2°C, and ice cream is generally stored at –23°C. Temperatures must be regulated in each part of the cold storage unit and must remain within their set ranges. An efficient cold storage would also include an ante room to avoid direct infiltration of warm ambient air into the cold rooms. The ante room also serves as warm-up chambers for produce stored, so they do not get wet due to condensation on unloading for dispatch.

2. Minimise Heat Loss

After making sure that different temperature ranges are set in the cold storage unit, it becomes necessary to ensure that such fixed temperatures are maintained, and there is no heat loss. Minimizing heat loss is crucial not just to achieve more energy savings but also to avoid spoiling the contents of the cold storage. The transfer of heat must be carefully restricted to prevent its flow from high-temperature areas to lower-temperature zones. It is a complicated task in a cold storage warehouse as new products are regularly entering storage, and the warehouse may need to be routinely reconfigured. High-speed or rapid doors and strip doors are effective solutions to this problem. They contain refrigerated air with great efficiency and at the same time allow unhindered access to people and vehicles to all areas of the site. Insulated curtain strips prevent temperature loss as well as stop dirt and foreign materials from entering the cold rooms. Efficient cold storages have multiple dock points for loading and unloading to prevent delays and faster movement.

3. Ensure Employees' Safety

Providing employees with proper personal equipment is a necessary step that ensures their safety and smooth functioning of the cold storage unit. Providing them with insulated coats, pants, gloves, and other gear they require to stay warm is a cold storage management practice that has several positive effects and improves efficiency throughout the cold storage warehouse. Employees should also be trained to familiarize themselves with the cold working conditions, to minimize any health risks to them and also to make sure that they do not compromise the efficiency of the operations. For example, if employees are prone to holding doors open to let the room temperature air in to keep themselves a bit warmer, temperature protocols would be violated, and a lot of refrigerated air may be lost. So, the best practice is to ensure that employees in cold storage warehouses are trained well and can always find the appropriate gear for a cold storage zone. The following measures can be taken to ensure safety of cold storage:

Table 18: Safety norms for good management of cold storages

Provision for handling accidental leakage of Ammonia	• Ammonia sensors in cold chambers near ACU[1]s & machine room • Emergency ventilation for machine room • Masks, First aid kit and Instructions for handling emergencies
Fire protection	• Fire sensors in cold chambers & machine room. Dry & water-based firefighting systems Sprinklers for high pressure receivers
Emergency alarm system in common public areas	• To be provided with switches near all cold store doors and alarms located

4. Manage Energy Demand

Energy savings is a prominent consideration in cold storage simply because it is more expensive to cool air than to heat it. While appropriate building design and automation system selection can minimize energy consumption in a cold storage unit, managing demand can also lead to savings. Controlling energy costs during high-demand periods minimizes the impact of surge pricing and can bring down costs on a per-kilowatt-hour basis. However, the challenge is that consumption and costs are highest on high-temperature days when the thermal load is at its peak. The key is to employ advanced control algorithms and sensors that allow smart energy management. Cold areas are over-cooled during periods of low demand, such as overnight, creating a thermal buffer that minimizes cooling requirements during peak periods. Use of IoT will help in remote management of cold storages and other components, where monitoring and control of multiple complex parameters like gas concentration, temperature and humidity can be achieved through automation. The automation of components can help in reducing cooling losses.

5. Maintain Proper Records

The contents of a cold storage warehouse are susceptible to temperature changes. That's why one of the most vital cold storage practices isn't just keeping the products cold but also keeping an accurate record of the details of their temperatures. Technology plays a huge role in this. Temperature sensors are used to automatically keep track of temperature, trigger alarms, and identify potential lapses. The use of sophisticated databases allows this collected data to be linked with products at the load unit level via Radio Frequency Identification (RFID) tracking without scanning every carton and stock keeping unit. Keeping accurate and up-to-date temperature records for all products in a cold storage is one of the best practices in cold storage management.

BIS has various standards (such as IS 7192, IS 7730, IS 9304, IS 7252) which prescribe temperature, RH and in some cases gaseous concentrations for storage of fruits and vegetables. There is a need for stricter enforcement of these standards and protocols, possibly through certain legislations / policies. This will not only help in enhancing skills and awareness for handling temperature sensitive products but also improve food safety and curtail food loss across the country. A single repository can be developed where all the applicable standards are available.

6. Keep a contingency plan

Contingency planning is also a key factor in managing a cold storage unit. If a truck breaks down, a refrigeration unit stops working or in the case of a power outage, one must be ready to respond immediately. To ensure efficient cold storage management, all parties involved must cultivate a strong partnership and have an excellent working knowledge of the best practices for cold chain handling and transportation.

7. Enhance skills through capacity building and training for system operators, engineers, technicians consultants and policy makers to promote sustainable cold-chain

Extensive capacity building and training is critical for effective promotion and deployment of sustainable cold storages and associated energy efficient and climate friendly cooling technologies. Training and capacity building should include farmers, cold storage operators, design engineers, service technicians, consultants, and potential funding organizations. Training and capacity building should cover aspects such as economic impacts and benefits of cold storage, innovative business models, temperature requirement of the produce and monitoring, installation and maintenance/repair of refrigeration systems, energy efficient and safe operation, passive design, management, recycling of equipment and refrigerant. Skill enhancement programmes such as "Pradhan Mantri Kaushal Vikas Yojana" could also be used to develop these required skills. Industry leaders, associations (such as ISHRAE), practitioners, construction professionals and academicians could work together to develop relevant training programmes. The International Organization for Standardization (ISO) is preparing a guiding document 'Refrigerating systems and heat pumps — Competence of personnel' which could be referred for training and capacity building.

8. Thermal Insulation & Refrigeration System, Control and Safety Devises

The components of an insulation and refrigeration system should be certified in form of a technical data sheet by the manufacturer confirming the rating and performance as per prescribed standards. Further, site inspection at appropriate stages of construction / erection and commissioning may be undertaken by an inspection team constituted by competent authority for this purpose. Finally, the manufacturer/ refrigeration contracting agency must issue a certificate of satisfactory commissioning of the cooling system in conformance to the performance indicators as per prescribed standards.

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