

Literature Review on Social Opportunities for the Solar Cold Chain System in India-An Exploratory Study

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Literature Review on Social Opportunities for the Solar Cold Chain System in India-An Exploratory Study

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ABSTRACT

India is amongst the prime producers of nutritious horticultural produce, spices, poultry, fruits, dairy, vegetables, fish and meat in the world. Cold chain system provides care and protection to the products in transit from the source to end user with standardised storage, distribution and inventory facilities. The operation of the cold chain system is limited to the temperature sensitivity of the perishable, bio medical, pharmaceutical and chemical products. The Cold Chain Management is based on the Product Life of the fresh and processed food products. Cold chain system is integrated through static and mobile infrastructure, service standards and protocol and skilled resources. The cold storage is used to preserve both fresh and processed food items. Cold chain increases the holding life of the produce and increase opportunities to the producers to reach more customers in the market. This paper addresses the knowledge gap based on the review of literature on the areas connected to cold supply chain to suggest opportunities for the inception of solar cold chain system in India.

Keywords: Cold chain system, Temperature sensitivity, Fresh and processed food, Holding life of product. Solar Cold Chain.

1. INTRODUCTION :

It is a cold logistic chain to provide care for the products from the source of production to the end user through undertaking storage, distribution and inventory activities without altering the features of the product under custody. India is one of the predominant producers of fruits, vegetables, meat, poultry etc. The country is ranked first in the production of Milk (165.4 Million Metric Tonnes per annum), second in the production of fruits and vegetables (277 million metric tonnes), fish (11.4 million metric tonnes) and meat (7.4 million metric tonnes) per annum respectively. Cold Chain System shall preserve and protect temperature sensitive products such as fruits, vegetables, meat, fish, ice cream, dairy products, chemicals, health care, etc which are highly perishable. It also carries temperature controlled supply chain to preserve and protect the properties of the bio medical, pharmaceutical products and chemical products. Even though India had 6300 cold storages functioning with the capacity of 30.11 million tons it was estimated that food wastage can be minimized only if the storage space is doubled to 61.13 million tons [1]. The Cold Chain Management System is a broader concept with multifaceted aspects connected to cold chain system such as pack house, refrigerated transport, storage, pre-cooling unit, sorting, grading, cold room, bulk cold storage, distribution hubs, reefer vehicles, reefer containers, ripening units, controlled atmosphere technology, retail shelf etc. Both fresh produce of nature such as fruits, vegetables, poultry, fish, egg, etc and processed products manufactured by altering its natural attributes such as pickles, flakes, canned vegetables, pulp, juices, etc are also preserved through cold storage system.

(a) Cold Supply Chain: The cold supply chain is designed for both fresh and processed products based on its holding life. Fresh food produce are natural products such as fresh fruits, milk, egg, fish, vegetables etc. harvested from the farm without altering its natural characteristics. The cold chain flow (Table-01).

Table-01: Cold Supply Chain of Fresh Horticulture Products

Stage	Function	Cold Chain Infrastructure
Preparatory Cycle	Cleaning, Sorting, Grading, Trimming, De-sapping, Fumigation, Washing, Waxing, Pre-Cooling, Pre-Conditioning, Grading, Packing, Cooling, Dispatch	Pre-cooling Units, Cold Room, Pack House, Cold Storage (Bulk & Hub)
Transport Cycle	Climate Controlled Cooling,	Reefer Vehicles and Containers
Storage Cycle	Cold Storage	Controlled Atmosphere Cold Storage, Distribution Hubs, Cargo Centres.
Distribution Cycle	Refrigerated Local Delivery	Refrigerated Transport Vehicles
Shelf Cycle	Merchandising and Retail	Front end Merchandising, Ripening Units, Retail Shelf/Cabinet, Insulated and Refrigerated Chambers

Processed Products are the food products manufactured through transformational processes to alter the natural, physical and chemical attributes making a new product such as pickles, ketchup, juices, pulp, chocolates etc. The Cold Chain flow (Table-02).

Table-02: Cold Supply Chain of Processed Food Products

Stage	Function	Cold Chain Infrastructure
Procurement	Procurement of Raw Materials essential for Production.	Farm Gate
Transportation	Short distance transportation from the procurement place to factory.	Vehicles and Containers
Production	Transformational Process-mincing, emulsification, cooking, dicing, pickling, preservation, canning, freezing, grinding, Packing	Industrial Plant, Equipment and Machinery
Storage and Distribution	Storage and Distribution	Refrigerated or Non Refrigerated Long Haul, IQF, Blast Freezers.
Sale	Retailing and wholesale distribution	Retail Shelf/Cabinet, Insulated and Refrigerated Chambers

(b) Product Life Span: Total life span of a product within which such product could be saleable. For fresh produces, it starts at harvest until it perishes and for processed food, from the stage of manufacturing to the date of expiry. Holding life [2] is the total time spent by a product in surpassing stages of preparation, transport, storage and front-end shelf (Figure-01).

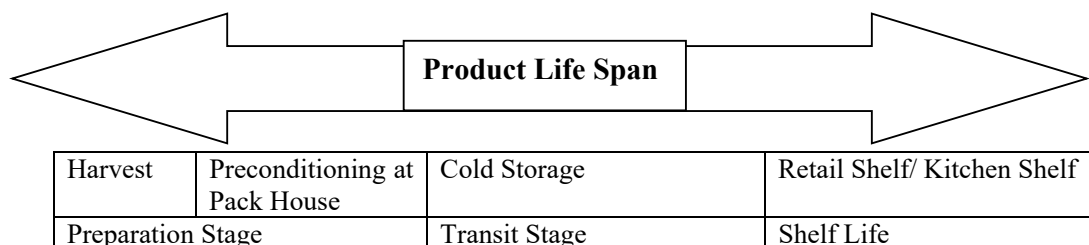


Figure-01: Product Life Span

Holding life comprises both long and short term holding. Long holding is for 3 to 10 months or longer for supplying products such as apple, pear, orange, kiwi, carrot, cabbage, potato, onion, dry chillies, frozen products, etc for the lean period or non-production period. Short holding maintains stock of products such as mango, litchi, pineapple, peach, plum, grape, banana, strawberry, tomato, brinjal, cauliflower and green leafy vegetables having short product life of 1- 4 weeks. The handling capacity of a storage unit for bulk storage is equal to the storage space but for storage hubs, pack houses, transport, etc it is the aggregate of storage space and weekly/monthly product cycle.

(c)Cold Chain Management: The cold chain handles horticulture products (fruits and vegetables), floriculture products (flowers), dairy products (milk, butter, ice creams), meat, fish, poultry, processed food products, pharma products and chemical products. The cold chain preserves products within the most suitable temperature throughout the supply chain through temperature tracking, container selection, ability of the transport provider, temperature-controlled transportation, distribution of route and contingency plans. Standard storage temperature [3] (Table 03).

Table-03: Standard Storage Temperature

Product Type	Product Category	Storage Temperature
Fresh Fruits and Vegetables, dairy products and dry fruits	Apple, Pears, Oranges, Potato, Carrot, Cauliflower Milk, Butter, Egg, dry fruits, nuts, dry chillies, etc.	Chill (0- 10 degree Celsius)
Sub-Tropical Fruits and Dairy Products	Mango, banana, papaya, milk power, chocolate, seeds etc.	Mid Chill (10-20 degree Celsius)
Frozen Food items	Frozen vegetables, fruit pulp, pineapple slices, etc, ice cream butter, fish and meat products.	Frozen (Below minus 18 degree Celsius)
Processed Food	Whole onion, dehydrated foods, roasted foods, sun dried products, pickle, jam, jellies, ready to eat food items, oil, etc.	Normal (More than 20 degree Celsius)

The consistent effort by the government in modernizing the supply chain segment and initiating Public Private Partnership is seen to be meritorious in building a proactive supply chain system in the country [4]. The government has developed a glossary of Standard terms and encourage 100 per cent foreign direct investment in the cold chain market. Since 2011-12 onwards the Cold Chain is included under the Infrastructure Sector. National Centre for Cold Chain Development (NCCD) initiated Infrastructure Development Project consisting 135 Cold Chain Project and 40 Mega Food Parks. Central Government has sanctioned a grant of Rs. 7000 Crores for the subsidies, tax benefits and technical training in connection with cold chain management. Ministry of Food Processing Industries (MoFPI) [5] provides grant in aid for storage infrastructure with 35 per cent of project cost in general areas and 50 per cent for different areas respectively. It provides processing infrastructure by granting 50 per cent of cost of the plant and machinery and 75 per cent for different areas subjected to Rs. 10 crore. It also provides financial assistance of 50 per cent of project cost with a limit of Rs. 50 crore in general areas and 75 per cent with a limit of Rs. 50 crore for mega food parks. National Horticulture Board (NHB) provides cold storage units having capacity within 10,000 MT with 40 per cent of cost of the project with a limit to 30 lakhs for general area and 50 per cent with a limit to 37.50 lakhs per project in the hilly areas. Small Farmers Agri-business Consortium (SFAC) through its Integrated Scheme for Agricultural Marketing (ISAM) provides 75 per cent of financial outlay with subsidy of 25 per cent of capital cost up to 2.25 crores in general areas and 33 per cent up to 4 crores for the scheduled areas. National Mission on Food Processing (NMFP) provides financial assistance of Rs. 5 crore per project and interest subsidy of 6 per cent subject to 2 crores for the cold chain projects. It also provides 50 per cent of project cost up to 2.50 crores to the processing centres along with a grant in aid of Rs. 50 lakhs for the reefer vehicles. Agricultural and Processed Food Products Export Development Authority (APEDA) provides assistance of 25 per cent of project cost to private companies for

infrastructure development. NABARD provides low interest loan out of its food processing and infrastructure fund to construct warehouses for agricultural produce.

2. RESEARCH METHODOLOGY :

This study is both descriptive and analytical by nature. The scope of this paper is limited to identify the impact of existing cold chain system to find out the existing scope for exploring socially responsible and ecological sustainable cold chain system in India. This paper also aims to derive the following objectives

1. To understand the fundamentals of product life span, Cold Chain System and its management.
2. To review on the aspects of safety, standards of existing cold chain system.
3. To identify the demand for multi product cold chain system.
4. To understand the effectiveness of cold chain system towards the preservation and protection of fresh and processed food products.
5. To explore the measures and steps adopted upon the temperature sensitive goods in the existing cold chain systems
6. To find out the existing research gap from the available literature to derive the scope for establishing eco-friendly or Sustainable Cold Chain System based on renewable sources of energy especially solar energy.

3. ANALYSIS ON REVIEW OF LITERATURE :

The paper analyzes research articles published on cold chain system during 2006 to 2020. This study describes about the conventional cold chain system in the light of both primary and secondary sources of data. The study identifies the research gap existing in the literature to establish opportunities for the inception of Solar Cold Chain System in India. The analysis over the literature (Table-04, 05 & 06).

Table-04: Cold Storage Capacity in India

Sl. No	Author/ Agency	Month/Year	Observation/ Findings
01	National Stock Exchange Limited (NSE)	December, 2010	Based on the Production of Fruits and Vegetables in the peak season and the highest delivery in a month to the market it is estimated that India requires the Cold Storage Capacity of 36.83 million MT more over and above the existing 24.29 million MT.
02	The Emerson Climate Technologies	2013	Almost 6,300 Cold Storages with 30.11 million tons were functioning in the country.
03	National Horticulture Board (NHB)	December, 2014	Cold Storage Space gap is estimated to 8.25 million tons and suggested to upgrade and modernise the non functional cold stores.
04	National Centre for Cold-Chain Development (NCCD)	2015	To meet consumption volume India require cold storage (Bulk) of 34164411 metric tonnes to hold fresh produce, Cold Storage (Hub) of 936251 MT with segregated Temperature Ranges consisting 616896 MT of Chilled products such as apple, grape, orange, kiwi, etc, 241353 MT of mild chilled category for mango, banana, papaya, etc and 78002 MT of frozen goods like ice cream, meat, etc respectively.
05	The Associated Chambers of Commerce and Industry of India (ASSOCHAM) [6]	2012	Cold chain industry in 2012 having the capacity of 30.11 million tonnes but it requires to grow at the rate of 25.8 per cent to value Rs. 640 billion by 2017

Table-05: Government Initiatives on Cold Supply Chain System

Sl. No	Author/ Agency	Month/Year	Observation/ Findings
01	Ministry of Food Processing Industries [7]	2014	The Government has developed 6891 cold storages having capacity of 31.82 MMT. The Ministry of Food Processing Industries developed Cold Storages with 0.19 MT and Mission for Integrated Development of Horticulture, Ministry of Agriculture developed cold storages having 10.39 Metric Tonnes.
02	Ministry of New and Renewable Energy, Government of India [8]	August, 2016	Extended the subsidy schemes to solar refrigeration units it will encourage their use. Only 10 solar cold storages are functioning in the country in which the first cost around 30-40 lakh, manufactured by Ecozen Solution and Promethen Power Systems using phase change material as insulation to trap solar energy for refrigeration along with batter backup.

Table- 06: Opportunities for the Cold Chain

Sl. No	Author/ Agency	Month/Year	Observation/ Findings
01	S. Shaw et al. [9]	2010	Recommend the benefits of incorporating environmental measures in the Supply Chain to enrich the Performance framework.
02	S. J. Jams & C. James [10]	2010	Cold chain can be improved by using energy efficient refrigeration system by controlling Carbon Di Oxide which protects environment.
03	R. Joshi et al. [11]	2011	Delphi-Analytic Hierarchy Process-Technique for Order Preference by Similarity to Ideal Solution method will help in evaluating the cold chain performance and try to improve the weaknesses to take proper decisions.
04	M/S. Hansa Research for National Horticulture Board [12]	2013-14	Out of total 5367 cold storages with 26.85 million tons almost 79% do not have transportation facility
05	Ministry of Food Processing Industries [13]	October, 2014	Recommended for the creation of additional 7.5 million MT cold chain capacity in the next five years.
06	Yes Bank [14]	November, 2018	India requires additional storage capacity of 30.98 million tons. The top five producing states are suffering cold storage capacity deficit of 23.5 million tons.
07	IMARC [15]	April, 2019	2011-18, the cold chain market found a growth with CAGR of 21.9 percent which is estimated to increase in future.
08	Ministry of New and	August, 2016	Extended the subsidy schemes to solar

	Renewable Energy, Government of India [16]		refrigeration units it will encourage their use. Only 10 solar cold storages are functioning in the country in which the first cost around 30-40 lakh, manufactured by Ecozen Solution and Promethen Power Systems using phase change material as insulation to trap solar energy for refrigeration along with batter backup.
09	CIPHET [17]	2016	Fruits and Vegetables post-harvest loss is between (4.58 to 15.88 per cent).

4. CONSTRAINTS OF CONVENTIONAL COLD CHAIN :

The following are the important challenges existing with the conventional cold chain system in India which lead towards the inception of cold chain run from the renewable sources of energy especially solar power.

(a) Cost Variant: The operation of cold chain involves cost related to operation, inventory, distribution, wastage and training [18].

(b) Energy Source: Conventional system cost only half of the solar based system but requires expenditure over grid power costing almost 20-30 per cent of the running cost of solar cold chain. Performance criteria must set on the customer demand, quality, ability and timeliness [19]. Solar cold chain will reduce cost thereby support rural areas which are not feasible to grid power supply.

(c) Poor Visibility during Transit: In the conventional cold chain management the tracking of products which are in transit is a challenge. The ICT technology provides greater visibility and control over the entire cold chain network by using Internet of Things [20].

(d) Less Capacity: National Horticulture Board (NHB) has reported about the Cold Storage Space gap is estimated to 8.25 million tons and suggested to upgrade and modernize the non functional cold stores.

(e) Outdated Technology: Since operating conditions of cold storage system will affect the storage temperature. The quality of air flow rate, wall insulation, emissivity, light density, external air infiltration will increase the energy consumption [21]. Out of 7000 cold storages almost 5000 are based on outdated technologies. Successful adoption of cold chain technology requires a multi disciplinary approach to tackle individual technological problems [22-23]

(f) Enabling Infrastructure: The holistic cold chain development is possible only along with the development of enabling infrastructure such as road, water supply, power supply, drainage system etc. In rural areas suffering from this basic infrastructure it will be an additional cost to create cold supply hub or warehouses.

(g) Real Estate Cost: Construction of cold storage space with 01 million cubic foot requires one acre land space which may costs around one crore. The real estate cost is very high.

(h) Uneven Distribution: There is uneven distribution of cold storages among states. Out of Total 7,645 cold storages Uttar Pradesh (2,299), Gujarat (764), Punjab (660), Maharashtra (604) and Karnataka (198), Meghalaya (4), Arunachal Pradesh (2), Lakshadweep (1) etc. respectively. Among cold storages is used for horticulture products (83 per cent), processed products (9 per cent), animal husbandry products (7 per cent) and pharmaceutical products (1 per cent).

(i) Lack of awareness: Almost 85 per cent stakeholders belonging to unorganised sector do not have quality infrastructure and 36 per cent are small players with less capacity below 1000 MT hence lack to maintain quality standards. Many stakeholders are not aware of temperature sensitivity and preservation of food which may increase the sale of expired products.

5. RESEARCH GAP IDENTIFIED :

After the analysis over varied literature about cold chain system, this paper identifies many research gaps to recommend the existing opportunity and scope towards inception of solar cold chain for both fresh and processed food segments in the country. Even though there is no single window solution to meet all challenges but an integrated approach will certainly improve the supply chain management [24].

- (a) Indian cold chain industry is fragmented with 80-85 per cent share in unorganised sector and 70-75 per cent share in the wholesale and 10-15 per cent share in the organised sectors. The improvement in the production technology and usage of information technology has helped cold chain system to penetrate into the organised market segments also.
- (b) The post harvest logistics were inefficient to meet increasing post harvest loss of fruits and vegetables. In India records wastage in fruits and vegetables (4.6-15.9 per cent), inland fish (5.2 per cent), marine fish (10.5 per cent), meat (2.7 per cent) and poultry (6.7 per cent) respectively causes an annual loss of Rs. 58,478 to Rs. 96,651 crores. One third of the horticultural products are suffering from Post Harvest Losses estimated to be USD 14 Billion [25]. 18.3 million tons fresh foods worth 3.9 billion can be supplied by reducing 15 per cent of the post harvest loss [26, 27].
- (c) The cold chain system store and transport fresh products from the farm to the customer. Around 40% of the product is wasted during this phase due to inefficient cold chain management systems.
- (d) Obsolete and inefficient cold chain infrastructure is hampering the export quantity resulting in the failure to meet the export demand.
- (e) There is a rise in the consumption level of meat based food products due to the meat processing industries in the country.
- (f) The National Center for Cold Chain Development (NCCD) recommends for the constitution of cold storage with 3.2 million MT capacity, almost 69,000 Pack Houses, 50,000 reefer vehicles & 8,000 ripening chambers respectively to meet present consumer demand.
- (g) Indian Cold Chain Market is growing with a CAGR of 14.8 per cent projecting 2,618 Billion by 2024. This proves that there is a demand for end to end cold supply chain over just the conventional cold storage system.
- (h) There is a need for National Policy on Cold-chain to provide directives on long term holistic infrastructure development in the country.
- (i) The handling capacity of a storage unit for bulk storage is equal to the storage space but in storage hubs, pack houses and cold chain transit it is the aggregate of storage space and weekly/monthly product cycle. Hence standardisation of machinery and equipment in the bulk cold stores, multipurpose stores, frozen food stores, mini walk in cold stores, controlled atmosphere stores, ripening chambers is the need of the century.
- (j) The untapped potential of cold storage system can be used to establish multipurpose cold storages systems to alternate the single commodity cold storages to handle products with varied temperature sensitivity and earn more revenue.
- (k) Indian geography is favourable to grow fruits and vegetables all over the year across the country. The States based on its ability and resource of producing a particular commodity is also vested with various opportunities to improve its Cold Chain Sector [28]. States of Himachal Pradesh, Delhi, Jammu & Kashmir, Uttarakhand, Mizoram, Arunachal Pradesh and Sikkim respectively produces varieties of apples can build and improve its CA Stores, reefer network, pre-cooling units. State of Andhra Pradesh, Gujarat and Maharashtra produce bulk varieties of mangoes can upgrade its ripening chambers, cold storages, CA storages and cold chain system. State of Andhra Pradesh can improve its kiwi trade by upgrading its infrastructure on cold chain and modern pack houses. State of Gujarat, Andhra Pradesh, Tamil Nadu and Maharashtra produce bananas in bulk can upgrade its pack houses and ripening chambers. State of Uttar Pradesh, West Bengal and Punjab bring the largest producer of potatoes needs to establish standard grading system. State of Andhra Pradesh, Kerala, Gujrat, Tamil Nadu, Karnataka, West Bengal, Manipur, Mizoram and Odisha is the largest producer of fish can upgrade its reefer vans, pre cooling units, freezing units and cold storages to improve its revenue. State of Maharashtra, Andhra Pradesh, Kerala, Uttar Pradesh, Nagaland, Assam and North Easter States are the largest producer of meat and meat products is left with huge opportunity to upgrade its cold chain system. Since pan India is the largest producer of dairy products the country requires many more processing plants, low cost technology and insulated vehicles to improve both revenue and employment.

6. CONCLUSION :

Cold chain is a logistics which connects producing places with consumption centres with its pack houses, bulk warehouses, cold stores, transport units, standards, protocols and human resources. According to the

Crisil Report on Indian cold chain industry is growing at 13 -15 per cent CAGR will value Rs 47,200 crore by 2022. Compound Annual Growth rate of Cold Chain Market from 2014-2019 was 23.88 per cent [29]. Cold chain is the integration of pre-cooling, food processing, refrigerated transportation (reefer trucks, reefer container, reefer vessels and ships), cold storages (bulk storages, multipurpose storage, small cold storages, frozen food stores, controlled atmosphere stores, mini units and walk in cold stores. Decision making relating to cold chain logistics is done by data analytics [30]. The demand for cold chain system relies on the consumption data and infrastructural gap. Lack of Post Harvest Logistics facility to transit the products from the farms to market results in the inflation due to the losses caused to the perishable products. Increasing demand for the horticulture products in India will provide opportunity to establish temperature-controlled warehouses. The total market share of cold storage system, about 88-90 per cent is captured by the cold storage and rest 10-12 per cent goes to the refrigerated transport system. New trend of demand started for the multipurpose cold storages and end to end services. The cold chain shall protect the product quality and safety [31]. Government can encourage upgrading existing units to solar refrigeration since the shelf life is almost 15 years. India is one among the prime producer of food crops, agricultural products which gives ample scope for the establishments of modern ripening units and pack houses. Fishery is considered to be the prime occupation of the majority people living in the coastal areas. In the interest of environmental protection, the country is showing ample interest towards energy efficient storage system. Ports are building integrated 'Cargo Complexes' to facilitate international trade and commerce. The inception of western life style, stressful work culture, MNC driven food habits have changed the consumer behavior from the fresh to processed and frozen food products. Modern health care innovations such as cutting-edge medicine, vaccines & bio-pharmaceuticals, clinical trial materials (Stored at temperatures from negative 45 to positive 25 degrees Celsius) are preserved and transported by cold chain system. It is possible to reduce 76 per cent food loss and 16 per cent CO₂ emission through private investment in the cold chain specially in the areas of pre-cooling and transport refrigeration [32]. Foreign refrigeration, insulation equipment manufacturers are turning up to invest in India due to the government policy of encouraging 100 per cent FDI in Cold Chain Sector. The ample scope for the processed food has brought change in the farming behavior by generating a shift from the cultivation of fruits and vegetables over growing crops. Hence this paper concludes that there is significant scope for the inception of Solar Cold Chain along with the required infrastructure in India.

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