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DECARBONIZATION
PLAYBOOK FOR COLD STORE

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CONTENTS

LIST OF FIGURE

LIST OF TABLES

LIST OF ABBREVIATIONS

APVAC	Atmospheric Pressure Vacuum Drying
BIS	Bureau of Indian Standards
CDSCO	Central Drug Standard Control Organization
CFCs	Chlorofluorocarbons
EV	Electric Vehicle
FIs	Financial Institutes
FPOs	Farmer’s Producer Organizations
FSSAI	Food Safety and Standards Authority of India
GHGs	Green House Gases
GWP	Global Warming Potential
HC	Hydrocarbons
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
IoT	Internet of Things
KPIs	Key Performance Indicators
kWh	Kilo Watt Hour
LED	Light Emitting Diode
NGOs	Non-Governmental Organization
ODP	Ozone Depletion Potential
PCM	Phase Change Materials
PUF	Polyurethane Foam (PUF)
RH	Relative Humidity
R&D	Research and Development
SHR-WH	Super Heat Recovery Water Heater
SOPs	Standard Operating Procedures
STL	Storage System for Low Temperature
TT-HE	Tube-Tube Heat Exchanger
VAMs	Vapor Absorption Chiller Machines
VCC	Vapor Compression Cooling
VFD	Variable Frequency Drive

Executive Summary

The Decarbonization Playbook for cold chain outlines a strategic framework for a transition to a low carbon operating ecosystem, reflecting on the commitment to environmental sustainability and responsible business practices. This playbook serves as a comprehensive guide to navigate the complexities of reducing our carbon footprint across various aspects of our operations such as energy consumption, supply chain, and transportation.

Recognizing the urgent need to address climate change, this playbook has been developed through a collaborative effort of members of CII Cold Chain Committee. The playbook encompasses a series of targeted initiatives and best practices tailored for the cold chain industry, with the overarching goal of significantly reducing greenhouse gas emissions, optimizing resource use, and enhancing overall environmental performance.

INTRODUCTION

Food and energy security have emerged as top priorities for India, with the government adopting sustainable measures to address these critical challenges. However, climate change has intensified concerns around food security, as erratic rainfall patterns disrupt agricultural cycles. One major issue exacerbating these challenges is the lack of an integrated cold chain network, which leads to substantial post-harvest losses between farms and markets. These losses are not only detrimental to food security but also contribute 8-10% of global greenhouse gas (GHG) emissions[1], adding to the environmental burden while driving up food prices.

To mitigate these issues, India must focus on expanding its cold chain infrastructure, both mobile and static. This expansion must prioritize energy efficiency and the use of environmentally friendly refrigerants to ensure sustainability. The country is already making strides towards sustainable cold chain development, with initiatives spearheaded by the National Centre of Cold Chain Development and significant support from national and sub-national governments for private sector involvement. These efforts are aimed at reducing food loss and enhancing food security for both rural and urban populations.

Despite these efforts, India's cold chain infrastructure still faces substantial gaps. According to a World Bank study, only 4% of the nation's fresh produce is currently covered by existing cold chains. This highlights the untapped potential within the sector, with an estimated market value of $29 billion by 2038 and the potential to create 1.7 million jobs[2]. However, the fragmented nature of the sector, limited upfront investments, and inadequate supporting infrastructure, such as roads and power supply, continue to hinder its growth.

There is an urgent need to address these barriers by enhancing the understanding of existing cold chain capacities, their energy consumption profiles, refrigerant usage, and the potential for transitioning to low global warming variants. Additionally, mapping food loss hotspots and improving logistics management will be key to building an efficient and sustainable cold chain system that aligns with the nation's food security and environmental goals.

1]UNEP Food Waste Index Report 2021
2]https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099920011222212474/p15743300f4cc10380b9f6051f8e7ed1147

The Decarbonization Playbook for the cold chain sector offers a roadmap for reducing the carbon footprint associated with the storage and transportation of temperature-sensitive goods. Developed through a collaborative effort of CII Cold Chain Committee, this playbook provides cold chain owners, startups, logistics players, and equipment manufacturers with actionable strategies to embrace decarbonization. In a world increasingly focused on low-carbon economies, adopting these strategies will drive innovation, reduce regulatory uncertainties, and enhance profitability and competitiveness.

Transitioning to a low-carbon cold chain is not only beneficial for the environment by reducing GHG emissions and preserving the ozone layer, but it also offers significant business advantages. By cutting waste, improving operational efficiency, and extending the shelf life of products, cold chain operators can realize cost savings and improved product quality while aligning with global sustainability goals. This playbook serves as an essential tool for stakeholders to support decarbonization across the cold chain sector and beyond.

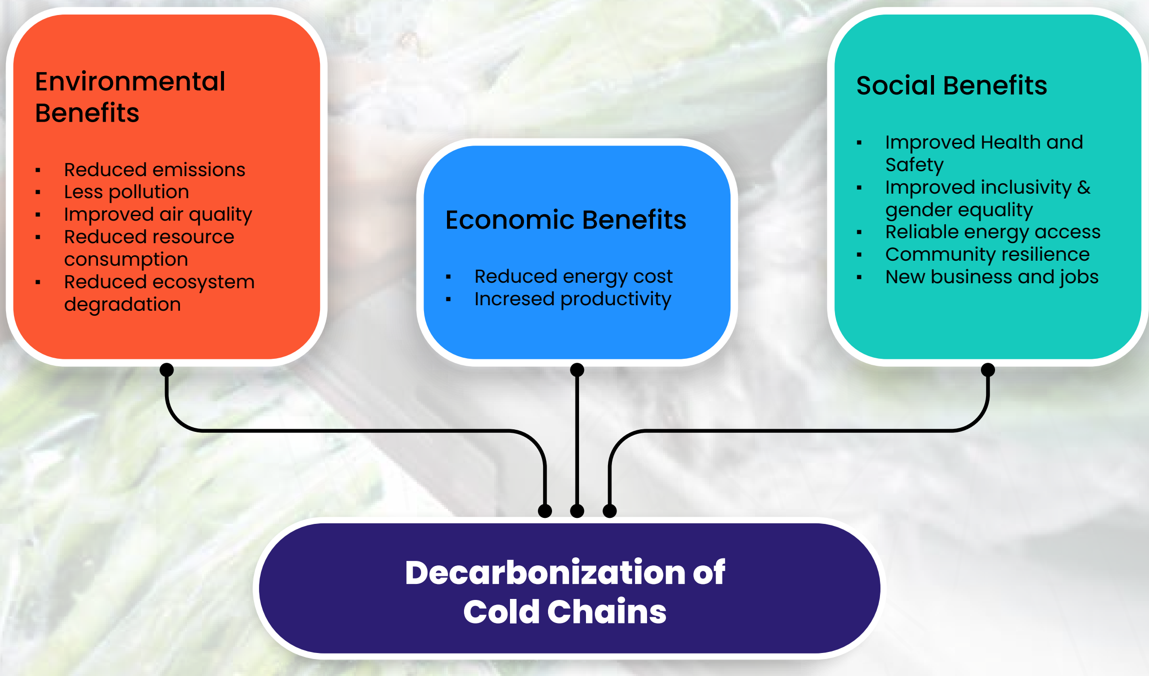
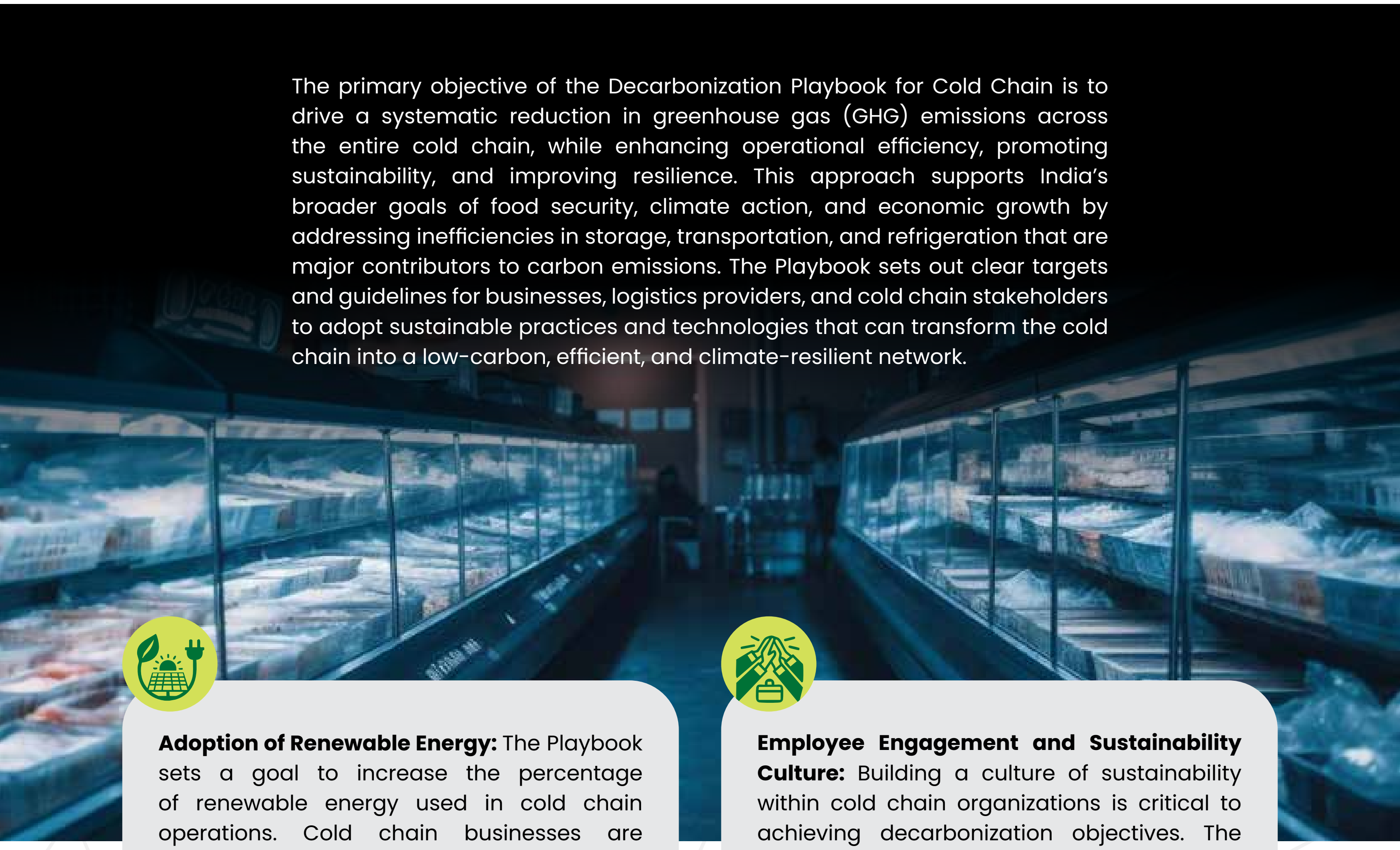


Figure 1 : Benefits of Decarbonization of Cold Chains

OBJECTIVES



The primary objective of the Decarbonization Playbook for Cold Chain is to drive a systematic reduction in greenhouse gas (GHG) emissions across the entire cold chain, while enhancing operational efficiency, promoting sustainability, and improving resilience. This approach supports India's broader goals of food security, climate action, and economic growth by addressing inefficiencies in storage, transportation, and refrigeration that are major contributors to carbon emissions. The Playbook sets out clear targets and guidelines for businesses, logistics providers, and cold chain stakeholders to adopt sustainable practices and technologies that can transform the cold chain into a low-carbon, efficient, and climate-resilient network.

Adoption of Renewable Energy: The Playbook sets a goal to increase the percentage of renewable energy used in cold chain operations. Cold chain businesses are encouraged to integrate solar, wind, and other renewable sources into their power supply, especially in regions with unreliable electricity grids. This shift towards renewable energy will reduce dependence on fossil fuels, lower operating costs, and enhance the resilience of cold chain infrastructure against future climate impacts.

Employee Engagement and Sustainability Culture: Building a culture of sustainability within cold chain organizations is critical to achieving decarbonization objectives. The Playbook emphasizes fostering employee engagement through targeted training and capacity-building initiatives. Employees play a vital role in driving sustainable practices, and their active participation is key to achieving lasting change.

Reduction in Refrigerant Impact: Refrigerants used in cold chain operations are often potent contributors to GHG emissions. The Playbook aims to promote the reduction through the transition to low global warming potential (GWP) alternatives. This involves promoting the adoption of advanced cooling technologies and phasing out high-GWP refrigerants in favour of eco-friendly alternatives. This transition will help preserve the ozone layer, reduce emissions, and contribute to a sustainable cold chain sector.

Carbon Footprint Reduction: The Playbook aims to achieve a significant reduction in the carbon footprint of cold chain operations by transitioning to low-carbon technologies. This includes adopting energy-efficient refrigeration units, optimizing logistics, and promoting sustainable transportation practices. By focusing on decarbonizing key stages of the cold chain, the Playbook seeks to align the sector with national climate goals and international commitments, including the Paris Agreement.

Energy Efficiency Enhancement: Improving energy efficiency is a key objective, targeting a gradual reduction in energy consumption across all cold chain operations. The Playbook promotes the integration of smart technologies such as energy management systems, digital monitoring tools, and the use of high-efficiency equipment. By optimizing energy use, cold chain operations can not only cut emissions but also reduce operating costs, improve profitability, and contribute to long-term sustainability.

Transport Emission Reduction: Transportation is a significant contributor to the cold chain's carbon footprint. The Playbook sets a target of reducing emissions from cold chain transportation by promoting improved logistics, the use of electric and hybrid vehicles, and optimizing routes. Better vehicle utilization, adoption of electric refrigerated trucks, and streamlining distribution networks will all contribute to minimizing emissions while maintaining the integrity of temperature-sensitive goods.

Use of Thermal Energy Storage (TES) System to Eliminate the Dependency on Diesel Generators: Cold storages in India are connected to diesel generators as power backup due to the lack of reliable grid electricity. This leads to increase in the operational expenses as well as carbon emission. The thermal energy storage is a cost-effective alternative to diesel generators. They store cooling when electricity is available and provide it when electricity is not available. They can be designed for even 4 to 10 hours of electricity available any time of day to operate cold storage without need of diesel generators. As cooling is stored in phase change material, the life of thermal storage is more than 20 plus years without any degradation in storage capacity. They are also environment friendly as no chemicals are involved.

Develop Circular Economy Practices: To achieve decarbonization in cold chain applications in India, the development of circular economy practices is essential. This involves creating a system where resources are reused, recycled, and repurposed to minimize waste and reduce carbon emissions throughout the cold chain process. This Playbook encourages implementing key strategies such as adopting sustainable packaging solutions that extend the shelf life of perishable goods, utilizing thermal energy storage systems to optimize temperature control without continuous refrigeration, and integrating advanced technologies like IoT for real-time monitoring of energy consumption and temperature management. Additionally, fostering partnerships between stakeholders—such as farmers, logistics providers, and technology developers—can facilitate knowledge sharing and innovation, leading to more efficient operations. By prioritizing these circular economy principles, India can enhance food security, reduce greenhouse gas emissions, and promote sustainable practices in its cold chain sector.

By achieving these objectives, we aim not only to mitigate the environmental impact of our operations but also to realize economic benefits, enhance brand reputation, and contribute to a more sustainable and resilient future. **This Decarbonization Playbook represents our roadmap for sustainable growth and responsible business practices**.

Current State Assessment

India's cold storage infrastructure is underdeveloped and heavily skewed towards the storage of a few crops, particularly potatoes, which account for over 60% of the country's cold storage capacity. India has approximately 37-40 million metric tons of cold storage capacity, but this is concentrated in a few states, with Uttar Pradesh, West Bengal, and Punjab accounting for over 70% of the total capacity[3] (Figure 2.). Despite the expansion of cold storage infrastructure, the sector remains fragmented, with outdated facilities that lack modern energy-efficient technologies. Additionally, a substantial portion of the infrastructure is located near production areas, making it difficult to maintain an effective cold chain that covers transportation and distribution across the country.

Number of Cold Storages in Major States of India

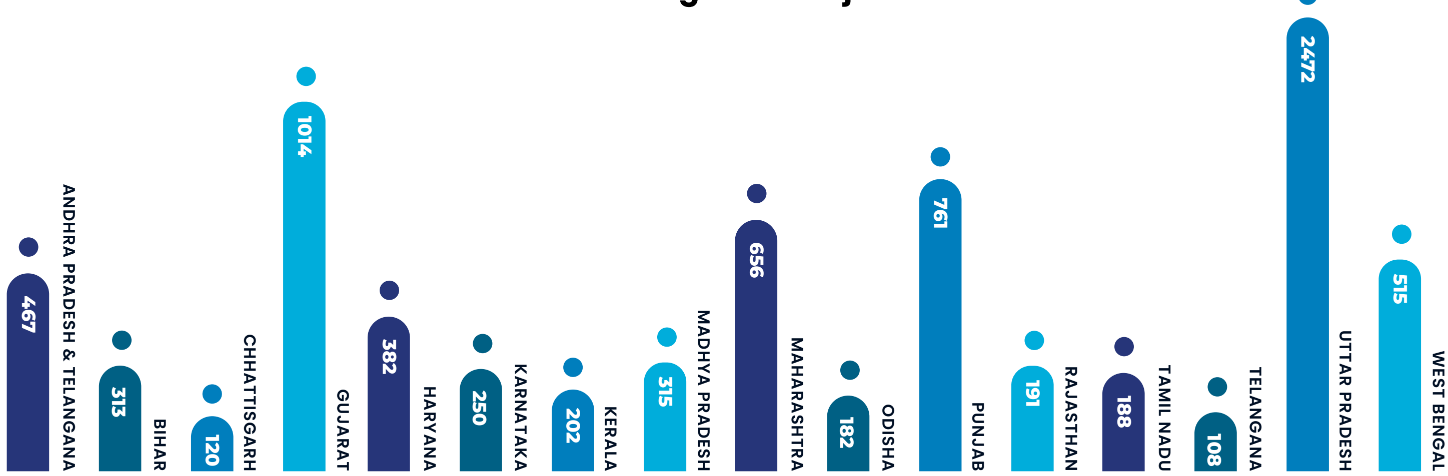


Figure 2 : State-wise number of cold storages in India,
Source: Lok Sabha Starred Question 12th December 2023

Many cold storage units in India are also energy-inefficient, relying on outdated cooling technologies that consume excessive power and use high-global warming potential (GWP) refrigerants. According to estimates, cold storage facilities consume an average of 25 kWh of power per square foot annually, with refrigeration accounting for over 70% of overall energy usage.[4,5]

Moreover, the cold storage sector suffers from uneven regional distribution, with southern and eastern parts of India having limited access to cold storage facilities **(refer Annexure A)**. This has led to significant post-harvest losses in perishables such as fruits, vegetables, fish, and dairy products. Inadequate cold chain coverage results in spoilage and reduced quality of perishable goods, with estimates suggesting that around 16-18% of fruits and vegetables are lost annually due to lack of proper cold storage infrastructure[6] .Storage temperatures also play a vital role in decreasing food loss, ideal storage temperature conditions to be maintained in cold storage facilities for different fresh products are depicted in **Annexure B**.

Carbon emission from cold stores depends on certain key factors including size of the facility, quantity of material stored, type of refrigeration system used, source of energy for power output and overall efficiency of the machines installed. To assess the current carbon emissions of a specific cold store, one would typically need to conduct a thorough carbon footprint analysis and an energy audit to understand and analyze the facility's operational data.

Carbon Footprint Analysis:
Conduct a detailed assessment of the cold store's current carbon emissions. Identify key sources of emissions with high global warming potential (GWP) including refrigeration systems, energy consumption, and transportation.

Energy Audit:
Assess the energy efficiency of existing systems and processes. Identify areas for improvement, such as insulation, lighting, and equipment efficiency, peak areas of refrigeration and possible measures to minimize power consumption.

Technology Assessment:
Technology assessment is crucial for decarbonizing the cold chain. By evaluating various technologies against criteria like GWP, ODP, energy efficiency, and cost, decision-makers can identify and prioritize solutions with lower environmental impact. This process helps select technologies that minimize greenhouse gas emissions, reduce refrigerant leaks, and optimize energy consumption, ultimately contributing to a more sustainable and environmentally friendly cold chain. A snapshot of existing technologies for cooling and their applicability across value chain is represented in **Annexure C.**

3] https://www.mofpi.gov.in/sites/default/files/OpportunitiesinColdChainSectorinIndia.pdf
4] https://nayaenergy.com/cold-storage-increasing-energy-efficiency/
5] https://www.nsspl.in/how-many-kilo-watts-are-needed-for-running-cold-storage/
6] https://www.clasp.ngo/wp-content/uploads/2023/06/Assessment-of-the-Cold-Chain-Market-in-India.pdf

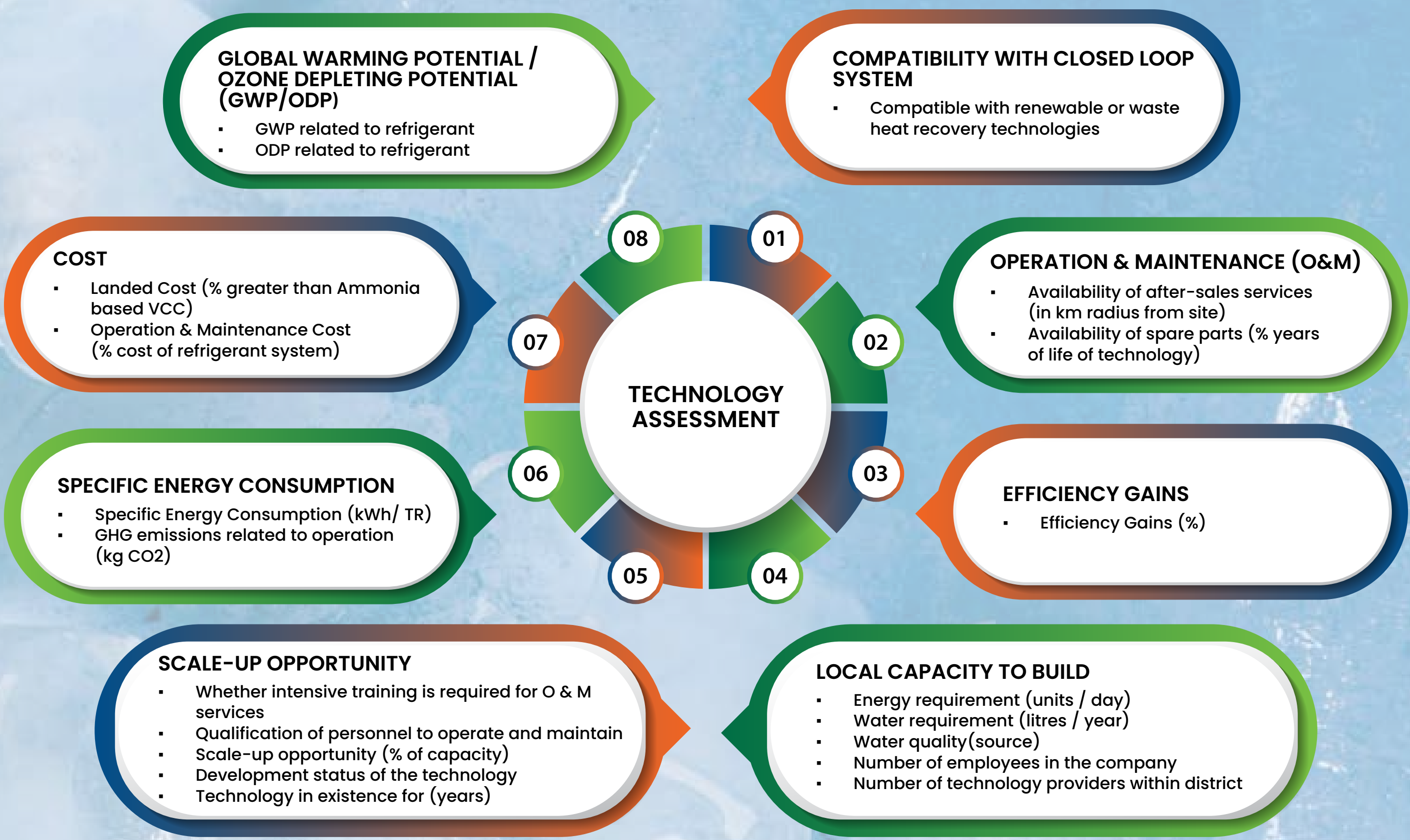


Figure 3 : Components of technology assessment for cold chain decarbonization

Decarbonization Strategies

Decarbonization strategies involve reducing or managing the carbon dioxide (CO_2) emissions associated with various processes in the cold chain. These strategies are critical for mitigating climate change and transitioning to a more sustainable and low-carbon future.

Upcoming and innovative technologies in cold chain 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 chain 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-chain 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.

Clean and energy-efficient technologies for cold-chain operations in India are available, but most are still in the initial stages of adoption. To maximize their effectiveness, these technologies need to be localized to align with region, culture, skills, and practices. The **Table 1.** below summarises several strategies for decarbonization that can be adopted

Table 1 : Decarbonization strategies for adoption

Name of Technology	Technology Description	Reduction in GHG/GWP/ ODP
FIRST MILE – FARM GATE		
Zero Energy Vegetable Storage using Evaporative Cooling	In rural areas of India, vegetarian food is often preserved in traditional pot–in-pot evaporative cooler made of clay. The inner pot provides the cooling space whereas the space between the inner & outer pot (annular) is filled with sand + water or only water. Due to heat transfer by convection & radiation from the surroundings the water from annular space evaporates from outside. This brings about cooling of the inner pot.	GHG GWP ODP
FIRST AND LAST MILE TRANSPORTATION		
Phase Change Materials (PCM) technology-based Chest Freezers/ Coolers	Phase change materials (PCM) based pouches are lined up on the evaporator coil of the inner shell assembly of deep freezers. The refrigerant flowing through the coil freezes the PCM present inside the pouch. This Innovative technology not only maintains the temperature of the food products during a power outage (for 12-14 hours) but also provides energy saving of 35% due to reducing the frequency of compressor cut-in and cut-off.	GHG GWP
PCM technology-based part load shipping solution	Part load temperature-controlled logistics solution consists of 3 main components: 1. Roto-moulded PUF 2. Insulated box 3. Advanced phase change material (PCM) and Recharging Station (high power freezer). The technology enables to maintain different temperatures as required by the product. It is most useful for part load consignments.	GHG GWP ODP
Electronic Level Controls	Ammonia Refrigeration Controls.	GHG
Refrigeration Drive	Variable Frequency Drive Solution for Refrigeration Systems.	GHG
Advanced Packaging Solutions	Advanced packaging solutions play a crucial role in decarbonizing cold chain applications in India by enhancing efficiency, reducing waste, and minimizing energy consumption. These solutions include technologies such as vacuum insulation panels, and PCM or gel packs, which help maintain optimal temperatures for perishable goods without relying heavily on energy-intensive refrigeration. Additionally, innovations in packaging design improve thermal performance and reduce heat transfer, ensuring that products remain within safe temperature ranges during transit. By optimizing packaging, companies can decrease their carbon footprint, lower operational costs, and enhance sustainability in the cold chain sector.	Reduce carbon footprint
PACKHOUSES/COLD STORAGE/BULK STORAGE		
Thermal Energy Storage System for low temperature (STL) applications	It is well adapted to air conditioning and industrial refrigeration systems. By smoothing the production of cooling energy, the STL optimizes the use of electrical resources and protects the environment.	GHG GWP
PCM technology based solar cold room	(PCM) filled heat exchanger plates are lined up on the inner side cold room wall. A condensing unit will run on solar power and will cater to the cooling requirement of 24 hours by charging the plates by running for just 4-5 hours when the sun is available. The PCM plates will work during non-sun hours to cater the cooling requirements of +2˚Cto +40˚C for 16- 20 hrs per day.	GHG

Name of Technology	Technology Description	Reduction in GHG/GWP/ ODP
Concentrated Solar Thermal	Various mirror-based technologies have been developed, which converts water into steam by using direct beam solar radiation. The steam then is used in VAMs to generate cooling.	GWP and GHG
Low ammonia charge 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, which, due to handling of smaller quantities and use of sensors to detect leaks, help in reducing the hazards of handling large volumes of ammonia.	R717 Zero ODP and very low GWP
Efficient Ammonia / CO2 brine system	CO2 is used in conjunction with ammonia as a cascade system, where larger quantities of ammonia cannot be used due to its toxic properties. Typically, ammonia is used for high stage compression and temperatures up to -100˚C are being maintained. Using cascade heat exchangers, low stage CO2 compressors are used for generating lower temperatures upto-400˚C. In some cases, it is also used as secondary coolant.	Proven qualities of Ammonia in reducing ODP and GWP. CO2 has GWP of 1 and no ODP
REEFER VEHICLES		
PCM technology-based reefer trucks	Phase Change Material (PCM) filled heat exchanger plates are used as cooling media in the reefer trucks involving full load consignments. These plates are charged during non-operational hours through grid powered- electric compressors mounted on the trucks.	GHG ODP GWP
Engine Exhaust Heat Recovery using Matrix Heat Recovery Unit	Using Engine exhaust (from moving and stationary systems) cooling can be generated, which in turn would eliminate need for a separate compression system in reefer vehicles.	GHG ODP GWP
PROCESSING APPLICATIONS		
PCM technology based 24x7 Solar Dryer	Phase change materials (PCM) integrated solar dryer offers an advantage of 24 x 7 consistent drying. PCMs are products/ chemicals which enable energy storage during sunshine hours in the form of latent heat. It allows storage of solar energy in PCM which gets harnessed during non-sunshine hours and providing consistent drying for 24 hours. The main objective of this technology is to productively utilize the abundantly available resource of sunlight and to enable uninterrupted supply of the products to market throughout the year.	GHG
Atmospheric Pressure Vacuum Drying (APVAC)	Preservation by drying using the APVAC process the vacuum is the very low partial pressure of the water vapour in the air after it is dehydrated to a dew point below zero degree Celsius. This air absorbs only water vapour from any moist material without heat or real vacuum, leaving other properties intact.	GHG ODP GWP
MULTISECTOR APPLICATIONS		
Super Heat Recovery Water Heater	Super Heat Recovery Water Heater (SHR-WH), using Vented Double Wall Tube-Tube Heat Exchangers, (TT-HE).	GHG GWP
Polyurethane System Insulation	With lower lambda and high fire resistance for Cold-chain insulation (Hydrocarbon as Blowing agent).	GHG GWP

Name of Technology	Technology Description	Reduction in GHG/GWP/ ODP
IoT Based Controls	These are new generation controls, which offer remote sensing and monitoring mechanisms for ensuring desired temperatures and %RH are maintained in every leg of cold chain. In conjunction with PCMs and other new technologies, it can help in maintaining and controlling required parameters.	GHG
Energy-Efficient Insulation Materials	Utilizing advanced insulation materials with higher thermal resistance to reduce heat transfer and therefore minimize emissions. Energy efficient materials such as puff panels, polyurethane, fiber glass ensure minimum temperature fluctuations, decrease energy requirements for cooling, and improve overall efficiency. Phase change materials (PCMs) play a crucial role in maintaining the integrity of the cold chain, where temperature control is paramount. The have a reversible mechanism of storing heat in cold stores and they release/ absorb energy at phase transition to provide useful heat or cooling. PCMs are chosen to match the required temperature of stored products. By stabilizing temperatures, PCMs help reduce energy consumption in refrigeration systems.	GHG GWP
CO_2-based heat pumps	Utilizing CO_2 as a refrigerant offers advantages over traditional refrigerants as it exhibits superior thermodynamic properties compared to conventional refrigerants. This translates to significant energy savings, particularly at higher operating temperatures relevant to industrial hot water or steam production along with refrigeration/air conditioning.	GHG GWP
LED Lighting	Replacing traditional lighting systems with energy-efficient LED lights helps in reducing energy consumption, lowers heat generation which does not impact product quality and shelf life, and has a longer durability compared to conventional lighting.	GHG
	Transport	
Electric Vehicles/ trucks	Replacing the traditional methods of transport will help in reducing the consumption of petroleum products, which results in reduction of pollution from vehicles, especially diesel vehicles.	GHG
Hydrogen Trucks		GHG
Multimodal transport (truck and rail)	Rail is more energy-efficient than trucks, especially for long distances, while trucks are essential for last-mile delivery. Combining both modes optimizes transport, minimizing emissions and ensuring efficient cold chain logistics.	GHG
Blockchain Technology	Blockchain technology can aid in the decarbonization of cold chain applications in India by enhancing transparency, traceability, and efficiency across the supply chain. It provides a decentralized ledger that allows stakeholders to access real-time data on the handling and storage of perishable goods, ensuring optimal conditions and reducing spoilage. Additionally, blockchain facilitates tracking carbon emissions at each stage, helping companies identify improvement areas to lower their carbon footprint. Smart contracts can automate compliance with sustainability standards, promoting environmentally friendly practices. Overall, blockchain integration fosters accountability and drives innovation towards sustainable practices, supporting national decarbonization efforts.	Helps in tracking of carbon emissions

Refrigerants

The refrigerant chosen for a particular application has a large effect on the efficiency of the refrigeration system **(Table 2)**.
Various criteria for selection of refrigerants are:

- The refrigerant evaporates at or above atmospheric pressure for any application.
- It operates preferably at positive pressures in all parts of the system.
- It has a low molecular weight and high critical temperature to minimize mass flow and pressure drop.
- Low specific volume is preferred, to minimize the size of compressor and piping.
- High latent heat and low mass flow are desirable for higher efficiency.
- High thermal conductivity gives high heat transfer coefficients.
- Low Global Warming Potential (GWP) and Ozone Depleting Potential (ODP)

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

- **Halogenated refrigerants:** Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs)

- **Natural refrigerants:** CO_2, ammonia, water, air, and hydrocarbons such as propane, isobutane, and propene

Table 2 : Types of Refrigerants

Type	Examples	ODP	GWP	Uses	Other Issues
CFC	R12 R502 R11	High	High	Widely used in most applications until 1990.	Now phased out of production.
HCFC	R22 R409A R411B	Low	High	Widely used in many applications. Not recommended for use after 1999.	To be phased out of production in 2015. Their use is also regulated increasingly strictly.
Ammonia	R717	Zero	Very Low	Used in Industrial systems since the birth of refrigeration.	Toxic and flammable react with copper.
HFC	R134a R404A R407C R410C R507	Zero	High	Started to be used in place of CFCs from about 1990.	Different compressor oil needed performance of some HFCs not as good as CFCs. Some reliability problems.
HC e.g. Propane, Isobutane Iso-pentane	R600a R290 Care 30 Care 50 R1270	Zero	Very low	R290 used in some industrial systems for decades. R600a now used in domestic systems. Care 30 and Care 50 now used in some commercial systems.	Flammable, but are effective refrigerants requiring minimal adjustments to existing CFC/ HCFC system.
CO2		Zero	Very Low	Widely used before the 1950s but superseded by halocarbons. Now being rediscovered as a primary and secondary refrigerant.	Not yet widespread commercial use as a primary refrigerant, but an interesting prospect. (High operating pressures required special materials and construction).

Operational Changes

Operational changes in cold chain are crucial to improving cold chain efficiency, reducing costs, and ensuring the quality and safety of temperature-sensitive products. It involves steps towards streamlining cold chain operations to ensure that products reach consumers in optimal condition, preserving their quality and shelf life. Operational changes can be further broken into:

Cold Store Management: This includes implementing smart cold storage systems for better management of atmospheric conditions including temperature, relative humidity, carbon dioxide emissions as well as application of chemical inhibitors which prevent growth of microorganisms. In addition to this, commodity specific protocols as a SOP based on real time demand would create a strong standard operating management system in cold chain operations.

Waste Reduction and Reuse: Enhance inventory management practices to reduce food spoilage and waste, which indirectly contributes to emissions. Better forecasting, inventory rotation, and real-time monitoring can help avoid unnecessary waste. Adopt circular economy practices by recycling packaging materials, reusing cooling agents, and repurposing or donating surplus goods to minimize the environmental footprint

Employee Engagement: Fostering employee engagement is a crucial strategy towards creating an awareness of the standard processes within the cold store unit. To inculcate a culture of sustainability and building skills sets within the ecosystem, there should be regular awareness programs covering safety procedures, cold chain regulations, equipment operation, and customer service to educate employees on energy saving practices.

Increase Awareness and Training: Conduct training programs for stakeholders in the cold chain sector on sustainable practices and technologies. Raise consumer awareness about the importance of sustainability in food preservation and distribution.

Monitoring and Reporting

Monitoring and reporting Key Performance Indicators (KPIs) for carbon emission management is crucial for assessing the effectiveness of sustainability initiatives and tracking progress towards environmental goals.

The KPIs for measuring overall impact of decarbonization includes:

Carbon Footprint: Measuring and reporting overall carbon footprint in kg or Tonnes of carbon dioxide equivalent (CO2e).

Water Use Efficiency: Tracking water use efficiency via deploying water conservation methods such as rainwater harvesting which can contribute to environmental sustainability.

GHG Emission Intensity: Calculating the emissions intensity per unit output, revenue, or another relevant metric. For example: Dividing total metric of an operation such as quantity of products stored (in Kg/Tonne), or the number of full-time employees associated with it.

Investing in Carbon Reduction Targets: Track and report on investments made in projects aimed at reducing carbon emissions, carbon offset projects to compensate unavoidable emissions. Post this, set specific measurable targets and regularly report on the progress towards achieving the targets.

Energy Consumption: Monitor and report total energy consumption, including electricity, natural gas, and other energy sources. Break down energy use by source and identify areas for improvement.

Regular monitoring and reporting of the KPIs would provide the cold store units with actionable insights into their carbon reduction efforts and enable more informed decision-making for stakeholders.

Stakeholder Collaboration

Stakeholder collaboration is essential in the cold chain industry to ensure the efficient and effective transportation and storage of temperature-sensitive products. This is needed to stay updated on evolving regulations related to cold storage and refrigeration and ensure compliance with relevant environmental standards. A close collaboration between supplier, cold store unit, logistics and transport providers, technology providers and organizations focused on environment sustainability would contribute to a collective problem solving and proactive response to problem solving.

Stakeholders Engagements

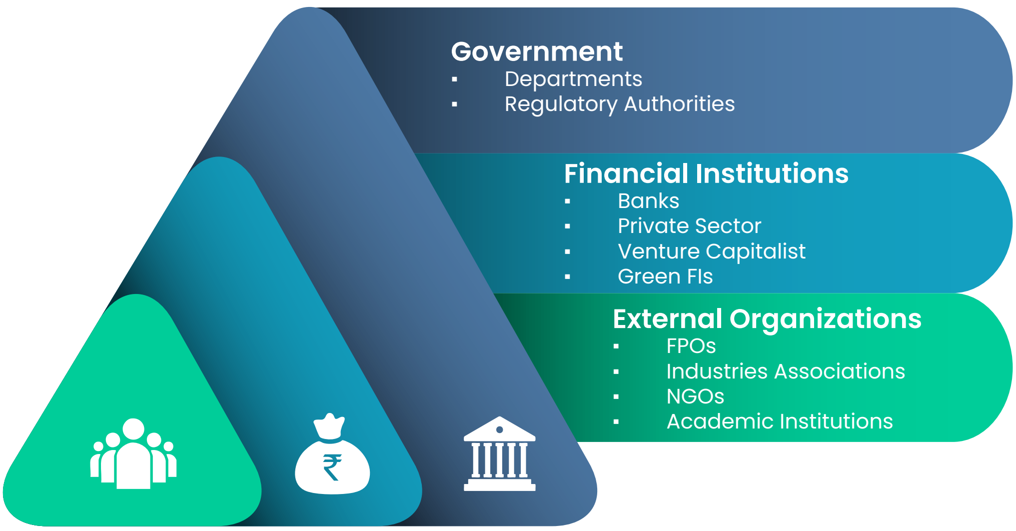


Figure 4 : Key stakeholders involved in cold chain decarbonization.

Compliance

The absence of a comprehensive regulatory framework for the cold chain industry in India limits the growth and development of the sector. Logistics companies operating in the cold chain industry in India need to adhere to the regulations and guidelines set by the government and the industry. They need to ensure compliance with these regulations to maintain the integrity and safety of the products being stored. The lack of standards and guidelines for cold storage facilities and transportation leads to a lack of quality and efficiency in the industry. Regulatory authorities such as FSSAI, CDSCO, and BIS enforce standards related to food safety, pharmaceutical distribution, and product quality which must be strictly adhered to.

Budget and Financing

Developing a budget for implementing decarbonization is an important aspect of the strategy. It is important to conduct a thorough cost-benefit analysis to understand the return on investment and potential long-term savings from decarbonization measures. Additionally, we need to explore available government incentives, grants, and financing options to support the transition to a more sustainable and decarbonized cold chain.

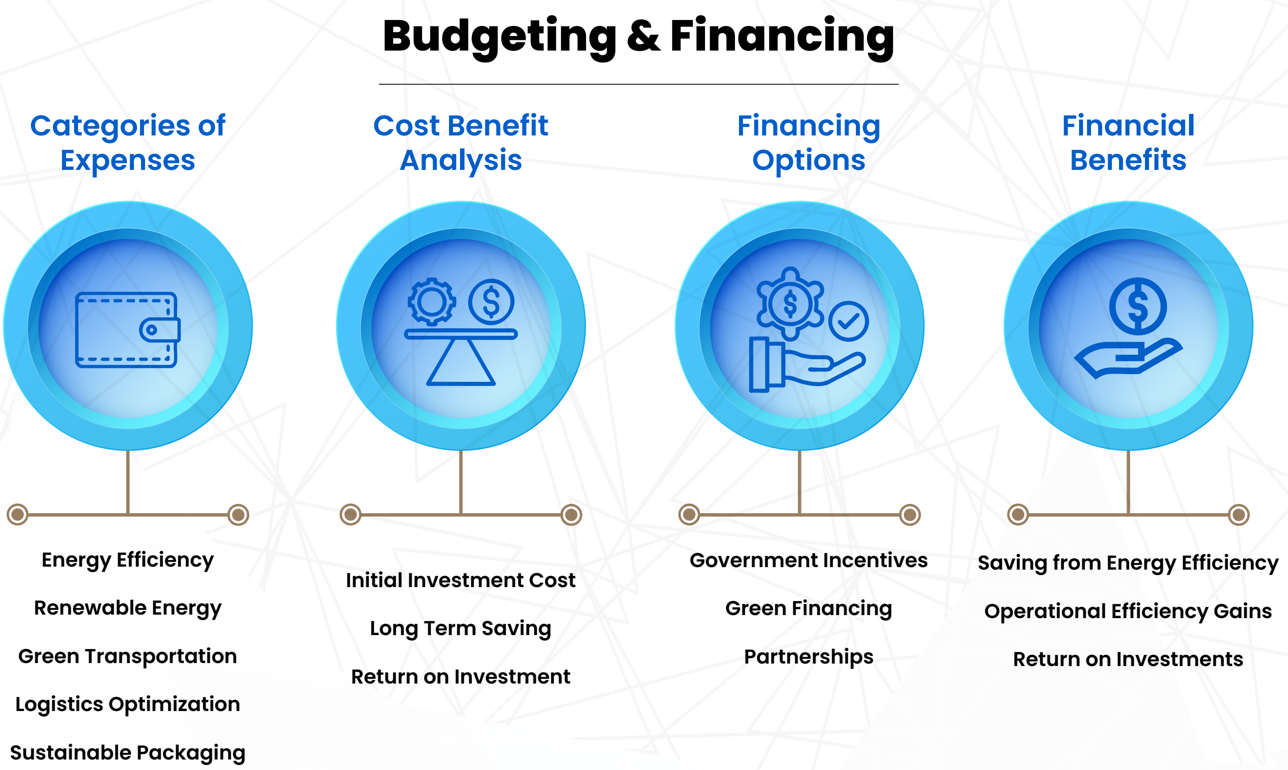


Figure 5 : Components of budgeting and financing for cold chain decarbonization.

The different kinds of expenses associated with the decarbonization strategy include installation of energy efficient refrigeration, costs with installation of solar panels, wind turbines for energy integration as well as advanced insulation materials such as puff panels which offer better cooling retention. Additionally, the costs include installation of route optimization software, upgradation to electric & hybrid vehicles for transportation and investing in packaging designs that enhance thermal insulation.

Access to modern environmentally friendly technology is usually cost-intensive to the stakeholders. Green financing can mitigate the high cost of technology in cold chain. Green financing is financial inflows from banks, micro-credit organizations, not for profit organizations for supporting the stakeholders in technology adoption. One needs to ensure financial benefits via multistakeholder partnership and increase investment in clean and green technology.

Table 3 : Expenses and financial options for decarbonization

Category	Description	Cost Considerations	Financing Options
Energy-Efficient Refrigeration	Upgrade to energy-efficient refrigeration units	High upfront costs; long-term savings	Green loans, subsidies, government grants
Renewable Energy Integration	Solar panels, wind turbines for energy	Installation costs, maintenance	Green bonds, renewable energy grants
Advanced Insulation Materials	Puff panels for better cooling retention	Medium to high installation costs	Energy efficiency incentives
Green Transportation	Electric and hybrid vehicle upgrades	Vehicle procurement, charging infrastructure	EV financing schemes, bank loans
Logistics Optimization	Route optimization software	Software development and integration	Private investment, tech subsidies
Sustainable Packaging	Thermal insulation-enhancing packaging designs	R&D and production costs	Partnership with packaging manufacturers

Conclusion

Implementing a Decarbonization Playbook for cold stores is a strategic and impactful approach towards reducing carbon emissions in the cold chain industry. By adopting sustainable practices and leveraging innovative technologies, cold storage facilities can contribute to environmental stewardship while potentially reaping long-term operational benefits.

This Decarbonization Playbook serves as a roadmap for transitioning towards a more sustainable, energy-efficient, and environmentally responsible operation. By embracing strategies of this comprehensive decarbonization playbook, cold storage facilities can not only reduce their carbon footprint but also play a pivotal role in creating a more sustainable and environmentally friendly ecosystem. Adopting the strategies would not only help in mitigating impacts of climate change but also support in positioning the cold chain business for long-term resilience and competitiveness in a rapidly evolving global marketplace. The implementation of the playbook requires collaboration across stakeholders, ongoing commitment, and a forward-thinking approach to shape a greener future for the cold chain industry.

Annexure A

S. No.	Name of state	No. of Cold Storages	Capacity of Cold Storages (in MT)
1	Andaman & Nicobar Islands (UT)	4	2210
2	Andhra Pradesh & Telangana	467	1893071
3	Arunachal Pradesh	2	6000
4	Assam	45	216388
5	Bihar	313	1476557
6	Chandigarh (UT)	7	12462
7	Chhattisgarh	120	553832
8	Delhi	97	129857
9	Goa	29	7705
10	Gujarat	1014	3974593
11	Haryana	382	867884
12	Himachal Pradesh	89	174072
13	Jammu & Kashmir	89	341515
14	Jharkhand	60	248629
15	Karnataka	250	838940
16	Kerala	202	96655
17	Lakshadweep	1	15
18	Madhya Pradesh	315	1364003
19	Maharashtra	656	1176499
20	Manipur	2	4500
21	Meghalaya	4	8200
22	Mizoram	3	4071
23	Nagaland	5	8150
24	Odissa	182	579321
25	Puducherry	4	185
26	Punjab	761	2588686
27	Rajasthan	191	652879
28	Sikkim	2	2100
29	Tamil Nadu	188	399690
30	Telangana	108	541397
31	Tripura	14	46354
32	Uttar Pradesh	2472	15045874
33	Uttarakhand	60	206621
34	West Bengal	515	5948316

Annexure B

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

Annexure C

Existing Cooling Technologies in Cold Chain

Cooling technology	Energy Source	Temperature Range	Refrigerant Use	Energy Consumption	Applicability to Products
Vapor Compression Cycle	Electric	Full temperature range, including freezing	Halogenated or natural refrigerants	High	All
Evaporative Cooling	Thermal (Passive)	Temperatures above 10˚C	Water	Low	Chilling-sensitive fruits and vegetables
Sorption Cooling	Thermal	Full temperature range, including freezing	Natural refrigerants	Low	All
Ice Production	Electric or Thermal	Temperatures above 0˚C	Halogenated or natural refrigerants	Low	Non-chilling sensitive produce only, fish and meat

Non-mechanical technologies available for cooling at small and large scale

Cold Chain Steps	Small Scale	Large Scale
Pre-cooling systems	Portable evaporative forced air-cooling systems	Slurry ice
Cold Storage	• Zero energy cool chambers (ZECC) • Evaporative cooled cool rooms (charcoal coolers) • Underground storage (root cellars) • Night air ventilation • High altitude storage • Radiant cooling • Solar chillers	• Evaporative cooled warehouses • Underground storage (caves) • High altitude storage • Radiant cooling
Processing – chilling and freezing	Non-available	Non-Available
Refrigerated transport	Evaporative cooled insulated transport boxes or trailers	Passive cooling (insulated pallet covers)

Applicability of cooling technologies across value chains

Cooling Technology	Fresh fruits & Vegetables	Dairy	Fish	Meat
Vapor Compression Cycle	Medium	High	Medium	Medium
Evaporative Cooling	Medium	Low	Low	Low
Sorption Cooling	Medium	High	High	High
Ice Production	Low	Medium	High	High

- High
- Medium
- Low

Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering Industry, Government and civil society, through advisory and consultative processes.

For more than 125 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. CII charts change by working closely with Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialized services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

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With 70 offices, including 12 Centres of Excellence, in India, and 8 overseas offices in Australia, Egypt, Germany, Indonesia, Singapore, UAE, UK, and USA, as well as institutional partnerships with about 300 counterpart organizations in almost 100 countries, CII serves as a reference point for Indian industry and the international business community.

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Food and Agriculture Centre of Excellence

FACE is CII's Centre of Excellence dedicated to building efficiencies across the agricultural value chain from farm to fork. FACE is charged with the mission of improving competitiveness of India' agriculture and food sector by catalyzing innovation, building capacity and enhancing productivity across the value chain. FACE works with farmers, companies, development institutions and the government to

- Improve on and off-farm productivity through the dissemination of best practices and technological innovation
- Invest in capacity building initiatives and skill development for supply chain participants across the value chain
- Strengthen linkages across the value chain through market access initiatives, thereby reducing losses and increasing farmer incomes

FACE's service portfolio comprises commodity specific value chain assessments and supply chain advisory services for food and agri businesses, training and consulting services in the area of food safety, and sectoral research across different market segments. FACE also works on projects in PPP mode, to develop business models that are scalable and replicable across geographies.

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