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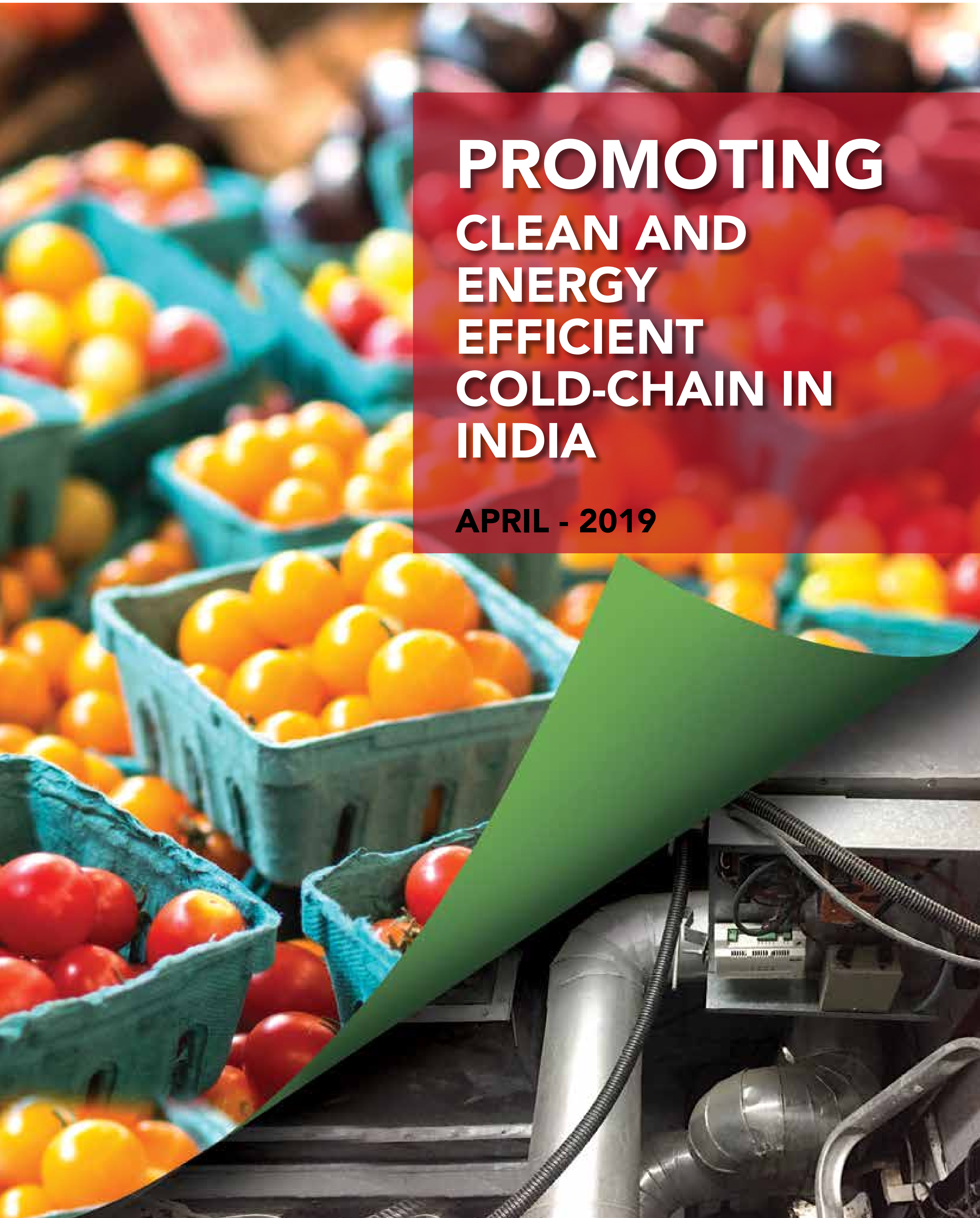

PROMOTING CLEAN AND ENERGY EFFICIENT COLD-CHAIN IN INDIA

APRIL - 2019

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FOREWORD BY
Toby Peters and Pawanexh Kohli

Professor Pawanexh Kohli, CEO & Advisor, National Centre for Cold-chain Development and Visiting Professor, Post-harvest logistics, University of Birmingham, and Toby Peters, Professor in Cold Economy, University of Birmingham

Today compared with the start of the 1960s, India now harvests 40 times as much tomato; 14 times more potato; 8 times more wheat; three times as much in poultry and meat, 13 times more fish; 8 times more milk, and almost 40 times more eggs. India's food production has massively outpaced population growth which grew 2.8 times from 461 million in 1961.

In India, despite sufficient and surplus production, under-nutrition prevails and hunger is not eradicated. An underlying problem is that historically we have correlated population (or demand), with food production (or supply). But production alone is not sufficient to ensure supply of food - the missing condition is physical and effective market connectivity. As we strive to produce more food, if the logistics mechanism is unable to cope with the flood of farm produce, the production does not equal supply, and the losses that result will wipe out much of the benefits.

Ineffective delivery systems also limits the producers' valuation to near-farm demand. Cold-chain is essential to connect a farmer to new urban markets further afield for increased volume demand and higher prices. But whether produce has a holding life of a week or forty weeks, the inventory must reach consumers in time, and in the right quality.

Cold stores are only one piece of the cold-chain. Storage by itself is not a solution. Cold-chain is not about preservation, it applies technology to stretch the marketable time of a perishable product, for a finite duration. In short, cold-chain buys time, to temporarily extend the saleable life. The time in hand should be fruitfully utilised to expand market reach, especially for highly perishable fresh produce.

In summary, cold-chain is an integrated, seamless and resilient network of refrigerated and temperature controlled pack houses, distribution hubs, vehicles and processes to maintain the safety, quality and quantity of food, while moving it swiftly from farm gate to consumption centre. These need to be suitably indigenised and made in country. Cold-chains enhance economic wealth, cash flow and security for farmers and improve food quality, safety and value to the customer; and must achieve this with minimum environmental impact.

However, here is the conundrum. While food lost in the delivery chain is avoidable through use of technology, cold-chain itself is an energy intensive application, often relying on diesel for off-grid and on-vehicle cooling. Any indiscriminate use of technology can lead to undesired hazards. Future development must harness the portfolio of renewable energy resources, new thermally-focused energy systems, innovative thermal management; not merely focus on optimising its existing fuel or electricity consumption.

How to use the integrated components of storage and transport for cross-geography access or distance-price arbitrage, time-arbitrage or even cross-seasonal trading becomes as important as the physical infrastructure to flow of food from farm to fork. Within this, the infrastructure is only half the solution. Equally important is, the flow of key information from wholesaler, retailer or consumer to producer – from fork to farm - which can help shape time of planting and harvest as well as choice of produce to grow. This will drive resource conscious robust business models and viable financing models to underpin the investment in clean cold-chain.

But whereas the cold-chain will morph over time, driven by market demand, the motivation for specific interventions should not simply be to accelerate deployment, but also address the challenge outlined above: the need to deliver market connectivity in an environmentally sustainable way. We welcome the opportunity to be associated and involved in this study by Shakti Foundation to explore how India can build out clean cold-chains.

PREFACE BY Krishan Dhawan

CEO, Shakti Sustainable Energy Foundation

The Government of India (GoI) has placed substantial emphasis on increasing farmers' income by 2022 through productivity gains. In 2016, the GoI launched 'Operation Green' to support agri-logistics, food processing units and food producer organizations. Developing "cold chains" is one of the key measures under "Operation Green" to arrest food loss from the farm gate to consumers.

Cold-chains are expected to proliferate rapidly in India during the next few years through a combination of market and policy driven efforts. According to India's Cooling Action Plan, under a business-as-usual scenario, the energy consumption and greenhouse gas emissions from cold-chains is likely to increase manifold by 2037.

But unplanned investments in the cold-chain sector can create a carbon intensive stand-alone infrastructure of cold storages, reefer vehicles and ripening chambers instead of a sustainable and cohesive agri-supply chain. As a signatory to the Paris Agreement and the Kigali Agreement, India will need to reassess the development of its cold-chains in order to reduce GHG emissions from this sector.

Recognizing this, Shakti in collaboration with key partners is supporting efforts to advance cleaner and more energy-efficient cold chains in India. A critical way to enable this transition is to introduce clean technologies, which will help prevent the long-term lock-in of fossil-fuel intensive technologies. This study, commissioned by Shakti and developed by MP Ensystems Advisory Pvt. Ltd. with support from the University of Birmingham, assesses existing technologies, energy consumption, use of renewable energy, and Global Warming Potential (GWP) of refrigerants that are currently used in India's cold-chain infrastructure.

Based on the empirical assessments in the state of Haryana, this study makes key recommendations for the development of clean cold chain in India: Promoting new business models (viz., IT enabled services for managing harvesting and logistics from fork to farm and delivering Refrigeration as a Service), developing cold-chain living labs and innovation centres, creating infrastructure for training and outreach, facilitating hackathons and preparing IT based agri-supply chain solutions.

I trust that this study will serve as an important reference for policy makers, farmer producer organizations, private sector and other stakeholders working to deliver cleaner and more energy-efficient cold chains while assisting India in meeting its ambitious climate goals.

Krishan Dhawan
Chief Executive Officer
Shakti Sustainable Energy Foundation

ABBREVIATIONS

APEDA:	Agricultural and Processed Food Products Export Development Authority
APVAC:	Atmospheric Pressure Vacuum Drying
ACFW:	Agriculture & Farmers Welfare
BAU:	Business-As-Usual
BEE:	Bureau of Energy Efficiency
CA:	Controlled Atmosphere
CFCs:	Chlorofluoro Carbons
CCDP:	Crop Cluster Development Program
CTARA:	Center for Technology Alternatives for Rural Areas
CSISAC:	Central Sector Integrated Scheme on Agricultural Cooperation
DFI:	Doubling Farmer's Income
FCI:	Fixed Capital Investment
FPCs:	Farmer Producer Companies
FPOs:	Farmer Producer Organizations
GHG:	Greenhouse Gases
GWP:	Global Warming Potential
$GtCO_2e$:	Gigatonnes of Carbon Dioxide equivalent
HFCs:	Hydro Fluoro Carbons
HFOs:	Hydro Fluorolefins
HSAMB:	Haryana State Agricultural Marketing Board
HSIIDC:	Haryana State Industrial Infrastructure Development Corporation
HWDT:	Hot Water Dip Treatment
IOT:	Internet of Things
ICAR-CIPHET:	Indian Council for Agricultural Research-Central Institute of Post-Harvest Engineering and Technology
LOI:	Letter of Intent
LULUCF:	Land Use, Land-Use Change and Forestry
MIDH:	Mission for Integrated Development of Horticulture
MOEF CC:	Ministry of Environment Forest and Climate Change
NABARD:	National Bank for Agriculture and Rural Development
NABCONS:	NABARD Consultancy
ICAP:	India Cooling Action Plan
NCCD:	National Centre for Cold-chain Development
NITI Aayog:	National Institution for Transforming India
NDC:	Nationally Determined Contribution
ODP:	Ozone Depleting Potential
ODS:	Ozone Depleting Substances
PCM:	Phase Change Material
QSRs:	Quick Serving Restaurants
REEFER:	Refrigerated Transport
SFACH:	Small Farmer'Agri-Business Consortium, Haryana
STL:	System for Low Temperature
SWOT:	Strength, Weakness, Opportunity and Threats
UoB:	University of Birmingham
VAMs:	Vapour Absorption Machines
VCC:	Vapor Compression Cycle
VFD:	Variable Frequency Drive
VHT:	Vapour Heat Treatment
WRI:	World Resources Institute
ZECC:	Zero energy cool chambers

NOTE:
Currency equivalence considered in the report: 1 US $ = ₹70

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1. ABOUT THIS STUDY

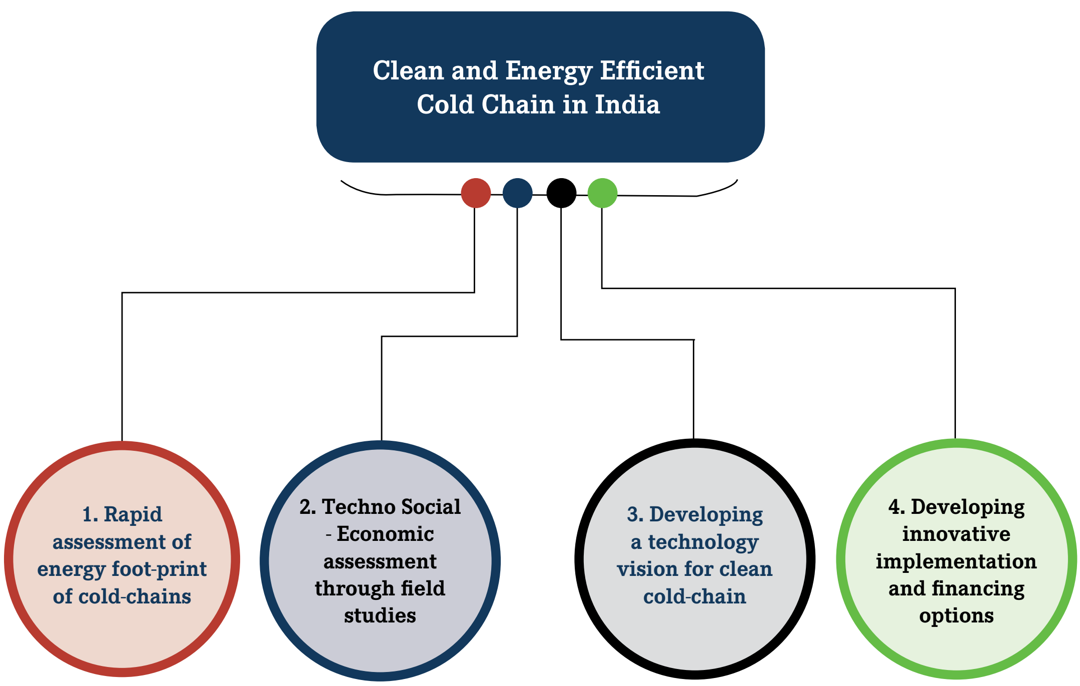
1.1 Goals and Objectives

This report is an assessment of clean cold-chain in India, it reviews existing technologies and their use, energy consumption, use of renewable energy, and Global Warming Potential (GWP) of refrigerants used. The report brings together the policy, finance and technology-innovation attributes of the evolving cold-chain in India in order to provide strong evidence and recommendations.

The study aimed to develop a vision for clean cold-chain and identify the actions and innovations required to make technologies affordable, financeable and implementable by the small and large implementation partners from warehousing, haulage and bulk-processing/storage.

The project has sought the active support and expertise of various organizations ranging from government agencies, institutions and businesses. The key organizations involved are listed in Table 10. The project goals are presented below in Fig.1.

Figure 1: Goals of the Study on Clean Cold-Chain in India



1.2 Methodology

A team comprising of experts from MP Ensystems supported by the University of Birmingham, and Shakti Sustainable Energy Foundation worked in four states in India during the period July to November 2018 to better understand the current state of cold-chain in India and how to ensure the transition to a developed cold-chain which exists pan India and has minimal environmental impact – i.e. curtailing CO_2 emissions and other pollution. This exploration was carried out in the states of Haryana, Punjab, Maharashtra and Karnataka; offering regional diversity. The purpose of the study was to explore systems-level thinking on the need for clean cold-chain: moving from the farm-to-the-fork and re-purposing value through the cold-chain from the fork-to-the-farm. It also explored the development of a broad roadmap for clean cold-chain development in India.

The systems-level thinking includes understanding of:

- Farming as a livelihood opportunity for farmers,
- The value-chains from the perspective of their energy footprints in particular.
- Current failures and barriers to the deployment of cooling technology,
- Role of technologies relevant to first and the last-mile of goods flow alongside cold storage, efficient (low-carbon) and clean (low-global-warming-potential and low Ozone-depleting potential) components of cold-rooms, packhouses, and processing plants.
- Projection of energy conservation (in GW) and GHG (CO2e), NOx and PM emission reduction due to adoption of energy efficient equipment technologies and low GWP refrigerants in cold-chain till 2030.
- Application of closed-loop systems resulting in maximized productivity per unit of energy
- Interventions to support deployment of low carbon technology including, but not limited, to finance, policy, training.
- Envisaging cooling as a 'service', role of data connectivity and IT-enabled/mobile technology platforms to inform the decisions on time-span of harvesting, improving the holding life and associated INR value of the products resulting in win-win for the producers and the consumers.

As a part of this exploration spread over the four states, the project team interacted with the following stakeholders:

1. Government (State and National) officials from agriculture, horticulture, electricity, renewable energy, energy efficiency and water resources departments (approximately twenty one-on-one interactions and one roundtable);
2. Ten small and large Farmer Producer Companies;
3. More than 50 farmers dependent on the farming sector (primarily fruits and vegetables) including women farmers;
4. Six agri-value-chain start-ups including those run by women entrepreneurs;
5. More than 30 Indian and UK technology providers dealing with integrated system designs, refrigeration systems/equipment, natural and low-GWP refrigerants, solar-PV and solar-thermal hot-water/steam generating units; phase-change materials in reefer-vans, cool-rooms, processing units and retail stores; IoT/AI/blockchain platform developers with applications developed for agriculture sector (spread over 2 round-tables and bilateral meetings);
6. Four leading banks in India providing credit to FPCs, farmers, technology providers; and vii) angel and venture capital fund managers focusing on agri-value-chains.

The report benefited from four case studies from the state of Haryana captured through in-person interviews.

1.3 Structure of the Report

Section 1: **About this Study** – Provides an overview of the objectives, methodology and structure of the report.

Section 2: **Context of Cold-Chains in India** – Provides an overview and definition of cold-chain and its role in agriculture, status of existing cold-chains and gaps, Government of India's planning with respect to 'Doubling Farmers' Incomes' and existing technologies in cold-chain.

Section 3: **BAU of Cold-Chains** – reviews through pilot and case studies in the state of Haryana, different business models, the technologies used, needs and demands; 4 case studies covering 4 business models are analyzed with a view to assess the techno-economical-social feasibility and linkages of value chain.

Section 4: **Technology Horizons** – assesses existing technologies across the various components of the cold-chain with respect to energy efficiency, cost-effectiveness, GWP/ ODP and GHG emissions/ carbon footprint, presents a list of new and alternative technologies which can be introduced through the different components of the cold-chain; and provides the parameters for assessment of technologies with respect to their readiness for application and their energy/ environment footprint;

Section 5: **New Business Propositions and Recommendations** – proposes two business propositions for a successful transition to clean cold-chain along with the tools and mechanisms required to implement such models including stakeholders, pre-launch activities, cost and revenue model.

2. CONTEXT OF COLD-CHAINS IN INDIA

2.1 Background

The agriculture sector forms a substantive part of the Indian economy, contributing up to 14.4% of GDP and 48.9% of employment (as of 2011-12) (NITI Aayog, Govt. of India, 2015). The sector needs to significantly reduce loss and wastage in the food chain if the Government of India's goal of doubling farmers' income by 2022 is to be achieved. A seamless cold-chain will reduce food loss, thereby raising farmers' income and giving them access to bigger markets and expanding their selling range. However, it is imperative that we develop practical and affordable cold-chain solutions without compromising climate goals, in order to ensure that the sector is resilient and future-ready.

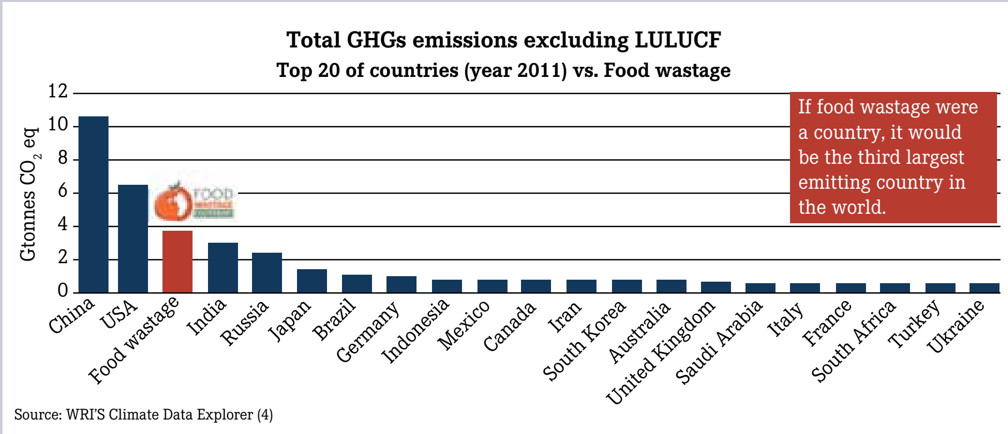
All farm-to-fork processes require improved efficiencies in the value chain, cold storage is a critical element at various stages. Cold-chain comprising of farm gate and first mile infrastructure - packhouses, cold storage, refrigerated transportation, ripening chambers - as well as last mile transportation and refrigeration, are important to facilitate the movement of the produce to the market-place in the best possible condition. Cold-chains need an essential push through benign policies, access to finance and technology innovations targeting reduced costs to the end-users. State and Central Government are facilitating investments and development of cold-chain infrastructure through various schemes, making them energy efficient and clean will ensure their long-term sustainability.

2.2 Indian Agriculture Scenario and Food Wastage

India is a predominantly agricultural country with nearly 50% of the population still rural-agrarian-based (NITI Aayog, Govt. of India, 2015). Gross value added by agriculture, forestry and fishing is estimated at ₹17.67 trillion (US$ 274.23 billion) in FY18. The Indian food and grocery market is the world's sixth largest. Milk production is the highest in the world at 165.4 million tonnes, while horticultural produce is the second largest at a record 307.16 million tonnes in 2017-18 (India Brand Equity Foundation, 2018).

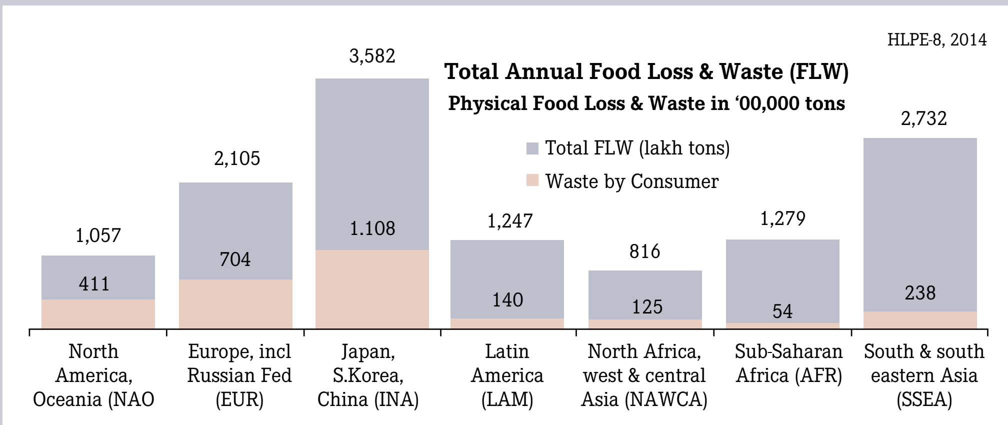
Despite these advances, Indian farmers still struggle with low-income levels. The agriculture sector would benefit from an income enhancement and loss reduction option. Post-harvest processes, especially in the first mile, are not advanced enough, resulting in up to 40% food waste at the farm gate, in transit and at the *mandi* (regional market). According to the National Center for Clean Cold-Chain development, 'Every wasted tonne of fruit and vegetables decomposes into approximately 1.5 tonnes of greenhouse gases' (GHG) (Kohli, Stop Food Loss To Stop Climate Change, 2016). Globally, mankind wastes about 1.3 billion tonnes of food, the highest share belonging to fruits and vegetables. The World Resources Institute (WRI) estimates that if worldwide food loss and waste was a country, it would be the third largest emitter of greenhouse gases in the world (Food and Agriculture Organization of the United Nations, 2015) (Fig 2 and 3 and Box 1).

Figure 2: Total GHGs emissions excluding LULUCF



***Source:** Food wastage footprint & Climate Change, Food and agricultural organization of the United Nations, Rome, (2015).*

Figure 3: Food Loss & Waste by Region



***Source:** HLPE, Food losses and waste in the context of sustainable food systems. (High Level Panel of Experts on Food Security & Nutrition of the Committee on World Food Security, Rome.), 2014*

In the absence of a cold-chain, food loss and wastage will have a far higher impact on climate change than the carbon footprint of the cold-chain and the GWP/ODP of the refrigerant gases used within it (Kohli, Stop Food Loss & Waste to Counter Climate Change, 2017).

2.3 Doubling Farmers' Income

The NITI Aayog's policy paper released in March 2017 titled 'Doubling Farmer's Income: Rationale, Strategy, Prospects and Action Plan', reported that 22.5% of Indian farm households have income below the poverty line. Farmers' incomes vary greatly between states - Punjab, Haryana and Kerala have the lowest rates below the poverty line - less than 5%. In states such as Jharkhand, nearly 45% of farm households have incomes below the poverty line (Chand, Doubling Farmer's Income: Rationale, Strategy, Prospects and Action Plan, 2017).

The agriculture sector is challenged with disproportionate income distribution amongst the stakeholders. A 2013 Report by Ernst & Young on reefer transportation in the food and

Box 1: Food Loss and Food Waste

"Food is lost or wasted throughout the supply chain, from initial agricultural production down to final household consumption. Food losses represent a waste of resources used in production such as land, water, energy and inputs, increasing the greenhouse gas emissions in vain." - *FAO, 2011*

Globally, food loss and food waste constitute 1.3 billion tons, of which 44% is attributed to fruits and vegetables alone. South and South-East Asia have the second highest footprint of food loss and waste amounting to 2,732 lakh tons after Japan, South Korea and China (Food and Agriculture Organization of the United Nations, 2015).

***Source:** Food and Agriculture Organization of the United Nations*

Assuming an average 10% loss post harvest, value lost by a farmer in India amounts to US $ 26.5 billion

*(**Source:** National Accounts Statistics2017,www.mospi.gov.in)*

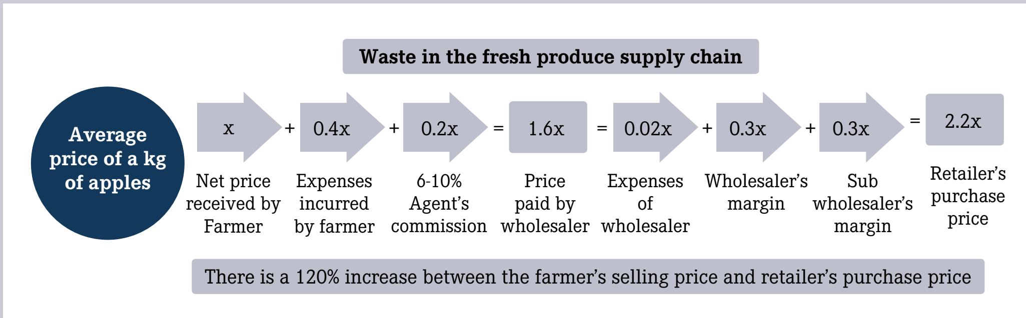
Food loss occurs when the food produced for human consumption is discarded, accidentally or intentionally, or is diverted for non-food purposes. The net result is less food available for all and wastage of the resources – land, water, electricity, fertilizer and pesticides – that went into its production. Food loss essentially means a loss of volume and value for the farmer. The primary cause of food loss is **lack of post-harvest connectivity to markets** due to problems in harvesting, storage, packing, transport, infrastructure or market / price mechanisms, as well as institutional and legal frameworks. For instance, harvested mangoes that get damaged in regular haulage are considered food loss.

Food waste occurs in the hands of retailers or consumers, consumers - consciously or unconsciously due to habitual practices or other factors such as improper storage, fulfillment of shelf life, unplanned buying, i.e., **food discarded at consumer-end.** Food waste occurs after monetization of the farmers' produce and hence does not lead to loss of value for the farmer.

For instance, a carton of spotted mangoes thrown away by a shop is considered food waste.

agriculture industry, shows the proportion of costs shared by various stakeholders along the supply-chain, Presently, each produce goes through an incremental price surge in the supply chain between the farmer and the retailer. Typically, the price at which the produce is sold to the retailer is 120% more than the price the farmer receives for the produce. (Ernst & Young PVt Ltd, 2013).

Figure 4: Illustrative example: Wastage of perishables on account of multiple handling not only causes waste, but also significantly increases final prices for consumers.



Source: *Refrigerated transportation: bottlenecks and solutions, Ernst & Young Pvt. Ltd., Kolkata (2013).*

Agriculture in India is characterized by informal or traditional supply chains that deliver products to local middlemen and then to small local stores. The bulk of the produce is sold by farmers in raw form and taken from field to mandi post harvest. Often this leads to glut in the market and farmers don't get the price for their crops leading to dumping and waste. According to an estimate prepared by Indian Council for Agricultural Research-Central Institute of Post-Harvest Engineering and Technology (ICAR-CIPHET), harvest and post-harvest losses for major food commodities covering crops, livestock and fish was ₹92,651 Crore (US$ 13.23 billion) during the year 2013-14.

An ICAR-CIPHET report based on a sample survey of 120 selected districts, published in 2015 estimated **losses in India in the range from 4.85% to 15.88%** in selected fruits and vegetables during the harvest and transit. Much of this loss can be prevented by use of efficient and modern infrastructure and farm facilities for storage and cooling (Kohli, FAQs on Cold-Chain Development, 2015). The global carbon footprint alone of food produced and not consumed i.e. either lost or wasted, is estimated to be 3.3 gigatonnes of carbon dioxide equivalent ($GtCO_2e$) (Food and Agriculture Organization of the United Nations, 2015).

2.4 What is a Cold-Chain?

A cold-chain is a system designed to integrate the entire set of activities needed to transfer the harvested agricultural produce from farm to consumer (fork), by using appropriate climate controls to maintain the quality and freshness of produce. NCCD defines a cold-chain as a "modern agri-logistics system that must incorporate at the minimum, the following infrastructure components:

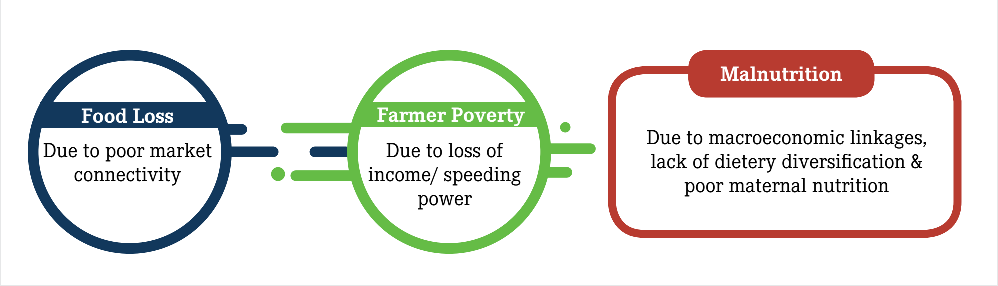
1. Modern packhouse at (or in proximity) to farm-gate.
2. Transport from packhouse to next stage in the supply chain.
3. Cold storage (hub) in proximity to market
4. Cold storage (bulk) when storing at farm-gate
5. Ripening units (in case of select produce only)

Box 2: Macro-economic linkages – Malnutrition and Farmer Poverty

According to the UNICEF's Countdown to 2030 – Maternal, Newborn and Child Survival Country Profiles App, 36% of children under the age of 5 were found to be underweight in India in 2015. The prevalence of anaemia (iron deficiency) among women aged 15 – 49 years was found in 51% of women (in 2016). With more than one-third of the world's undernourished children being in India, the issue of malnutrition is of national and global concern (UNICEF, 2017).

The National Food Security Act was revived in 2014 with a view to end malnutrition and the world's largest programme on child malnutrition – the Integrated Child Development Services (ICDS) has been in force in the country since 1975 (Singh & Pandey, 2018).

Malnutrition is directly linked to poverty. While evidence to linkages with agricultural productivity is indirect, literature suggests a multifaceted linkage and the need for a 'nutrition-sensitive' agricultural development (Kadiyala, Harris, Headey, Yosef, & Gillespie, 2014).



According to a paper on 'Agriculture and Nutrition in India: mapping evidence to pathways' published in the New York Academy of Sciences in 2014, there are six possible linkages between malnutrition and agriculture related to farmer poverty:

1. Agriculture as a source of food
2. Agriculture as a source of income for food and non-food expenditures
3. Agricultural policy and food prices
4. Women in agriculture and intra-household decision-making and resource allocation
5. Maternal employment in agriculture and childcare and feeding
6. Women in agriculture and maternal nutrition and health status

Post-harvest food loss due to a lack of cold-chain infrastructure and post-production management is an economic burden on the food supply system as well as on the farmer. It is effectively a loss of saleable volume and value that should be mitigated in order to ensure maximum agricultural output and increased income to the farmer (NITI Aayog, Govt. of India, 2015).

Farming assets or activities have been found to have direct effect on nutrition of women and children related to household income and expenditure. Literature point out the direct correlation between farming income and calorie intake and allude to the importance of diversification of livelihood and food sources, especially with increasing land fragmentation and landlessness (Kadiyala, Harris, Headey, Yosef, & Gillespie, 2014).

The glossaries of definitions of various components of the cold-chain are provided in **Annexure B.** The Post-harvest infrastructure protocols for different horticultural produce, their temperature requirements, and the details of the major cold-chain infrastructure components are given in Table 1 and 2.

Table 1: Post-Harvest Infrastructure Protocols for Selected Products and list of Products Selected

Products	Logistics Flow (to-be read in order of component listed)	Category (Temperature Range)
FRESH FRUITS		Chill (0^0C to 10^0C)
1. Apple	CS – PH – T – CH - t - FE	
2. Grapes	PH – T – CH - t - FE	
3. Orange	PH – T – CH - t - FE	
4. Strawberry	PH – T – CH - t - FE	
5. Kiwi	CS – PH – T – CH - t - FE	
FRESH VEGETABLES		
6. Potato	CS – Ts – FE	
7. Tomato	PH – T – CH - t - FE	
8. Cauliflower	PH – T – CH - t - FE	
9. Okra	PH – T – CH - t - FE	
10. Carrot	CS – PH – T – CH - t - FE	
11. Cabbage	CS – PH – T – CH - t - FE	
FRESH FRUITS		Mild-Chill (10^0C to 20^0C)
12. Mango	PH – T – CH – RC - t - FE	
13. Banana	PH – T – CH – RC - t - FE	
14. Papaya	PH – T – CH – RC - t - FE	
OTHER FOOD PRODUCTS		Frozen (below -18^0C)
15. Processed Products	PU – T – CH - t - FE	
16. Meat & Meat Products (Livestock, Poultry, Fish)	PU – T – CH - t - FE	
17. Dairy products (Ice-Cream, Butter)	PU – T – CH - t - FE	
18. Onion	SS - Ts – FE	Normal (20^0C to 30^0C)

LEGEND:
CS - Cold Storage Bulk; CH - Cold Storage Hub; FE - Front-end merchandising; PH - Packhouse;
PU - Food Processing Unit or Allied; t – last mile Transport; T - Long Haul Reefer Transport;
Ts – Non-reefer Transport; RC - Ripening Chamber; SS – Storage Structure

Source: *All India Cold-chain Infrastructure Capacity Assessment of Status & Gap. New Delhi: NCCD, (2015)*

Table 2: Energy Demand throughout a typical vegetable chain

		Diesel / Gasoline	Electricity	Natural Gas
	Fertilizers			✓
PRODUCTION	Irrigation	✓ (pumps)	✓ (pumps)	
	Cultivation on Farm	✓ (machinery)	✓ (greenhouse)	✓ (heating greenhouses)
	Harvesting	✓ (machinery)		
STORAGE	Storage / Refrigeration		✓	
TRANSPORT	Transport	✓	✓	
PROCESSING	Sanitizing / Cleaning		✓	✓
	Grading and Sorting		✓	
	Peeling / cutting		✓	✓ (steam)
	Blanching	✓ (boiler fuel)	✓ (heat)	✓ (heat)
	Cooling		✓	
	Drying	✓	✓	✓
	Freezing		✓	
PACKAGING	Can filling		✓	
	Can exhausting	✓ (heat)	✓	✓ (heat)
	Can sealing		✓	
	Heat sterilization	✓	✓	✓
	Packaging		✓	

Source: *Opportunities for Agri-Food Chains to Become Energy-Smart, Food and Agriculture Organization of United Nations*

According to Toby Peters, Professor of Cold Economy, University of Birmingham, "Cold-chain is not just about farming, it is also about improved nutrition and limiting climate impact." In one of the stakeholder consultation workshops during the course of the study, he defined Clean cooling as the provision of cooling through efficient and sustainable means that contributes towards achieving society's goals for greenhouse gas emissions reduction, climate change mitigation, natural resource conservation and air quality improvement. Clean cooling must be affordable, accessible, financially sustainable, scalable, safe and reliable to help deliver our societal, economic and health goals.

"COLD-CHAIN IS NOT JUST ABOUT FARMING, IT IS ALSO ABOUT IMPROVED NUTRITION AND LIMITING CLIMATE IMPACT"

- Prof. Toby Peters

Clean cold-chain must be designed with a systems thinking approach to include all cooling services such as space cooling, refrigeration of essential food – dairy and cooked items, pharmaceuticals, reefer transportation and data centers. Such design thinking is required to be applied at community, village, district and regional level to optimize energy resources such as solar PV and thermal, wind, biogas/ biomass, waste to energy systems, thermal storage materials and harnessing liquid air and waste heat/ cold, and reduce electricity grid dependence.

2.5 Gaps in Existing Cold-chain

The National Centre for Cold-chain Development (NCCD) has identified best practices in post-harvest handling of produce (Kohli, FAQs on Cold-Chain Development, 2015). Key aspects are below:

Figure 5: Gaps in Existing Cold-Chain

Farm	Packhouse	Reefer Vehicle	Cold Storage/Ripening Chambers
• **Managing timing** of harvest with regard to logistics and market and holding life. • **Least damage** to produce as possible. • **Close proximity to pre-conditioning centers** – preferably within a 2-4 hour radius. • **Use of post-harvest handling carriers** to mitigate transport damage to pre-conditioning centre	• **Sorting of produce** by market value / destination • **Curing of root & tuber crops** (eg. red chillies, potatoes, cassava, yams, onions). • **Washing or cleaning** to remove field residues, pesticide or treat with fungicides. • **Drying** in case of washing and pre-cooling (where required). • **Segregation/ Grading** by size of produce for logistics handling before packaging. • **Rapid pre-cooling** for most fruit and vegetable crop types or slow cool down for vegetables such as onion and potato	• **Dispatch** from farm-gate to pre-conditioning centers, cold storage and retail points. • **Pelletized stowage** to destination storage using appropriate pelletized material handling equipment until dispatch to retail points.	• **Rapid chilling or blast freezing** of harvested animal product - meats or milk. • **Short-term storage** prior to onward dispatch to market centers or for long-term storage. • **Divert low value** or non-marketable surplus to food processing facilities • **Farm-coding** – record-keeping for traceability of produce. • **Maintaining temperature and humidity** parameters throughout the logistics chain. • **Maintaining living (breathable and disease free)** environment for fruits and vegetables, throughout the logistics chain. • **Follow guidelines to avoid incompatibility,** cross-contamination or tainting of produce

A 2015 report by the NCCD estimated the cold-chain infrastructure in March 2014 to be 31.82 million tons of cold storage space, which amounts to a gap of 3.28 million tons between required and available (Table 3) cold storage space (Bulk & Hub)(NCCD, 2015). Based on the emerging trends in the cold-chain sector, a much higher level of infrastructure may be needed. As such the numbers in the table below should be viewed as indicative of future requirements.

The break-up of existing cold-storage use is summarized in the diagram below indicating that almost 83% of the current cold-storage facilities are used for agri-horticulture produce (Fig. 7). On-site visits indicate that the majority are used for potato storage.

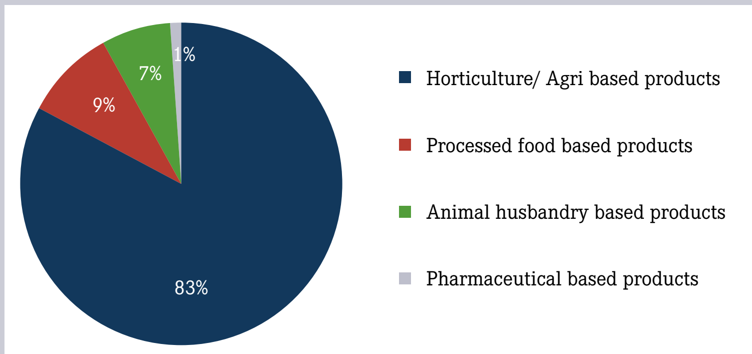
Table 3: Cold-chain Infrastructure gap

Type of Infrastructure	Infrastructure Requirement (A)	Infrastructure Created (B)	All India Gap (A-B)
Packhouse	70,080 nos.	249 nos.	69,831 nos.
Cold Storage (Bulk)	341,64,411 MT	318,23,700 MT	32,76,962 MT
Cold Storage (Hub)		9,36,251 MT	
Reefer Vehicles	61,826 nos.	9,000 nos.	52,826 nos.
Ripening Chamber	9,131 nos.	812 nos.	8,319 nos.

Source: *All India Cold-chain Infrastructure Capacity Assessment of Status & Gap. New Delhi: NCCD, 2015*

Figure 6: Segment-wise Segregation of Cold Storage

> ""ALMOST 83% OF THE EXISTING COLD-STORAGE FACILITIES IN THE COUNTRY ARE BEING USED FOR AGRI-HORTICULTURE PRODUCE"
>
> - NCCD 2015



Source: *All India Cold-chain Infrastructure Capacity Assessment of Status & Gap. New Delhi: NCCD,. (2015).*

2.6 Existing Cooling Technologies in cold-chain

Currently ammonia-based chillers are the predominant technology used in cold-storage in India. Natural refrigerants such as ammonia have a low GWP as compared to the CFCs and HCFCs deployed almost fully in the cold-chains of the Western world, which usually have several 1000 times the GWP of carbon dioxide, along with high ODP. Estimates show that only 4% of India's crops move through the cold-chain as compared to 70% in the UK (Birmingham Energy Institute, 2017).

> "INDIA HAS THE LARGEST FOOTPRINT OF COLD STORES IN THE WORLD ESTIMATED AT NEARLY 130 MILLION CUBIC METERS OF REFRIGERATED WAREHOUSING SPACE. 97% OF THESE USE NATURAL REFRIGERANT GASES, I.E. AMMONIA. IN-EFFECT, THIS IS THE WORLD'S LARGEST COLLECTION OF USERS OF AMMONIA-BASED REFRIGERATION."
>
> - Pawanexh Kohli, Stop Food Loss & Waste to Counter Climate Change, 2017

With increasing awareness on cold-chain requirement and with attractive financial incentives provided by national and state governments, the number of cold-storage and other cold-chain components are likely to increase. The India Cooling Action Plan (ICAP) released by the MOEF&CC in March 2019, estimates a 4 – 5 times increase in the number of packhouses between now and 2037-38 (Ministry of Environment Forest and Climate Change, 2019) and similar increases in reefer vehicles and cold storage.

Different technologies are employed across the cold-chain – from farm to fork – involving post-harvest pre-cooling, pack house technologies including sorting and grading, cold storage, ripening chamber, reefer vehicles and retail refrigeration. In this chapter the focus is on cooling or refrigeration across the cold-chain.

Increasing the holding life and shelf life of the commodity while maintaining its freshness, is at the heart of initiatives towards reduction food losses and increase in value and income for the farmers. Once a produce is harvested, the degradation process begins naturally. This differs from one produce type to the other. It is estimated that food degradation increases 2 to 3 fold with every 10^0C rise in temperature (defined as Q10 coefficient) (Kitinoja, 2014). The theoretical relationship between temperature increase and degradation is given in Table 4.

Table 4: Theoretical relationship between temperature, respiration rate and deterioration rate of a non-chilling sensitive fresh commodity

Temperature ^{0}C	Assumed Q10	Relative shelf life (%)	Loss per day (%)
0	-	100	1
10	2.0 to 3.0	33 to 50	2 to 3
20	2.0 to 2.5	13 to 50	7 to 8
30	2.0	7 to 10	10 to 14
40	1.5	4 to 5	20 to 25

Source: *Kitinoja 2014*

Table 5: Key characteristics of different cooling technologies

Cooling method	Principal Application				Operating energy	Refrigerant use
	Food Products	Temperature range	Cold-chain steps	Other		
Vapour compression cycle	All food products	Full temp range (including freezing)	Entire cold-chain		Electric	Halogenated or natural refrigerants
Sorption	All food products	Full temp range (including freezing)	Entire cold-chain, but limited applicability in transport		Thermal	Natural refrigerants
Evaporative cooling	Chilling sensitive fruit &vegetables	Temperatures of above 10^0C	Mainly bulk storage, household refrigeration	Climatic limitations (low humidity)	Thermal (passive)	Water
Ice making	Non-chilling sensitive produce only (fish & meat)	Temperatures around 0^0C	Entire cold-chain		Electric or thermal	Halogenated or natural refrigerants

Source: *Cold-chain technologies: Transforming supply food chains by Sathguru. ASSOCHAM, 2017.*

There are many technical, logistical and investment challenges as well as economic opportunities related to the use of the cold-chain. Refrigeration is generated using 2-main techniques, Vapour Compression Cycle or Vapour Absorption Cycle. Although Vapour Absorption Cycle was invented and used prior to invention of Vapour Compression Cycle, the ease of operations, use of electronic drivers and maintenance and size of the system has made Vapour Compression cycle more popular. The primary segments of an integrated cold-chain and the conventional technologies along with their key characteristics, are summarized in Table 5.

Conventional cooling technologies are typically based on grid-based thermal electricity. The average operational energy for a conventional Vapor Compression Cycle (VCC) based cooling system is about 2 kWh/ TR (Surange, 2018).

Refrigerants

The refrigerant chosen for a particular application has a large effect on the efficiency of the refrigeration system. 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)

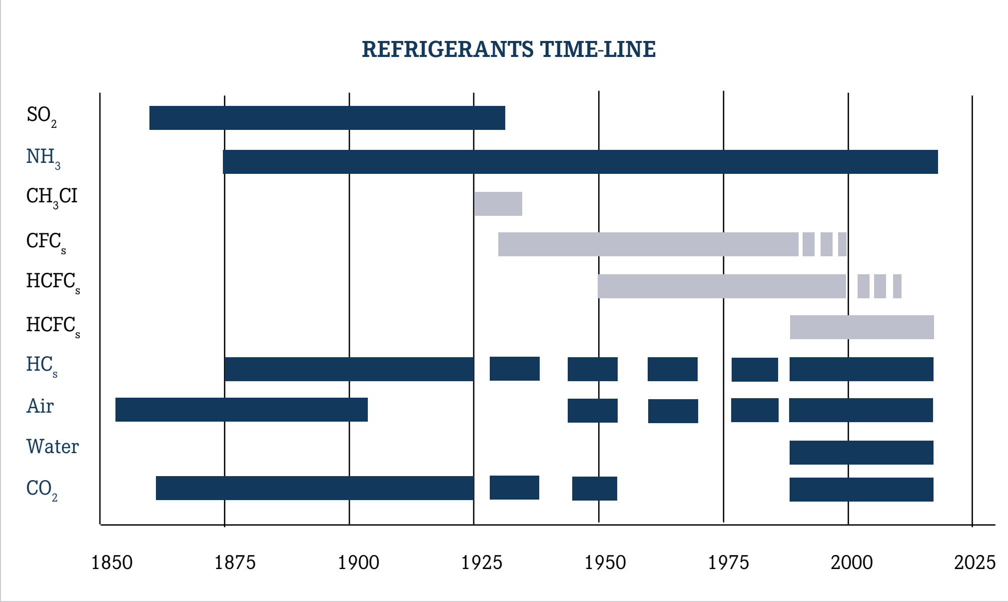
The refrigerant industry in general, and in India has faced various challenges due to the impact of refrigerants on the global environment. Chlorofluoro carbons (CFCs) which were very popular in the past, have already been phased out due to their ozone depletion potential. HCFC's which were suggested as an alternative, are also now being phased out in stages in most countries including India. Hydro fluoro carbons (HFCs) like R134a, R404a, R407c, etc. are currently in use but have been found to have high global warming potential (GWP). Finally, Hydro Fluorolefins (HFOs) have been developed with zero ODP and very low GWP. However, currently, their commercial production is low as cost is high.

The refrigerants which are here to stay are the natural refrigerants:

- Hydrocarbons: R-290 propane, R-600 isobutene (although these have high flammability they are already being extensively used in European countries due to their zero ODP and negligible GWP);
- R-717 (Ammonia), a trusted refrigerant has been used for industrial refrigeration for more than a century in India - it is the refrigerant used in nearly 90% of the plants in Indian cold-chain industry;
- R-744 (CO2) used in the past, is getting popular as a primary as well as secondary refrigerant (challenges include high operating pressures, toxicity and low critical pressure).

A timeline of refrigerants used is given in Fig. 8

Figure 7: Refrigerants time-line



Source: *Association of Ammonia Refrigerants 2018.*

Reasons why ammonia has been a favourite choice of refrigerant (Association of Ammonia Refrigerants, 2018) in India include:

- Low capital and operational cost – it is the cheapest refrigerant in the market. For example the price per kg for R404A / R407C is about 10 times the price of Ammonia and for a large cold storage, the operation costs are 20-30% lower with Ammonia than R 404A / R407C
- Easy availability and 'made in India' – does not need to be imported unlike many other refrigerants.

  Easy to use - density of at 1.013bar at boiling point: 682kg/m3 (ammonia liquid), 1413kg/m3 (liquid HCFC) and 1376kg/ m3 (liquid R134a)
- Energy efficient - only half as much refrigerant needs to be purchased to charge a system because the density of Ammonia is half of halocarbons.

To date, ammonia based VCC systems for cold storage have been typically used for large potato cold storage in India. However, innovation on use of ammonia for low capacity and low charge systems, are being developed. A summary of commonly used refrigerants and their environmental impact with respect to Global Warming Potential (GWP) and Ozone Depleting Potential (ODP) is given in **Annexure C.**

Existing cold storage units surveyed in the states of Punjab and Haryana were built post-independence and comprise of an outer envelope made of brick mortar double cavity wall with rice husk filling and thermocol lining. The R-value of these envelopes has not been ascertained and as such the quality of their construction may be lacking and may not be providing adequate insulation. A poorly insulated building – with high U-value – can result in a significant increase in cooling and thereby increased energy consumption.

It is important to adhere to Building Envelope thermal transmission or U-values for cold storage and pack houses as prescribed in international standards such as ASHRAE. Existing energy

Table 6: 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	• None available	• None available
Refrigerated transport	• Evaporative cooled insulated transport boxes or trailers	• Passive cooling (insulated pallet covers)

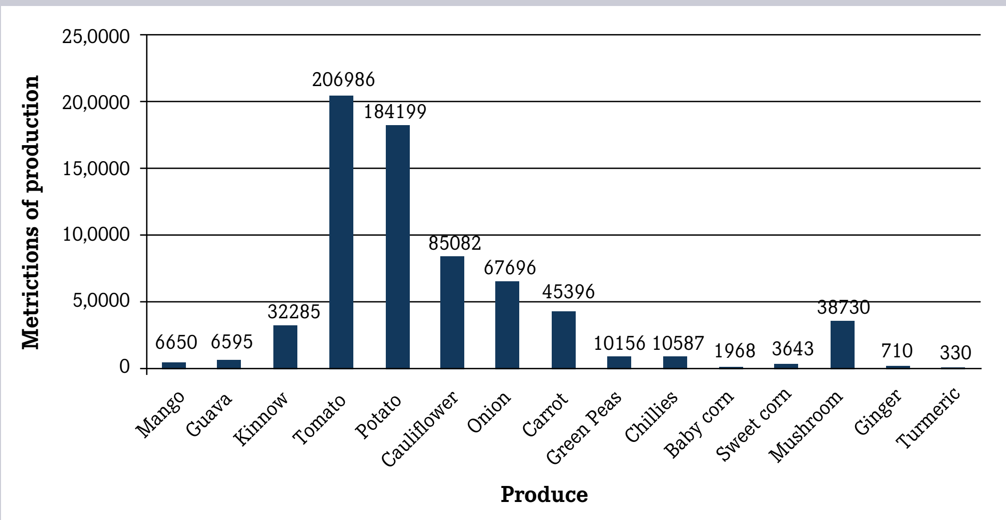
Source: *Assocham, Cold-chain technologies: Transforming supply food chains. Sathguru, 2017*

efficiency building codes are not applicable for cold-chain, so guidelines pertaining to cold-chain focus on maintaining quality and not the energy efficiency and sustainability of the system. Some of these schemes have worked better than others, however, significantly more on-the-ground support needs to be provided to develop the projects to ensure government subsidies are directed and used well.

2.7 Support from Government

The State and Central Governments through the DFI (Doubling Farmer's Income) mission as well as for agriculture and export promotion, are providing subsidies, grant-in-aid and soft loans for supporting farmers, farmer producer organizations (FPOs) and private entrepreneurs. Some

Figure 8: Horticultural produce in Haryana surveyed by Department of Horticulture for cluster formation in CCDP



Source: *Haryana Fresh 2018.*

of these schemes from the Central Government and the Government of Haryana, are listed in Table 7.

Following communications with officials from the State Government of Haryana, the Horticulture Department's Crop Cluster Development Program (CCDP) was identified as one of the most progressive and advanced schemes to promote clean and efficient cold-chain infrastructure. The Department of Horticulture, along with the Small Farmer's Agri-Business Consortium, Haryana (SFACH) has developed crop clusters, assessing the tonnage of production and growth season for different crops (Fig.9). The Department has an overall budget of ₹510 crore(US$ 73million) for providing upto 70% subsidy to Farmer Producer Organizations (FPOs) for cold-chain infrastructure including pack houses, ripening chambers, sorting and grading facilities, cold storage and reefer vehicles. The scheme has received proposals from 47 FPOs and has already shortlisted and issued a Letter of Intent (LOIs) to 21.

Table 7: Schemes from the Central Government and the Government of Haryana

CENTRAL GOVT. SCHEMES			
S.No.	**Scheme**	**Funding for**	**Extent of Funding**
1.	Mission for Integrated Development of Horticulture (MIDH)	Energy Efficient Cold Storage Infrastructure up to 10,000 MT	None available
2.	Scheme for Integrated Cold-chain and Value Addition Infrastructure under PRADHAN MANTRI KISAN SAMPADA YOJANA	Integrated Pack House, Ripening Chamber, Cold Storage Units, CA units, Reefer vehicles and similar infrastructure	Grant-in-aid of up to 50% of cost for all states and 75% of cost for N-E States
3.	SFAC Venture Capital Assistance Scheme	Agriculture and allied sectors	Interest free venture capital to agribusiness projects by way of soft loans to the extent of 26% of promoter's equity or 50 lakhs (US$ 71500) whichever is lower.
4.	Central Sector Integrated Scheme on Agricultural Cooperation (CSISAC)	Marketing, Processing and Storage	Grant-in-aid/ subsidy of up to 25% of project cost capped at ₹5 cr (US$ 0.71million) per project per proposal
5.	Financial Assistance under Agriculture and Processed Foods Export Promotion Scheme of APEDA	Agri-Exporters for pack houses, precooling units, cold storage and refrigerated transportation etc., cable system for handling of crops like banana, pre-shipment treatment facilities such as irradiation, Vapour Heat Treatment (VHT), Hot Water Dip Treatment (HWDT), etc.	Up to 40% of the total cost subject to a ceiling of ₹100 lakhs (US$ 0.14Million) for each of the activities

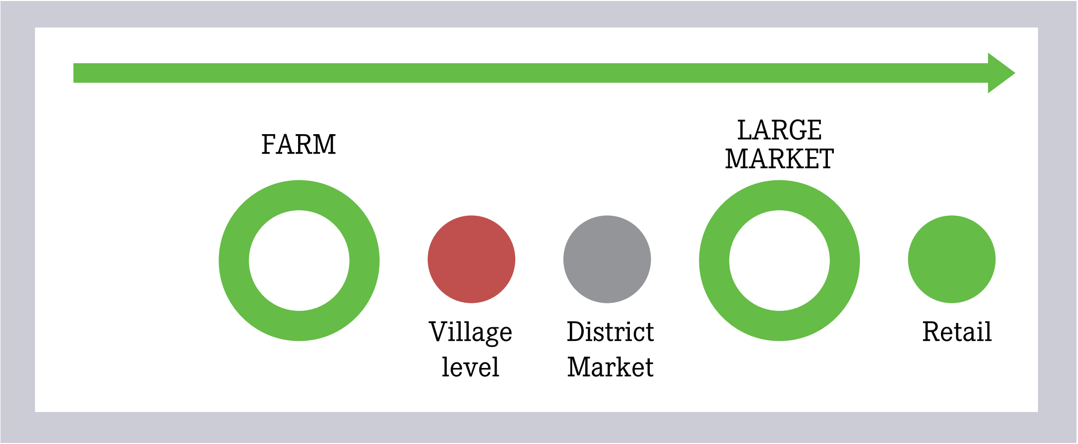
HARYANA STATE GOVT. SCHEMES			
S.No.	**Scheme**	**Funding for**	**Extent of Funding**
6.	Assistance to set-up Food Parks in 'C' and 'D' category (categories defined as per the location)	Individual units as part of Food Parks	25% Capital Investment Subsidy on FCI (fixed capital investment) limited to ₹1 cr (US$ 0.14 million); 100% SGST reimbursement for 10 years
7.	Assistance to set-up Food Parks in 'C' and 'D' category	Individual units as part of Food Parks	25% Capital Investment Subsidy on FCI (fixed capital investment) limited to ₹50 lakhs (US$ 71000); 100% SGST reimbursement for 10 years
8.	Support for Integrated Cold-chain and Value Addition Infrastructure	Storage infrastructure, packhouses, transportation infrastructure, value addition and processing infrastructure and irradiation facilities.	35% Capital Investment Subsidy on project cost limited to ₹5 cr (US$ 0.71 million)
9.	Support for establishing backward and forward linkages in rural areas	For creating effective backward & forward linkages for perishable agri-horti produce through setting up of minimum processing facilities such as primary processing centers/collection centers at farm gate, distribution hub and retail outlets at the front end	50% Capital Investment subsidy on project cost limited to ₹2.5 cr. (US$ 0.36 million) for rural areas across state and 50% Capital Investment subsidy on project cost limited to ₹3.5 cr. (US$ 0.5 million) in rural areas in "C" and "D" category blocks.
10.	Special support to promote integrated packaging of horticulture produce i.e. Fresh Fruits and Vegetables grown in the state	Integrated packhouse(s) for horticulture produce i.e. fresh fruits and vegetables.	Upper limit of capital investment subsidy to the tune of up to ₹3.5 Cr (US$ 0.5 million) (50% capital investment up to the limit of ₹3.5 cr.)
11.	Crop Cluster Development Programme (CCDP) in "Baagwani Villages" under Plan scheme on "On-farm and Marketing Support to Horticulture Farmers"	Setting up cold-chain related infrastructure	70-90% on the component of eligible project cost up to ₹6 cr (US$ 0.86 million) per integrated project including plant and machinery

Source: *Possible Financing Mechanisms to Facilitate Investment in Clean Cold Chain Nabcons 2018*

3. BUSINESS-AS-USUAL OF COLD-CHAINS

To assess the social, economic and technical aspects of cold-chain, it is important to understand the user requirements and perspectives. This chapter outlines case studies of cold-chain users to capture material flow (material loss and value loss of the farm produce); energy flow including GHG, GWP, ODS; financial flow within and outside individual value chains; technology and applications; schemes and support provided by various government departments; and business models adopted. The Business-As-Usual (BAU) cold-chain scenario is depicted in (Fig.9).

Figure 9: Cold-chain - Business-As-Usual (BAU) scenario



3.1 Empirical Evidence from Haryana

Pilot visits were conducted at *mandis* (farmer markets), pack houses, cold storage units and bulk cold storage units in Panchkula, Sonepat and Shahbad in Haryana, and Ropar in Punjab – to provide an initial understanding of the functioning, resources, supply chain and operational requirements. In addition, 7 stakeholder consultations were organised in collaboration with like-minded organizations in Mumbai, Delhi, Chandigarh, Ahmedabad and Washington D.C. A summary of the key consultation workshops is given in Annexure E.

Government Commissioned Packhouses to Support Mandis Operated by Individual Farmers/ FPOs/ Wholesalers

The packhouses commissioned by government of Haryana around 2010-12 at *mandis* located at Shahbad, Panchkula and Kurukshetra are available on lease. The Farmer Producer Organization (FPO)-operated *mandi* at Panchkula is equipped with a packhouse of capacity 5 MT. The FPO includes more than 300 marginal farmers who sell a variety of fruits and vegetables sourced from their own fields in the region. Every participating farmer has been given a membership card to occupy and set up a small retail shop in the space provided at the *mandi*. The FPO also manages wholesale trading of other agricultural products. Similarly, individual or group of farmers and FPOs run *mandis* at Shahbad and Kurukshetra as well. The packhouse at Shahbad has one pre-cooling unit of 5 MT; storage space of more than 100 MT; cold storage units of 25 MT for potato and other vegetables and fruits; and a 20 MT ripening chamber. Cooling technology used in all of these is Freon-based VCC refrigeration system and equipment supplied by *Blue Star* and *Bitzer*.

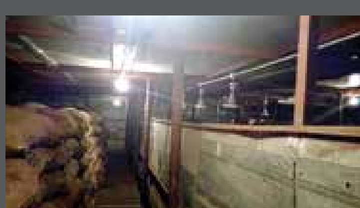
Privately-Owned Cold Storage at Sonepat, Haryana

Set up in 2006, the bulk cold storage at Sonepat handles 11,000 MT of apple, kiwi, banana and other fruits sourced from Himachal Pradesh, Kashmir, and Assam. It supplies to various locations within India and handles import-export trade with Iran, New Zealand and other countries. Most of its customers are wholesalers and retailers from Delhi, Mumbai, Bangalore, Hyderabad and Sikkim. It deals directly with farmers except for a few FPOs in Shimla.

The facility was setup with a financial support of 40% subsidy and land that was available for a low price under the mega food park scheme.

It has state-of-the-art equipment with Controlled Atmosphere (CA) conventional Freon-based VCC refrigeration system. Solar PV is installed which helps to reduce the energy bill by 10%. The ROI was 6 years and profit margins range from 10% to 40 %.

Privately Owned Cold Storage at Ropar, Punjab



This privately owned facility, in Ropar, is more than 30 years old. It has a 22,000 MT cold storage capacity. It handles potato (seeds), apple, banana, flowers, butter, and produces ice blocks to cater to local needs. Most of the customers are from the region. Another equally old cold storage in the vicinity with the capacity of 11,000 MT deals with apple (domestic as well as import-export), banana, potato and ice-production. Both facilities use ammonia based VCC refrigeration system and ensure capacity utilization of 80%.

The supporting packhouses in Shahbad and Panchkula were under utilized. According to the users, following are the reasons for poor utilization of the facilities.

- Lack of appropriate infrastructure to transport the produce from farm-gate to the packhouse.
- Limited financial capacity of marginal and small farmers to store the produce at the farm-gate. They therefore try to encash the produce as soon as possible. Distress sale is a well- known phenomenon.
- Higher cost of electricity coupled with lower operational efficiencies

3.2 First and Last Mile Considerations in Cold-Chain

Field studies show that most of the wastage occurs at first mile (the flow of produce from the farm-gates to a local aggregator) and last mile (final haulage of produce from the wholesale markets closer to the centres of food demand in towns and cities – to retail chains) of the cold-chain. The first stage of the cold-chain is important to ensure longer holding life of the products. Cold-chains need to be created through a bottom-up approach as last mile logistics are also not in place.

Only large and established business formats have been able to utilize the cold-chain. However, most of the farmers in India have small and medium size land holding (below 4 ha). Thus, there is a strong need to create support for building capacity at first and last mile to realize the Government of India's goals on Doubling Farmers' Income.

Barriers to the deployment of cooling technologies were identified throughout the perishable produce food supply chain, from first mile to last mile. In addition, a number of overarching issues that have implications across the cold-chain were noted.

1. First mile failures and barriers

There is currently limited availability of infrastructure and technology suitable for first mile business processes, including:

- Limited capacity for storage at farm gates;
- Lack of adequate/ continuous power supply;
- Inadequate knowledge and skills to carry out processes efficiently to ensure productivity and financial viability.
- Furthermore, for many farmers operating at small-scale the use of existing cold-chain facilities incurs high costs.
- Despite some government activity, there is an overall lack of policy support to facilitate first mile processes in the cold-chain; the focus remains further along the value chain, closer to last mile processes. Even where the government has developed pack-houses, there is often poor use of these facilities due to:
    - o Lack of appropriate infrastructure to transport the produce from the farm-gate to the pack-house. First mile transportation is dependent on farm vehicles such as tractor trailers, which are inadequate in maintaining freshness of horticultural produce and lead to losses. Conventional refrigerated reefer vehicles are financially unaffordable for farmers unless the services are grouped under an FPO or cooperative;
    - o Limited financial capacity of marginal and small farmers to store the produce at the farm-gate;

- o Higher cost of electricity coupled with lower operational efficiencies;
- o Poor operation and maintenance of facilities;
- o Lack of understanding of business, specifically farm to fork business models.

2. Last mile failures and barriers

A lack of appropriate infrastructure and utilisation of equipment as well as a failure to take full advantage of the potential of new technologies is resulting in barriers in the last mile of cold-chains in India.

- Many businesses providing logistical support from warehouses to retail shops are not organised businesses, which results in haphazard network management.
- With an advent of e-commerce in India, the logistics process is not fully developed to optimize supply and demand in the food produce value-chain.
- There is low use, if at all, of IT techniques to optimise haulage using a hub-and-spoke model.
- There is a lack of infrastructure (right-of-way to food supply vehicles as an example) and technology (e.g. low-carbon transportation including refrigerated small trucks using phase-change materials to retain produce quality), which prevents appropriate transportation of goods from large warehouses close to town/city centres on to retailers.
- The equipment used in the transfer of produce from physical to mobile infrastructure is not always best suited to handling perishable food produce.
- There is a lack of space and infrastructure within retail stores leading to sub-optimal management and storing of produce.

3. Failures and barriers with implications across the cold-chain

- Attention has been focused in India on cold storage rather than the cold-chain as a whole. During the fieldwork it was evident that policy-makers continue to an approach of incentivising cold-rooms, instead of supporting the transfer of goods from farm-gates to retailers. In several states, such as Haryana and Maharashtra, current policy is to create large cold-rooms instead of locating smaller cold-rooms/pack-houses close to farm-gates, which would facilitate better use of storage. The latter would also enable better mapping of the release of produce to markets, resulting in maximised use of surpluses.
- There is a lack of knowledge and skills which hampers use of the cold-chain:
    - o There are varying literacy levels amongst farmers;
    - o Many farmers lack knowledge of optimum post-harvest care of produce;
    - o A 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 could be.
- There is a poor understanding among farmers and policy makers of the techno-economics of the cold-chain, from farm to fork, and the benefits this can bring in terms of reducing food produce losses and maximising income to farmers.
- Market data does not reach farmers, preventing them from maximising the profit from their produce. All the produce harvested in a given location tends to be transported from

crop clusters to the marketplace at the same time, creating a surplus and depressing produce prices, and this is exacerbated in areas of crop clustering. If farmers could access timely information of market demand and pricing they could instead stagger harvesting and release produce to the market at stabilized/assured pricing.

- There are no direct incentives to farmers to adopt cold-chain technologies, particularly in comparison with Minimum Sales Price of produce, which insure farmers against contingencies.

3.3 Understanding Cold-Chain through Case Studies

Based on field visits and personal interviews, four case studies of organizations currently using or proposing to use cold-chain infrastructure, are presented below. Of the four case studies, Case Studies 1 and 2 are from recently formed Farmer Producer Companies (FPCs) - Crown Fruits and Vegetables Producer Company Ltd. and Optimal Agro Producer Company Ltd. - that have been issued a Letter of Intent (LOI) from the Horticulture Department of Haryana. Case Studies 3 and 4 are privately owned companies AHA LLB and Elle.

The case studies provide organization information, and material, finance and energy flows through the different stages of the cold-chain from farm-gate to the retail market.

CASE STUDY 1: CROWN FRUITS AND VEGETABLES PRODUCER COMPANY LTD., KURUKSHETRA, HARYANA

A multi-crop FPC, its major produce comprises potato, tomato, onion, capsicum and cucurbit. Presently, most farmers in the FPC sell their produce at local markets. Through the Crop Cluster Development Program (CCDP) of the Govt. of Haryana, the FPC aims to reduce the wastage of produce, which is currently estimated at 15-20% of the total, and avail higher market value for their produce by selling in markets in Delhi and Himachal Pradesh. It is investing in commissioning an integrated packhouse with 3 lines for sorting, grading and packaging.

It is planned to transport the produce through regular open haulage trucks to Delhi in a single day. The reefer vehicles will be used for transporting the produce to Himachal Pradesh. Currently, the produce (tomato) is sold at average price of ₹5 per kg. (US$ 7cents) In new identified markets, the same produce will fetch up to ₹40 per kg(US$ 56cents per kg). The annual sales are expected to increase from ₹245 Lakhs (US$ 0.35 million) to ₹2584 Lakhs, (US$ 3.74 million) where wastage is reduced to 5%. The likely cost of additional supply chain components would be around ₹17 to 20 per kg. (US$ 25 cents to US$ 29 cents per kg) The investment is expected to increase income of individual farmers substantially.

	Farm gate	Integrated Pack house	Reefer Transport	Market
Organization Information	FPO with more than 500 acres farmland, 700 farmers, Cluster Land Production throughout the year	Pack house with 3 lines for sorting grading and packing Line 1 – Tomato – 5 MT/ hour Line 2 – other vegetables – 2 Mt/ hour Line 3 – Potato onion and grading Cold room cum staging unit – 280 MT Cold storage – 3000 MT	Contracts out reefer vehicles if required for serving markets at Himachal	Anandpur mandi at Delhi, Himachal
Material flow through cold- chain	Annually 6800 T produced: Potato ~ 3000 T, Tomato ~ 5OOT, 0nion ~ 600 T, Capsicum ~ 300 T, Cucurbit ~ 2400 T 20 % material loss (~ 1360 T)	100 % material flow (possible) through cold storage ~ 5440 T 2 % material loss (~ 109 T)	material flow through reefers (~ 5331 T) Losses 3 % ~ 160 T	5 % material loss (~ 259 T) Total Sales 4913 T Current sales at ₹5/kg ~ ₹245 lakh (US$ 7 cents/kg ~ US$ 0.35 million) Expected sales at ₹40/kg (US$ 57 cents/kg) (assuming 5 % losses) ~ ₹2584 lakh(US$ 3.7 million)
Financial flow through cold-chain	Annually 6800 T produced: P~3000 T, T ~ 500T, O ~ 600 T, C1 ~ 300 T, C2 ~ 2400 T 20 % material loss (~ 1360 T)	Total investment: ₹742.8 Cr, (US$ 0.1 billion) GoH subsidy: ₹531.21 Cr (71.5% of project cost); (US$ 76.34 million) Equity contribution by FPO: ₹59.75 Cr (8%) (US$ 8.5 million) Proposed Term loan from bank: ₹150 Cr (20%); (US$ 21.5 million) Arrangement by FPO from other means: ₹1.85 Cr (0.2%) (US$ 0.26 million)	Cost ₹4.5/ kg/ km for reefer (US$ 60 cents/kg)	
Energy and environmental footprint of cold- chain		Annual Electricity for only cold storage ~ 172 lakh units ~ ₹1379Lac(US$ 1.98 million) ₹5/kg (US$ 7 cents/kg) ~ ₹245 lakh ((US$ 0.35 million) GWP ~ High (10 to 100) ODS ~ 0.05	Diesel consumption for engine – 35,171 Ltr (₹28 lakh) (US$ 40040) Diesel consumption for cooling – 22,510 Ltr (₹18 lakh) (US$ 25740) GWP ~ High (10 to 100) ODS ~ 0.05	Total increase in electricity cost is 53 % of expected annual turn over Total increase in diesel cost is 1.8 % of expected annual turn over

CASE STUDY 2: OPTIMAL AGRO PRODUCER COMPANY LTD., AMBALA, HARYANA

Optimal Agro Producer Company Limited is an FPO with 160 farmers located at Ambala in Haryana. Annual aggregate production is estimated at 7100 MT comprising mainly Papaya, Marigold, Sweet-corn, Capsicum, Tomatoes and Banana. It plans to sell the produce at local Mandis and Azadpur Mandi at Delhi.

Through the Govt. of Haryana's CCDP, the FPO is investing in commissioning an integrated Pack-House with processing lines for grading, sorting, packaging, 7 ripening chambers with capacity of 16 to 20 MT each, 1 cold storage with capacity of 20 MT, 1 pre-cooling chamber with capacity of 16 to 20 MT.

It is estimated that the cold-chain will provide scope for expanding the markets up to Kolkata, Siliguri, Hyderabad, Kota and Mumbai. The FPO aspires to utilize cold-chain to increase turn over to ₹1971 lakhs (US$ 2.82 million) by realizing highest economic value and reducing the waste to 5%. Further, after a few modifications in farming processes the produce will be compliant for markets in UAE and would be fetching ₹400 per kg (US$ 5.70) per kg

	Farmgate	Integrated Packhouse	Reefer Transport	Market
Organization Information	FPO with 500 acres farmland, 160 farmers, Cluster Land Production throughout the Year	7 ripening chambers of 16 to 20 MT 1 cold storage (15 T) 1 pre-cooling chamber of 16 to 20 MT) including grading, packing and cold-room facilities Total storage capacity would be 180 T X 3 = 540 T	Contracts out reefer vehicles if Required	Current market at local mandis, Anandpur mandi at Delhi. Expected market at Kolkata, Siliguri, Hyderabad, Kota and Mumbai (holding time 4 months) Exports to UAE in future
Material flow through cold-chain	Annually 7100 T produced 20 % material loss (~ 1420 T) T	Material flow through cold storage ~ 5680 T 2 % material loss (~ 114 T)	100 % material flow through Reefers (~ 5566 T) 3 % material loss (~ 167 T)	Current sales 5399 T at ₹5/kg (US$ 7 cents/kg) ~ ₹256 lakh (US$ 0.36 million) Expected sales 6745 T at ₹40/kg (US$ 57 cents/kg)~₹1971 lakh (US$ 2.82 million)
Financial flow through cold- chain	Major cost components: Raw material and man power	₹3.93 Cr (total project cost) (US$ 0.56 million) ₹2.61 Cr (govt. subsidy) (US$ 0.37 million) ₹1 Cr (bank loan) (US$ 0.14 million) ₹0.3 Cr (FPO equity contribution) (US$ 0.04 million)		
Energy and environmental footprint of cold-chain		Annual Electricity for only cold storage ~ 47,30,400 units ~ ₹378 lakh (US$ 0.54 million) GWP ~ High (10 to 100) ODS ~ 0.05	Diesel consumption for engine – 2,85,913 Ltr (₹228 lakh) (US$ 0.33 million) Diesel consumption for cooling – 182,984 Ltr (₹146 lakh) (US$ 0.2 million) GWP ~ High (10 to 100) ODS ~ 0.05	Total increase in electricity cost is 19.2 % of expected annual turn over Total increase in Diesel cost is 19 % of expected annual turn over

CASE STUDY 3: AHA LLB, SHAHBAD, HARYANA

AHA LLB is a private company run by a progressive farmer and entrepreneur. Through contract farming it produces 3500 MT of iceberg lettuce, tomato and capsicum annually and supplies to Quick Serving Restaurants (QSRs) such as Subway and McDonald's at Delhi and Mumbai through reefer vehicles. Currently, 400 farmers cumulatively owning 500 acres of farmland are engaged in Himachal Pradesh. The company provides full assistance to farmers in terms of capital investment for nursery development, drip irrigation, power pumps, sprinklers, technical inputs, monitoring and scheduling and assures farmers 100% buy back. Thus, farmers are insulated from the market shocks. The company owns the cold storage facilities and maintains the entire cold-chain through contracting. The capital cost of a 15MT integrated pack house is estimated at ₹20 lakhs (US$ 28600) and operational cost at ₹1 lakh (US$ 1430) per month.

Having an established business, the company now aspires to expand the agricultural activities in its own land in Shahbad and is considering investing in a Pack-house of 15 MT.

	Farmgate	Integrated Packhouse	Reefer Transport	Market
Organization Information	Private Entrepreneur 500 acres farmland, 400 farmers Contract Farming, Cluster Land Production throughout the year	Cold storage – 15 MT With material handling lines	Contracts out reefer vehicles if required for serving QSRs at Delhi and Mumbai	Market at Delhi, Mumbai
Material flow through cold-chain	Annually 3500 T produced: Potato – 2000 T Tomato – 1000 T Capsicum – 500 T	2800 T through cold storage	Material flow through Reefers (~2744 T)	Total Sales 3325 T Current sales at ₹1330 lakh (US$ 1.9 million) Exports not viable due to very high air freights
Financial flow through cold-chain	Major cost components: Raw material and man power	Capital cost: ₹20 lakhs; (US$ 28600) Operating cost: ₹1 lakh (US$ 1430) per month(approx.)	Cost ₹20/ kg(US$ 29 cents/kg) for Mumbai ₹12/kg (US$ 17 cents/ kg) for Delhi	
Energy and environmental footprint of cold-chain		Annual Electricity for only cold storage ~ 30,22,200 units ~₹242lakh (US$ 0.34 million) GWP ~ High (10 to 100) ODS ~ 0.05	Diesel consumption for engine – 53,569 Ltr (₹42 lakh) (US$ 60000) Diesel consumption for cooling – 34,284 Ltr (₹27 lakh) (US$ 38610) GWP ~ High (10 to 100) ODS ~ 0.05	Total increase in electricity cost is 18 % of expected annual turn over Total increase in Diesel cost is 5.3 % of expected annual turn over

CASE STUDY 4: ELLE, KARNAL, HARYANA

Elle Farms is a proprietorship company located at Karnal, Haryana. It produces about 60 T of button mushrooms annually. The production is climate-controlled mechanized process. It has an integrated post-harvest management unit with equipment for sorting, grading and packaging, a pre-cooling unit, a 30 MT cold room with a Freon based VCC refrigeration system. They have also installed Solar PV 60 kW with net metering to reduce the energy bill.

Currently it supplies to markets at Karnal, Panipat and NCR- Delhi. It is aspiring to reach out to markets in Mumbai and Bangalore. Current revenues including at retail outlet at Karnal and at other markets are at ₹43.35 lakh (US$ 60000). At newer markets the price will be ₹150 per kg (US$ 2.15).

	Farmgate	Integrated Packhouse	Reefer Transport	Market
Organization Information	7 Acres, leased farmland, Cluster Land Produced under controlled temperature and humidity Mechanization level: Tractors, trolley, ripper, all farm equipment, fully mechanized farming	Sorting, grading and packaging. Pre cooling Unit Cold storage with 2 to 25 degree – automatic timer Humidity controlled all equipment 30 MT cold room with VCC using Freon Solar PV 60 kW with net metering	Own 3 reefer vehicles, contracts out other vehicles if required	Current market at Karnal, Panipat, NCR, Delhi. Future possibilities in Mumbai, Bangalore
Material flow through cold- chain	Annually 60 T Button Mushrooms produced 25 % material loss (~ 12 T)	100 % material flow through cold storage unit (~ 48 T) 40 % sales at retail outlet (~ 19.2 T) 2 % material loss (~ 1 T) Sell at ₹100/ kg(US$ 1.43) ~ turnover ₹19.2 lakh (US$ 26961)	100 % material flow through Reefers (~ 28 T) 3 % material loss (~ 1 T)	Current: 5 % material loss (~ 2 T) Sales of 24 T Sell at ₹100/ kg (US$ 1.43/kg), ~ ₹24 lakh (US$ 34320) Total current sales ₹43.35 lakh (US$ 61990) Expected sales at new markets will be ₹85.5 lakh (US$ 122265)
Financial flow through cold- chain	Major cost components: Raw material and man power	Capital Cost ₹2.5 Cr (US$ 0.36 million) (covered through loan) Cold room cost ₹1.5 Cr (US$ 0.2 million) (40% ~ ₹60 lakh (US$ 90000) through subsidy, other part through loan) Solar PV with 70 % subsidy	Cost ₹4.5/ kg (US$ 6 cents/ kg) for reefer ~ Total ₹1.5 lakh (US$ 2145) (including other transport related costs)	6 to 8% profit annually (including sales at both points)
Energy and environmental footprint of cold- chain		Annual Electricity ~ 1,57,680 units ~ ₹12.6 lakh (US$ 18018) Annual captive diesel consumption ~ 1500 Ltr ~ ₹1.2 lakh (US$ 1716) Solar PV 60 KW with net metering GWP ~ High (10 to 100) ODS ~ 0.05	Diesel Cost ₹1.23 lakh (US$ 1758) ~ 1544 Ltr for engine Diesel Cost ₹0.8 lakh (US$ 1144) ~ 988 Ltr for cooling GWP ~ High (10 to 100) ODS ~ 0.05	Total increase in electricity cost is 15.2 % of expected annual turn Over Total increase in Diesel cost is 2.4 % of expected annual turn over

3.3 SWOT Analysis of existing Business Models

Based on interaction with users and stakeholders of various cold-chains, a SWOT (Strength, Weakness, Opportunity and Threats) analysis was performed to study the pros and cons of each existing business model. The SWOT Analysis is presented in Table 8.

Table 8: SWOT analysis of various types of existing business models

	Strengths	Weakness	Opportunities	Threats
Government owned, available on lease	✓ Readymade infrastructure available (time and resources saved) ✓ No capital investment by users for developing infrastructure ✓ Not affected by market turbulence	✓ End users are not directly engaged – does not cater to needs of farmers ✓ Lack of man power, funds, expertise, etc ✓ Delays in paperwork, daily decision making processes etc.	✓ Huge unutilized infrastructure ✓ Easy to provide support through subsidies and schemes ✓ Clean and Energy-efficient technologies can be tried and tested ✓ Other formats such as BOT (Build, Operate, Transfer) can be adopted	✓ No economic viability of the facilities ✓ The liability of financial returns is distributed and not guaranteed.
FPO owned	✓ End users are directly engaged ✓ Culture of cooperation promotes the synergy in business processes ✓ Direct share in the monetary benefits of the organization implies efficiency ✓ Improvement of skill sets, knowledge, and awareness on newer practices, processes and outputs	✓ The culture of cooperativeness is limited, as groups are solely held together by market principles ✓ Organizational issues - contract designing, distribution of incentives, monitoring of members, land holding patterns, crop selection, collectiveness of resources etc. ✓ Lack of knowledge of technology and appropriate infrastructure required	✓ Members can provide and exchange resources in the group for common benefit ✓ Possibility of streamlined mass production system ✓ Multiplier effect of income generation, employment and output	✓ Share-holding pattern may create fractions in FPO ✓ Power struggle is an inherent feature. The FPO run facility may be captured by the bigger players, especially who owns the land on which the facility is created
Individual Owned or Private Company	✓ Profits being the core principle, leads to better capacity utilization and efficiency ✓ Easy to adopt newer processes and technologies ✓ Easy to develop contracts, for example, contract farming	✓ Attracts large formats ✓ Limited scope for small and marginal farmers ✓ Financial burden is not shared ✓ Capacity to absorb market shocks is minimal	✓ Farm size in Punjab/ Haryana is larger than other states; majority farmers have land holding of more than 1 Acre – Enough to create individual facilities. ✓ Development of entrepreneurship, skills sets	✓ Monetary benefits are concentrated; profits are not shared with farmers ✓ Possibility of over-exploitation of land, water and other resources, which may pose a threat to food security

4. TECHNOLOGY HORIZONS

4.1 Energy Efficient and Clean Cold-Chain

While the increase in cold-chain infrastructure brings hope to improve market connectivity and reduce food loss in the agriculture sector, this is likely to come with huge energy costs, carbon dioxide emissions and if designed in conventional western world style, with the potential of causing grave damage to the ozone layer, in addition to the climate crisis.

As a signatory to the Paris Convention and the Kigali Amendment, India, while gearing up to its developmental goals, will also have to live up to its Nationally Determined Contribution (NDC) in terms of GHG emissions. It is here that a system-level thinking of energy requirements for cold-chain and the cold economy as a whole, comes into play.

The University of Birmingham in its report on 'India's Third Agricultural Revolution – Doubling Farmer's Income through Clean Cold-chains', suggests the creation of a series of regional 'living labs' called the India Clean Cold-chain Centers as a means of solving the interlinked challenges of clean cold-chain development. These centers would demonstrate and evaluate the cold-chain as a continuous chain of sustainable technologies connecting farm to consumption center, rather than as a series of isolated facilities. They would demonstrate not only clean cold technologies, but also the business and funding models, skills and market engagement needed to support them in the Indian context, and would also catalyze the growth of manufacturing supply chains. The report explores the potential of using new alternative technologies: phase change materials, use of compressed air and LNG, waste heat recovery, Solar PV and Concentrated Solar as well as other renewable energy sources in a seamless end-to-end cold-chain model developed and designed specifically for Indian farming communities (Birmingham Energy Institute, 2017).

4.2 Technology Horizons

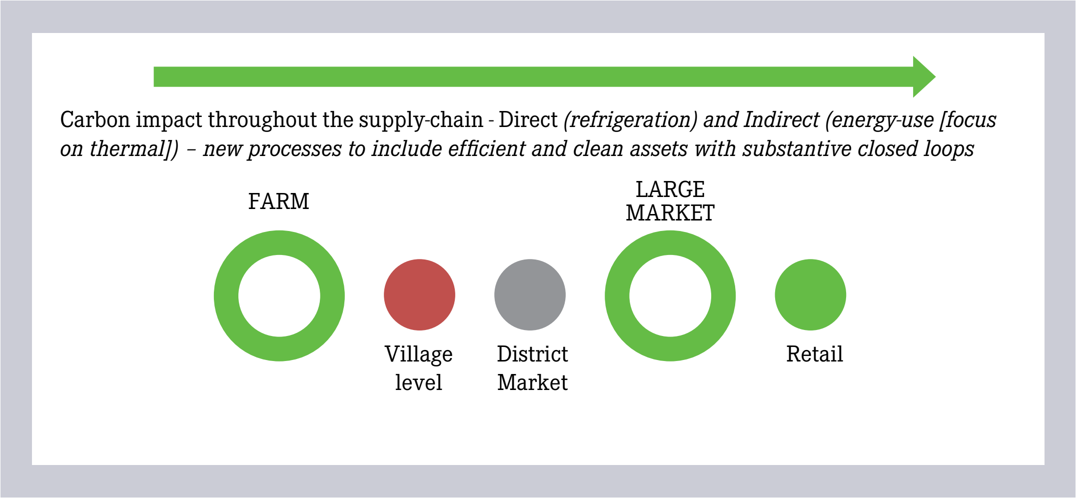
Cooling is energy intensive. According to the Green Cooling Initiative (GCI), led by GIZ Proklima, the worldwide cooling sector consumes 3900 TWh (2018 levels) and is projected at current consumption rates to increase by 90% to 7500 TWh in 2050. Total carbon dioxide emissions from cooling amounted to 4 GT of CO2e in 2018 (University of Brimingham; The Institute for global intervention; Birmingham Energy Institute, 2018).

Upcoming and innovative technologies in cold-chain are mainly related to alternative sources of energy for cooling. Either renewable energy source 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.

The schematic diagram of the cold-chain integrating clean and energy efficient technologies is given in Fig. 11.

Figure 10: Schematic diagram of the cold-chain integrating clean and energy efficient technologies



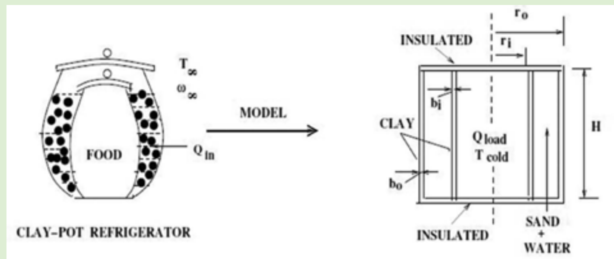
Based on a workshop on technologies for sustainable and energy efficient cold-chain in India organized in October 2018, a list of technologies have been summarized in Table 9 below. The table segregates the technologies under 6 major sections:

1. First Mile – Farm Gate
2. First and last Mile Transportation
3. Packhouses / Cold Storage / Bulk Storage
4. Reefer Vehicles
5. Processing applications
6. Multi-sector applications

This study has found that clean and energy efficient and clean technologies for cold-chain deployments in India are available. However, apart from a small number, they are still at the early adoption stage and localisation through adaptation to in-country and regional, cultures, skills and practices, is required.

Table 9: Clean Cold-chain technologies

CLEAN COLD-CHAIN TECHNOLOGIES

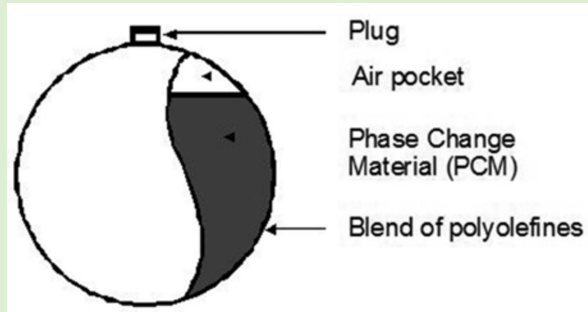
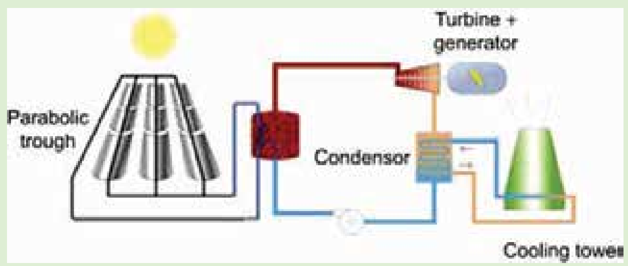
	1. FIRST MILE – FARM GATE			
Technology and Company Name	**Technology Description**	**Technology Diagram**	**Capacity Range**	**Reduction in GHG / ODP /GWP**
Zero Energy Vegetable Storage using Evaporative Cooling *CTARA (Center for Technology Alternatives for Rural Areas), IIT Bombay* ***Vikash Jha*** *cae188vikashkumarjha@gmail.com* *http://www.ctara.iitb.ac.in/*	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.		2	GHG ODP GWP

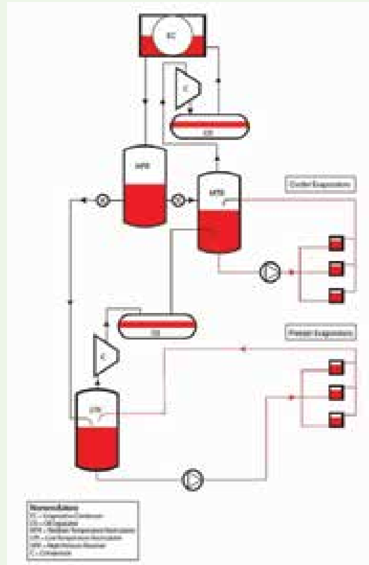
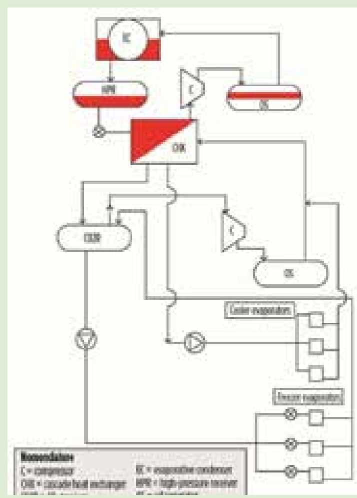
2. FIRST AND LAST MILE TRANSPORTATION

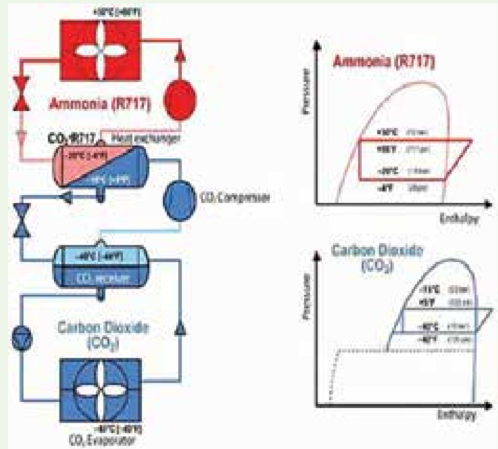
Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
Phase Change Materials (PCM) technologybased Chest Freezers/Coolers *Pluss Advanced Technologies Pvt. Ltd.* *Vishnu shashidharan* *vishnu@pluss.co.in* *http://www.pluss.co.in/*	Phase change 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.		200lt to 1000lt food storage capacity.	GHG GWP
PCM technology based part load shipping solution *Pluss Advanced Technologies Pvt. Ltd.* *Vishnu shashidharan* *vishnu@pluss.co.in* *http://www.pluss.co.in/*	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.		25Lt., 50Lt., 100Lt. and 150Lt. insulated boxes with PCM technology	GHG ODP GWP

Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
Electronic Level Controls *Danfoss Industries Pvt. Ltd.* *Nagahari Krishna L* *Nagahari@danfoss.com* *https://www.danfoss.com/en-in/*	Ammonia Refrigeration Controls		Electronic Controls – Any capacity	GHG
Refrigeration Drive *Danfoss Industries Pvt. Ltd.* *Nagahari Krishna L* *Nagahari@danfoss.com* *https://www.danfoss.com/en-in/*	Variable Frequency Drive Solution for Refrigeration Systems		Drives – Depending upon Motor KW	GHG

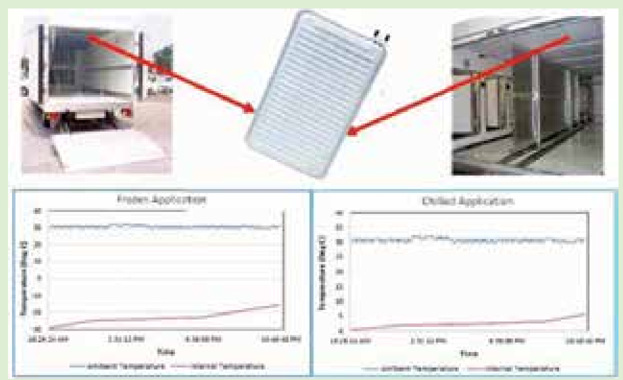
3. PACKHOUSES / COLD STORAGE / BULK STORAGE

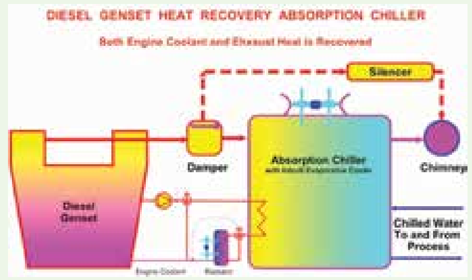
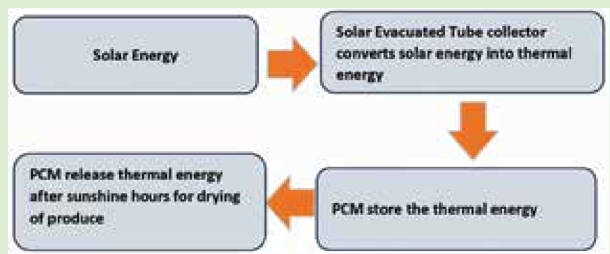
Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
Thermal Energy Storage System for low temperature (STL) applications *Kehems Technologies Pvt. Ltd.* *Rohit Yadav* *rohityadav141@gmail.com*	It is well adapted to air conditioning and industrial refrigeration systems. By smoothing the production of cooling energy, the STL optimizes the use of electrical resources and protects the environment.		Customized solutions 30 TRH to 35000 TRH	GHG GWP: 30% - 70%
PCM technology based Solar cold room *Pluss Advanced Technologies Pvt. Ltd.* *Vishnu shashidharan* *vishnu@pluss.co.in* *http://www.pluss.co.in/*	Phase change materials (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 to +4^{0}C for 16-20hrs per day.		5 MT	GHG
Concentrated Solar Thermal *Clique Solar* *Mr. Abhishek Bhatewara* *adb @cliquesolar.com* *http://www.cliquesolar.com/*	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.		VAMs of different capacities are available from different manufacturers	Helps in reducing GWP, GHG, as no fossil fuels are used

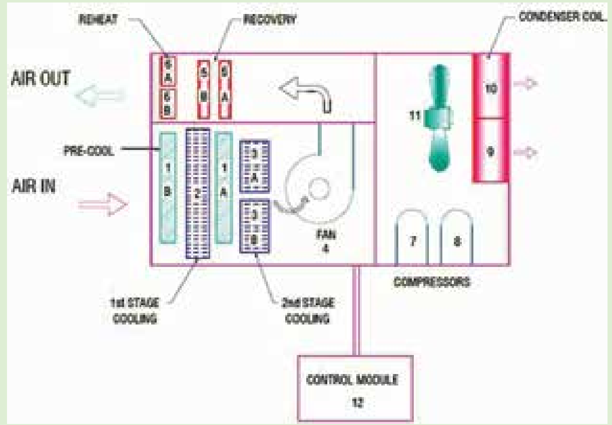
Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
Low ammonia charge system *Association of Ammonia Refrigeration* *Anand Joshi* *anand@manikengineers.com* *http://ammoniaindia.org/*	Though Ammonia is one of the better refrigerants as far 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.		50 TR and above	R717 Zero ODP and very low GWP
Efficient Ammonia /CO_2 brine system *Association of Ammonia Refrigeration* *Anand Joshi* *anand@manikengineers.com* *http://ammoniaindia.org/*	CO_2 is used in conjunction with NH3 as a cascade system, where larger quantities of NH3 can't be used due to its toxic properties. Typically, NH3 is used for high stage compression and temperatures upto -10^{0}C are be 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		50 TR and above	Proven qualities of Ammonia in reducing ODP and GWP CO_2 has GWP of 1 and no ODP

Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
Low Capacity Ammonia system *Association of Ammonia Refrigeration* *Anand Joshi* *anand@manikengineers.com* *http://ammoniaindia.org/*	Trials are being conducted to manufacture lower capacity Ammonia systems in India and in next 1 year, such systems shall be commercially available in the market		5 TR and upto 50 TR, specifically aimed at lower capacity systems	R717 Zero ODP and very low GWP

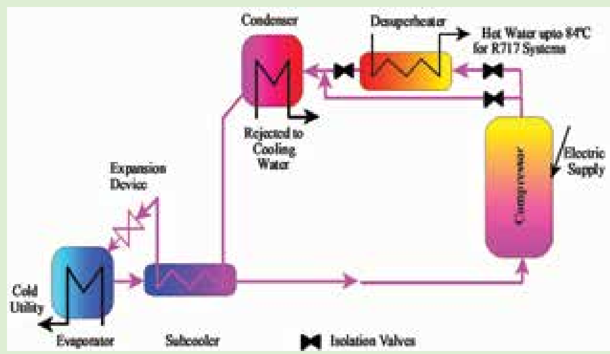
4. REEFER VEHICLES

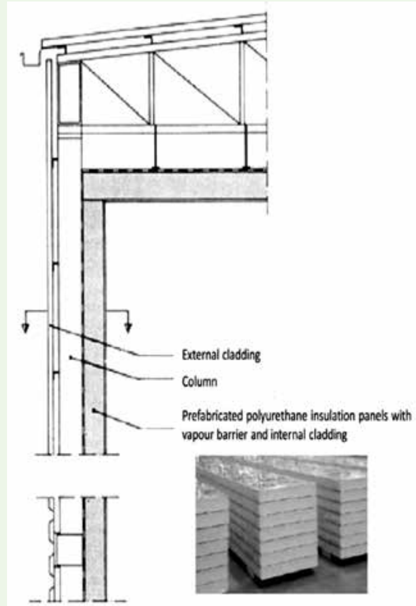
Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
PCM technology based reefer Trucks *Pluss Advanced Technologies Pvt. Ltd.* *Vishnu shashidharan* *vishnu@pluss.co.in* *http://www.pluss.co.in/*	Phase Change Material (PCM) filled heat exchanger 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.		2MT to 5MT	GHG ODP GWP

Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
Engine Exhaust Heat Recovery using Matrix Heat Recovery Unit *Dr. Milind Rane, IIT Bombay* *ranemv@iitb.ac.in https://www.me.iitb.ac.in/~ranemv/Heat_Pump_Lab.html*	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		0.3 TR to >1,000 TR	GHG ODP GWP
5. PROCESSING APPLICATIONS				
Technology and Company Name	**Technology Description**	**Technology Diagram**	**Capacity Range**	**Reduction in GHG / ODP / GWP**
PCM technology based24x7Solar Dryer ***Pluss Advanced Technologies Pvt. Ltd.*** *Vishnu shashidharan vishnu@pluss.co.in http://www.pluss.co.in/*	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.		Loading capacity of 15-20 kg/day	GHG

Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
Atmospheric Pressure Vacuum Drying (APVAC) ***Panasia Engineers Pvt. Ltd.*** *Surendra Shah* *mail.surendrashah@gmail.com* *https://www panasiaengineers.com/*	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.		Any	GHG ODP GWP

6. MULTI-SECTOR APPLICATIONS

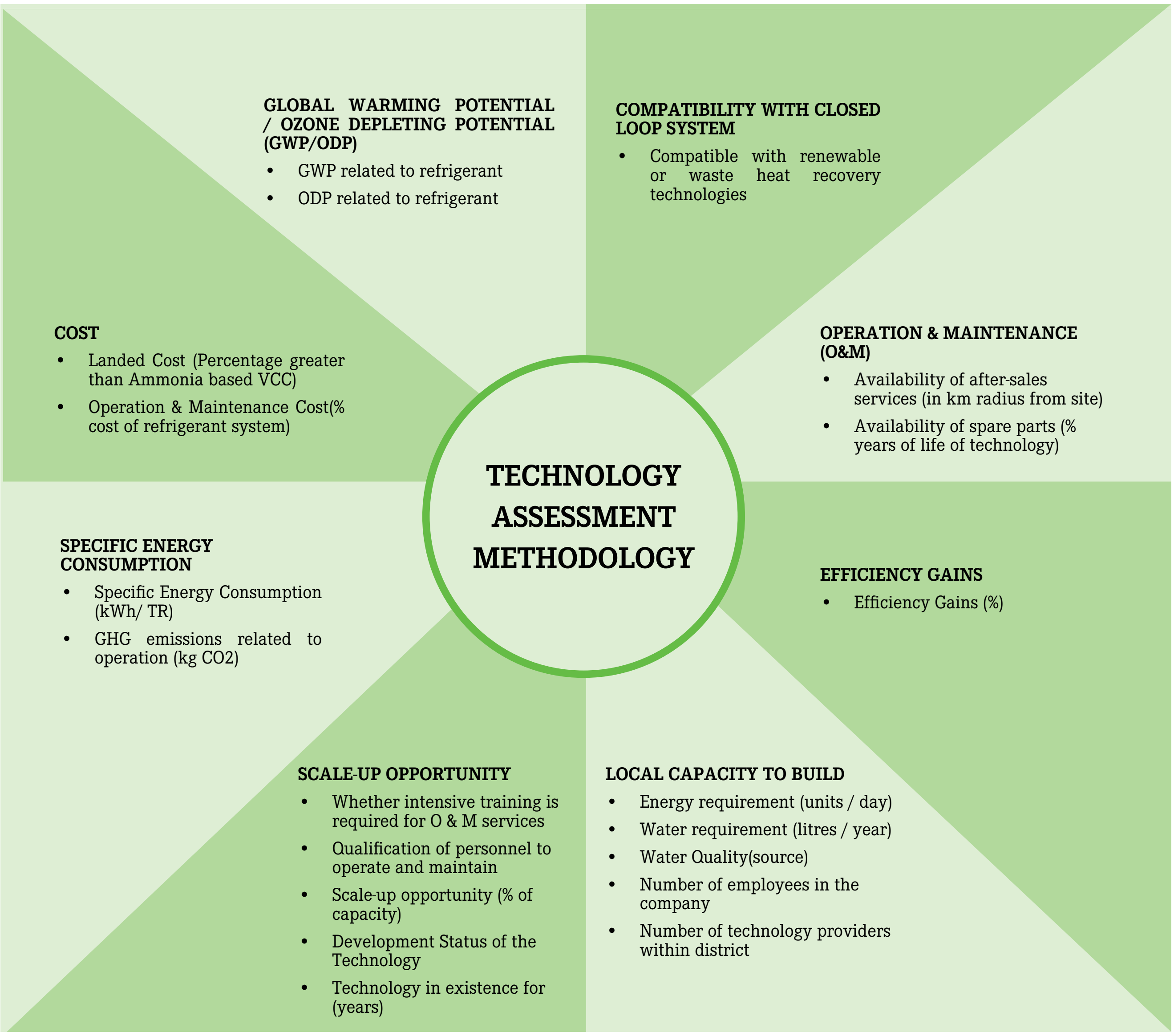
Technology and Company Name	Technology Description	Technology Diagram	Capacity Range	Reduction in GHG / ODP / GWP
Super Heat Recovery Water Heater ***Dr. Milind Rane, IIT Bombay*** *ranemv@iitb.ac.in* *https://www.me.iitb ac.in/~ranemv/Heat_Pump_Lab.html*	SHR_WH, using Vented Double Wall Tube-Tube Heat Exchangers, TT_HE		0.1 TR to >1,000 TR	GHG GWP

Polyurethane System Insulation ***Huntsman International India Pvt. Ltd.*** *Chandra Kumar Patel* *Chandra_kumar_Patel@huntsman.com* *http://www.huntsman.com/*	With lower lambda and high fire resistance for Cold-chain insulation. (Hydrocarbon as Blowing agent)			GHG ODP: 0 GWP: 11
IOT Based Controls ***Carel ACR Systems India Pvt. Ltd.*** *Sanjog Belatikar* *sanjog.belatikar@carel.com* *https://www.carel.com/*	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.	 (Source: https://yourstory.com/mystory/dd3c200f5e-revolution-in-farming)	No limitations, as long as there is internet connectivity and server space available	Helps in reducing wastages and thereby reducing GHG

4.3 Technology Assessment Methodology

There are several formal ways to assess technologies. We developed our own methodology to assess the efficacy of technologies used in clean and efficient cold-chains. The methodology involved consideration of the following 8 criteria based on the assumption that the baseline technology is a Vapor Compression Cycle (VCC) using Freon gas and a cold storage / pack house facility of capacity 250 MT. The Technology Assessment Methodology is summarized in (Fig.11).

Figure 11: Technology Assessment Methodology



Merit order of clean-cooling interventions

Each clean cooling intervention carries with it capital and operating costs, energy demand and direct and/or indirect emissions. Consideration of these factors should inform the development of cooling strategies and mix of interventions. With this in mind, a merit order ranking has been developed: interventions are ranked in highest to lowest merit order.

- Demand mitigation via behaviour or operating practice change – for example, data driven harvesting to avoid unnecessary storage and loss.
- Demand mitigation via system or application design – for example, insulation and natural ventilation.
- Making use of free cooling resources that are hyper local – for example, evaporative or sky cooling
- Making use of more remote free cooling resources via district cooling type network infrastructure – for example cooling systems that make use of bodies of water or even LNG regasification.
- Making use of other free cooling resources via conversion technologies – such as sorption cooling technologies capable of converting waste heat resources into cooling, including engine exhaust heat recovery in reefer vehicles.
- Energy consumption demand flexibility – for example, via deploying thermal energy storage to enable better integration with renewable energy resources.
- Optimum efficiency improvements and low GWP refrigerants in cooling equipment selection – for example, via enhanced performance or seasonal energy efficiency rating (SEER).

5. NEW BUSINESS PROPOSITIONS AND RECOMMENDATIONS

Successful development and implementation of the clean cold-chain could solve many issues related to high food losses in a sustainable way, delivering economic, environmental and societal benefits while reducing resource depletion for future generations. However, many of the outreach methods typically used for engaging growers, traders, storage operators, transporters and marketers do not yet incorporate clean cold-chain development and management. Given this, one must also note that successful communication is not just practical information about a single technology.

It is clear from the research and analysis undertaken for this report that the conventional ways of dealing with cold-chains needs substantial change. Based on the findings of the study, MP EnSystems Advisory Pvt. Ltd. and the University of Birmingham have developed 4 core recommendations for action discussed in detail below:

- Promote new business models, specifically: *'IT enabled services to manage harvesting and logistics fork to farm*' and *'Cold as a Service'*
- Living Labs
- Training
- Hackathons and a framework for IT solutions

These, combined with suggested actions for government, aim to outline a system level approach that addresses needs from the first to last mile of the cold-chain as well as those of the broader community.

5.1 Promote New Business Models

We propose the development of new business propositions, specifically 'IT-enabled services to manage harvesting and logistics' and 'Cold as a Service'.

Business Proposition 1: IT enabled services to manage harvesting and logistics fork to farm

The Information Technology Bill passed in May 2000 paved the way for India's IT revolution boosting e-commerce and internet related business. The knowledge revolution, as it is now termed, resulted in cyber cafes in rural areas providing villagers access to computerized land records. Project Gyandoot, for example, helped farmers get the best prices for their produce from nearby markets (Paradkar, 2000).

Agri App, iffco kissan app, Agri Media Video App, Farm Bee RML Farmer and Kisan Yojna are some of the popular android-based apps which provide services such as online markets, solutions to agricultural queries, latest technologies for improving agricultural production and latest mandi prices (Tat, 2018). The mKisan portal of the Government of India under the National e-Governance Plan - Agriculture (NeGP-A), provides SMS (short messaging service) portal for farmers reflecting low internet penetration in rural areas but nearly mobile connectivity to nearly 8.93 crore farm families enabling state and central government organizations to reach out to farmers through internet, touch screens kiosks, agri-clinincs and Kisan call centers. The portal, through services such as USSD (Unstructured Supplementary Service Data), IVRS (Interactive Voice Response System) and Pull SMS, enables farmers and other stakeholders to receive messages and web based services on their mobile without having internet access (Ministry of Electronics & Information Technology Government of India, 2014). *Annex E* provides a list of free apps related to agriculture provided by the Ministry of Agriculture, Government of India.

With increased penetration of mobile-based apps and technologies in rural areas, there is significant potential to leap frog into an information-based system that economically empowers individuals to make informed marketing decisions and deliver increased financial value for farmers. Similar projects have already been introduced in the agri-sector. Large-scale dissemination through targeted programs can radically accelerate this phenomenon. The proposed model would enable the assessment of the value of a fork-to-field flow of information and explore how best to capture and present data to farmers to support their immediate and long-term commercial decision-making. Figure 12 below sets out more detail of this proposition.

Figure 12: Business Proposition 1: IT-enabled services to manage harvesting and logistics

Business proposition 1: IT-enabled services to manage harvesting and logistics
Primary goals: • Linking the market requirement for fruits and vegetables with the time of harvesting • Reduce food produce losses in the supply chain by accurately linking time of harvesting, storage and market
Prospective businesses: • Farmers' Producers' Organisations created subsidiary companies or business units • Social entrepreneurs supported through impact investors – start-ups with IT skills • Established Indian and overseas brands
Pre-launch activities: • Market assessments, understanding of holding life of produce in each of the food logistics supply chains • Understanding of inventory management at the farm-gate, within haulage and at the markets (wholesale and retail) • IT platform development considering connectivity in the rural sector, data capture of commodity prices etc.
Cost and revenue model: • Initiation costs to include setting up of IT platforms, and development of Apps that operate robustly with 3G/4G connectivity' • Revenue generation through a subscription-based model – an annual fee to be charged to the group of farmers and create advertisement sales.
Other benefits: • Computer literacy within villages - including adult education and skills acquisition, • Local youth engagement creating community IT hubs to assist villagers to access global platforms, and associated job creation, • Extension of logistics support services in health and educational systems

Business Proposition 2: Cold as a Service

Rather than the conventional business-as-usual approach of selling cooling equipment to farmers and burdening them with the capital and financing costs of aquiring the assets, an alternative approach is proposed in which the specific thermal (hot or cold) requirements necessary for establishing the food supply chain are assessed, alongside the broader needs of local communities, and delivered by a third party through the most effective and efficient means. In such a model, cooling infrastructure becomes a service not a product, is funded by potential assett owners such as entrereneurs or logisitics companies, and would be utilised for multiple purposes in addition to agricultural production, including for example: storage of vaccines and medicines; support to secondary agriculture and processing activities; preparation and use of ice for fisheries, etc.

Based on models discussed here, we have proposed a model cold-chain to be implemented under the Govt. of Haryana CCDP scheme. Details of the scheme and the proposed model are given in Annexure D.

Figure 13: Business Proposition 2: Cooling as a service

Business proposition 2: Cooling as a service that provides affordable access, improves market connectivity, and maximises efficiency for the lowest carbon footprint.

Primary goals:

- Create affordable access to clean and efficient cold-chains – first and last-mile transportation, cold-rooms with energy efficient and low GWP/ODS use systems,
- Promote waste-to-energy and solar-thermal/solar-PV systems to reduce use of fossil-based systems,
- Create grid-support services through the use of cold-chain assets
- Promote innovative technologies such as phase-change-materials and eutectic plates for use in cold-store construction and transportation networks

Prospective businesses:

- Energy service companies, equipment leasing companies and integrators creating a "pay-as-you-go" model for number of hours of operations of cold-rooms and miles travelled during the transportation phase,
- Farmers' Producers' Organisations created subsidiary companies or their business units or social entrepreneurs carrying out the above-mentioned activities.

Pre-launch activities:

- Standardised designs for alternate refrigerants, alternate energy technologies,
- Understanding of operation and maintenance requirements,
- Development of a business model and plan to launch one service extended to multiple states,
- Understanding of energy markets and possible renewable energy integration/grid-support opportunities.

Cost and revenue model:

- Project development and implementation costs considering the Central and State government subsidies/ incentives available,
- Revenue generation through a monthly fixed fee and/or operating expenses benchmarked to the use of cooling as a service,
- Cross-sale of hot water and secondary cooling to healthcare and rural industries.

Other benefits:

- Job creation for local young women and men involved in the operation and maintenance services
- Extension of logistics support services in health and rural industries, e.g. storage of vaccines and medicines

> "A KEY ACTIVITY SHOULD BE THE DESIGN OF THE SYSTEM LEVEL (BUILT ENVIRONMENT, LOGISTICS AND TRANSPORT) APPROACH TO COOLING, THAT IS A MULTI-SECTOR, MULTI-TECHNOLOGY, MULTI-ENERGY SOURCE INTEGRATED APPROACH TO COOLING, TO DELIVER MAXIMUM ECONOMIC, ENVIRONMENTAL AND SOCIETAL IMPACT."
>
> - Prof. Toby Peters, University of Birmingham

Example of cooling as a service – Phase Change Material Technology based cooling charging stations

- Public and / or private projects create centralised 'PCM charging stations' - with the help of local utilities these cooling 'charging stations' can be operated during off-peak hours of the 'time-of-the-day-tariff', to minimise charging costs (or with local renewable energy resources to reduce energy costs and GHG emissions).
- If standardised charging panels are produced, have a bar-code for identification, and are subject to a monetary deposit for 'hire', farmers/ FPOs/ or anyone who wishes to use them can take the charged panels from the local 'charging station', use them, and then return them in another location (for example at the market where the farm produce would be taken for sale). The discharged panels can be handed over to the local charging station for re-charging and the user's monetary deposit returned.
- Users pay for renting these panels, in order to cover operation and maintenance costs.
- The bar-code would offer important information such as how many charging cycles have been completed so far, the residual life of panels etc., as well as facilitate a user paid monetary deposit scheme.
- When used with refrigerated reefers, the panels would eliminate the distance barrier, as en-route 'charging stations' would enable users to rapidly exchange depleted panels for fresh fully charged units, thereby allowing the vehicle to continue its onward journey.
- This system would have the additional benefit of creating new business opportunities for local people.

5.2 Develop Living Laboratories – Clean Cold-chain Living Lab and Innovation Centres

There is a growing portfolio of cold-chain technologies suitable for small-scale, medium scale and larger scale food supply chain businesses. Low tech evaporative cooling methods, solar powered refrigeration systems, phase change materials and radical innovations, such as liquid air technologies, all possess great potential to provide clean cooling along every step of an integrated supply chain.

In order to gain acceptance and use it is not enough to simply demonstrate that each of the new clean cold technologies works in isolation. Instead we need to test, evaluate and demonstrate bundles of technology working together from end to end in real operating environments, rather than as a series of discrete facilities. We also need to prove, and provide evidence for, the economic value returned to the community, as well as demonstrate affordable and workable business models.

We propose a series of Clean Cold-chain Living Lab and Innovation Centres to test, validate and demonstrate innovative and integrated solutions (technology and business model) for sustainable clean cold-chains, as well as community cooling solutions, in real world based controlled environments. These entities will test and demonstrate not only technologies but also the potential for climate change mitigation, funding models, business models and approaches to governance. These labs will be technology agnostic and identify the positive and negative consequences of deploying any new interventions.

Labs will also be physically permanent entities with appropriately skilled and trained staff complements, equipped with essential technologies and test bed facilities (packing, cooling and/or temporary cold storage, leasing reefer vehicles and other equipment and tools for improved postharvest handling), to provide training and advisory services through evidence-based demonstrations. Audiences would include, local trainers, outreach teams, extension service providers, growers, farmers, logistics operators and other stakeholders involved in food supply chains. Labs would conduct training programs to build and improve local capacity and share knowledge on improved technologies, business, marketing, etc.

5.3 Training and development

Our research has confirmed that:

- High food loss and waste are exacerbated by a lack of knowledge and poor levels of access to education and training on the need for cold-chains and their delivery and maintenance.
- Effective promotion and deployment of clean cold-chains, associated technologies and the design of facilities is only possible through awareness raising, capacity building and training provision. This includes a broad audience; not just farmers and operators but engineers, repair service workers, storage and transport operators as well as private sector consultants and potential funders.
- Understanding the economic impacts and broader benefits of clean cold-chains, and the development of alternative business models, is important to justify the investment.
- The success of prospective value-chains would depend heavily on how enterprises evolve.
- The creation and empowerment of women-led businesses in the value-chains should be an integral part of the training effort.

In meeting these, it is important to address some key messages:

- Each type of food produce has its own specific temperature range that must be maintained throughout the cold-chain.
- Timely, appropriate and correctly carried-out service checks of equipment, maintenance and repair are key to accurate and reliable temperature control, as well as maximum energy efficiency, leakage reduction, etc. These in turn minimise cost and maximise effectiveness.

- Apart from the use of mechanical refrigeration units, other passive elements such as insulation or door seals, to create heat transfer barriers / reduce leakage, are important to optimised and energy efficient cold-chains.
- The market connectivity and the flow of data back to the farm, and how to analyse, interpret and apply it, is essential to successful use of cold-chain infrastructure.

With the development of IT-enabled mobile communication technologies, and through these e-learning programs as well as other platforms for information exchange, training methods have evolved to (theoretically) reach audiences in just about every possible corner of the world. However, at the same time the educational needs and learner understanding levels of each target group remains diverse. It is essential in promoting the implementation of clean cold-chain technology to choose a joined-up inclusive approach with the most appropriate methods applied for each target audience. An innovative training course developed by Elle Farms on high value foods, is documented in *Annexure F*

A training and skills programme should include seven key elements:

1. **Clean Cold-chain Living Labs and Innovation Centres** (as described above)
2. **Business incubation training**

Based on our assessment so far, the success of prospective value-chains will depend heavily on how the stakeholder enterprises evolve. In particular, Farmers' Producers' Organisations (FPOs) and Farmers' Producers' Companies (FPCs) emerging as social entrepreneurs could be a key route to the success of clean and efficient cold-chains, with value creation throughout the farm-to-the-fork space for their farmer members. However, the experience of launching FPOs/FPCs is historically poor and needs substantial strengthening. As such, a training module on incorporating and running local rural business and creating partnerships is an essential component. Such a module, run through the Living Lab, can deliver educational materials and a forum for the members to come together, incorporate the businesses, establish dos/don'ts of capital expenditure and working capital management, create processes to take capital expenditure decisions, develop an understanding of the inputs, costs and corresponding sustained productivity gains, and embed digitisation of accounts and settlement processes. This part of the training component could be delivered through participation of business schools with expertise in supporting rural enterprises (IRMA-Anand and ISB-Mohali for example).

3. Enhanced IoT, AI and Block-chain applications

Part of the Living Lab training offer can also include launching bespoke competitions / Hackathons to solve specific business problems. The Living Lab can provide the knowledge base and platform to test the solutions virtually against specific targets in a safe environment, for example to reduce costs incurred per ton of produce sold through the value-chain. The Living Lab can also embed real-time proof-of-concepts by creating on-going learning-by-doing and doing-by-learning loops

4. Curriculum development for university students and professionals

Topics related to clean cold-chain need to be integrated into the curriculum of relevant courses in universities and technical colleges. Not just agriculture and allied programmes of study, but also across a broader range of offerings to capture the next generation of professionals who will be involved in all aspects of the sector including: technology development; system design and build; financing providing training or maintenance; and setting strategy and policy at local, national government and with supranational agencies.

5. Massive Open Online Courses (MOOCs) and e-Learning Programs

MOOCs are open access online learning platforms aimed at enabling unlimited participation. They include reading materials, lecture videos and quizzes. Forums allow interaction among students and also with tutors to discuss, clarify concepts and receive feedback on assignments and quizzes. MOOCs and e-Learning have undergone several innovative modifications and are emerging as a popular, low cost and convenient mode of learning.

6. Information and communication technologies (ICTs)

ICT assists in overcoming several barriers such as time, distance, language and lack of proper infrastructure. As one example, the mobile phone has been proved to be a very effective way of gathering data as well as to disseminate essential information to broad populations within a short time period. Interactive e-programmes and video can reach a wide range of audiences and transfer messages accurately, overcoming language, literacy levels and other barriers.

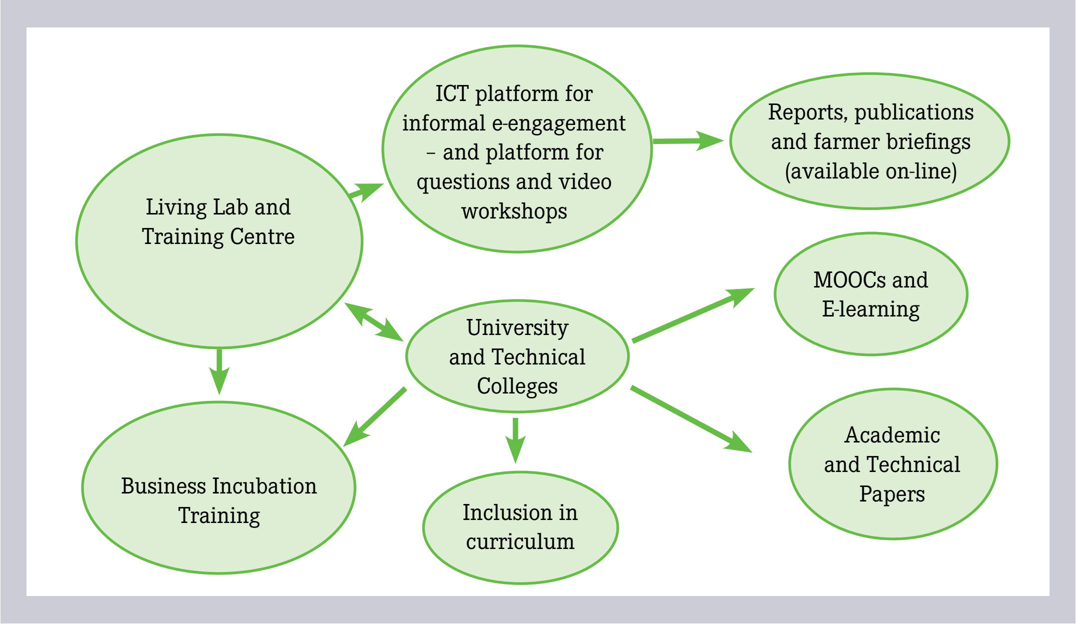
7. Written communication/ Publications

Dissemination of information through written reports and other publications is still a very effective tool, especially when combined with online downloads. There are different modes of written communication including journal publications, technical manuals and reports, white papers, books, brochures, posters, leaflets, booklets and newsletters; each with differences in length, depth of content, technicality, presentations and illustrations. They can be used to provide layers of depth of information, with different communication modes used based upon the target audience, their understanding level and the topic of interest.

Additionally information and knowledge building should include:

- Training for farmers on better management of produce both pre-harvest and post-harvest.
- Development of interlinked R&D centres in existing agriculture universities to support cold-chain related research and information required by farmers.
- R&D to study and support clean cold-chain technologies suitable to a region, preparation of a roadmap for implementation and cost-benefit analyses.

Figure 14: Training and Development for Clean Cold-Chain Network Diagram



5.4 Facilitate Hackathons and prepare a framework for IT solutions for clean cold-chain in India using the latest block-chain technologies.

Participants could include representatives from FPOs, technology consultants and providers, government representatives, funding agencies, bi-lateral organisations, consultants, and entrepreneurs, or interested individuals and organisations including designers, programmers, coders, developers, recruiters, CEOs. Participants could develop independently or in groups, possible 'open source' solutions and software codes for developing deploying and adopting a clean cold-chain.

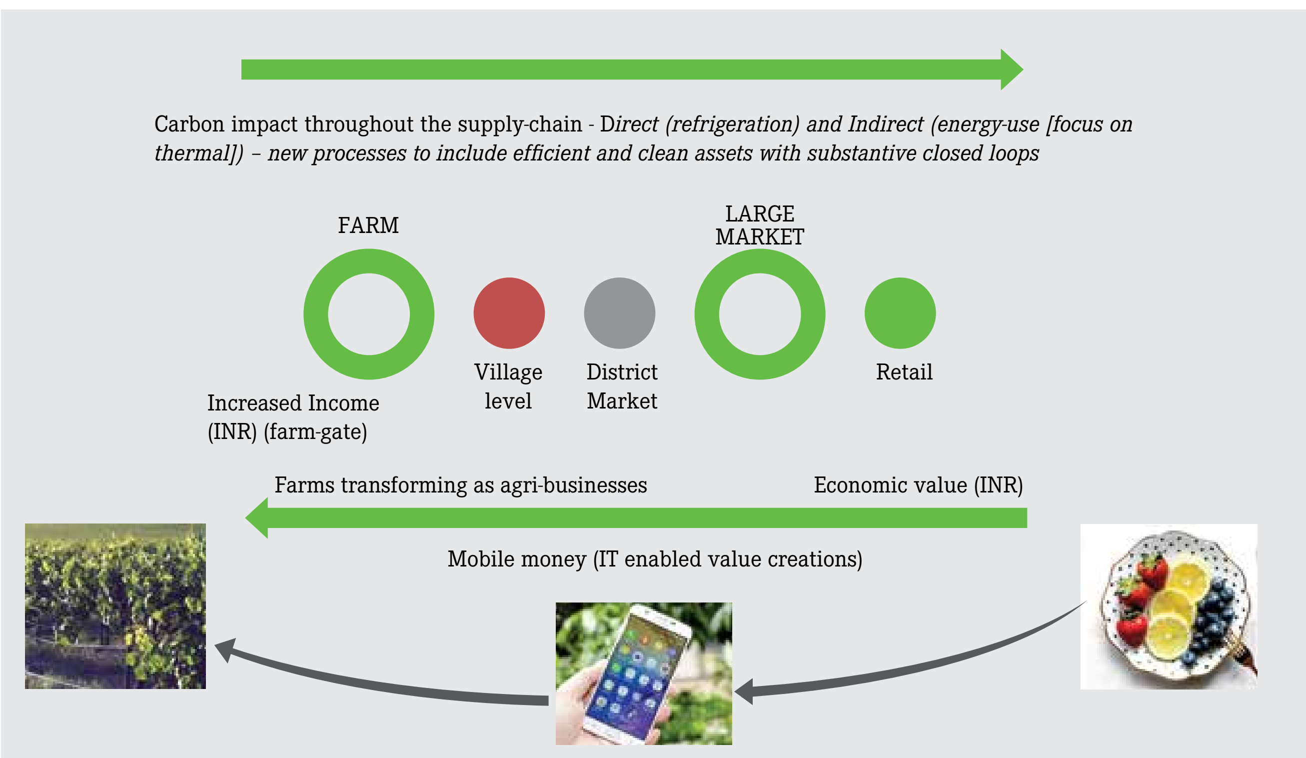
This activity will require an informed needs assessment process developed with the farming community, and identification of the drawbacks, gaps and requirements of the existing system. Taking into account, existing schemes and infrastructure, it would address how IT can enable enhancements achieved through cold-chain infrastructure and deliver value back to the farm from the fork.

5.5 Recommended government action to support clean cold-chain implementation

In addition to these core recommendations, government interventions have been identified, which would support GoI objectives for doubling farmer income and supporting a sustainable agriculture sector as a national economic growth engine. Specifically these are:

- Integration of national and state-level government schemes across ministries in order to deliver a unified clean cold-chain program. This intervention to include, but not be limited to the Ministry of Environment Forests and Climate Change, Bureau of Energy Efficiency, State Agricultural Marketing Boards, as well as between state departments such as agriculture and IT.

Figure 15: New Business Propositions



- Decentralisation of government schemes and subsidy programs with maximum outreach through NGOs. Schemes should incorporate energy efficiency norms, standards and design guidelines for installation and maintenance.
- Technical and administrative support for effective adoption of schemes.
- The provision of a voluntary star rating for cold-chain facilities to encourage efficiency and create awareness
- Development of a model cold-chain to demonstrate end-to-end clean cold-chain infrastructure.
- Create a suitable environment for appropriate financial models to help facilitate access to financing cold chains.

Community Cooling Hubs

The provision of cold-chains to support food production and distribution is one very important component of meeting the requirement for cooling in a rural community. However, within such communities there are a broad range of cooling needs, which include for example: veterinary and human vaccines and medicines; health services; comfort; workplace and school house productivity; domestic refrigeration; commercial services and in some cases humanitarian logistics. Currently these needs tend to be considered in isolation and, therefore, the cooling solutions for each is typically delivered separately. An integrated Community Cooling Hub (CCH) is proposed by the University of Birmingham as a more sensible systems level approach which has the potential to meet community cooling needs in a more efficient, affordable and sustainable way.

Community Cooling Hubs would be focused on all social and development goals, not just cold chains, and be built on the principle of community-ownership. They would consider the wider opportunities - and unintended consequences - of cooling. An assessment of local needs would provide the foundation for a localised portfolio of clean cooling solutions.

A CCH model should:

- Evaluate and aggregate cooling demand across the community (with food logistics as the primary cooling load) to optimise system efficient energy and resource management.
- Combine system level thinking with innovative 'Cooling as a Service' models – to enable centralised services and maintenance, leading to better performance and resource efficiency.
- Stack (bundle) revenues in business models to maximise economic opportunity for the local community.
- Not pre-suppose a technology solution but understand the portfolio of needs and potential matching sustainable supplies, and develop the optimum mix of cooling solutions in order to meet those needs (see Merit Order Ranking box for help on determining an appropriate mix of solutions)
- Harness free, waste to thermal, and thermal to thermal solutions, and thermal storage

An example of the range of needs that could be met via a CCH is illustrated below:

- Food: precooling, packing and storage; food logistics; community domestic refrigeration, retail refrigeration.
- Business opportunities: temperature controlled spaces for third party food processing; temperature-controlled stalls for vendors of fresh or short-life products; and ice vendors.

- Community cooled meeting area providing comfort from the heat e.g. via shading, and chilled benches. Could be used by school during the day and broader community in the evenings.
- Human and animal health: secure vaccine and medicine storage; front-line disaster storage; veterinary logistics; human vaccine and health logistics; and humanitarian logistics.

Next steps to deliver Community Cooling Hubs

Through engagement with example communities across a range of States, a collaboration led by University of Birmingham working with MP EnSystems, Shakti Foundation, NCCD, NIFTEM and IMechE intends to:

- Explore wider economic, environmental and social reasons to bring affordable cooling to communities and understand collaborative economic and business models;
- Investigate the viability of integrating food cold-chains with other cold-dependent services such as secondary agriculture, vaccines, community health facilities and humanitarian logistics;
- Understand Willingness to Pay (WTP) and benefits of the business model vis-à-vis Business-as-Usual scenario;
- Develop strategies and co-benefits to create sustainable community cooling services;
- Explore community refrigeration and common services models to be developed for test-case communities in India and trialled through Living Labs.

6. REFERENCES

1. Association of Ammonia Refrigerants. (2018). *Sustainable and Energy Efficient Technologies for Clean Cold-Chain.* Mumbai: Association of Ammonia Refrigerants.
2. Balayan, D. S. (2015, September 3). Comprehensive Assessent of cold-chain capacity in India. New Delhi, India.
3. Birmingham Energy Institute. (2017). *Doubling Farmer's Income through clean cold chain.* Edgabaston: University of Birmingham.
4. Birmingham Energy Institute; Birmingham Policy Commission. (2015). *Doing Cold Smarter*. Edgabaston: university of Birmingham.
5. Chand, R. (2017). *Doubling Farmers' Income Rationale, Strategy, Prospects and Action Plan.* New Delhi: Niti Aayog.
6. Chand, R. (2017). *Doubling Farmer's Income: Rationale, Strategy, Prospects and Action Plan.* National Institution for Transforming India. Delhi: NITI Aayog.
7. Committee for Doubling Farmer's Income. (2017). Post-production *Agri-logistics: maximising gains for farmers*. Ministry of Agriculture and Farmer's Welfare, Department of Agriculture, Cooperation and Farmers' Welfare. New Delhi: Ministry of Agriculture and Farmer's Welfare.
8. Ernst & Young Pvt. Ltd. (2013). *Refrigerated Transportation: Bottlenecks and Solutions.* Delhi: Ernst & Young Pvt. Ltd.
9. Ernst & Young. (2013). *Refrigerated transportation: bottlenecks and solutions.* Kolkata: Ernst & Yound Pvt. Ltd.
10. FAO. (2011). *Global food losses and food waste – Extent, causes and prevention*. Rome.
11. Food and Agriculture Organization of the United Nations. (2015). *Food Wastage Footprint and Climate Change.* Rome: FAO.
12. India Brand Equity Foundation. (2018, November 20). *Agriculture in India: Information About Indian Agriculture & Its Importance.* (Ministry of Commerce and Industry, Govt. of India) Retrieved Novmber 10, 2018, from Indian Brand Equity Foundation: www.ibef.org
13. Kadiyala, S., Harris, J.,Yosef.,S & Gillespie, S. (2014). Agriculture and Nutrition in India. In *Annuals of the New York Academy of Sciences* (pp. 43-56).
14. Kitinoja, L. (2014). *Exploring the Potential for Cold Chain Development in Emerging and Rapidly Industrializing Economies through Liquid Air Refrigeration Technologies.* Postharvest Education Foundation.
15. Kohli, P. (2015, March 20). *FAQs on Cold-Chain Development.* (N. C.-C. Development, Producer) Retrieved October 20, 2018, from https://nccd.gov.in: https://nccd.gov.in/PDF/General-Queries-Cold-chain.pdf

16. Kohli, P. (2017). Stop Food Loss & Waste to Counter Climate Change. *WRI Journal*.

17. Kohli, P. (2016, September 20). *Stop Food Loss To Stop Climate Change*. Retrieved September 15, 2018, from Huffingtonpost.in: https://www.huffingtonpost.in/pawanexh-kohli/stop-food-loss-to-stop-climate-change_a_21473513/

18. Ministry of Electronics and Information Technology. (2014). *mKisan Portal - Mobile based Services for Farmers.* Ministry of Agriculture, Governmnet of India.

19. Ministry of Environment Forest and Climate Change. (2019). *India Cooling Action Plan*. Delhi: MOEF CC.

20. National Cold Chain Development. (2017). *Study on FPO model for marketing of vegetables*. New Delhi: NCCD.

21. NCCD. (2015). *All India Cold Chain Infrastrcuture Capacity (Assessment of Status & Gap).* Delhi: NCCD.

22. NITI Aayog, Govt. of India. (2015, December 16). *Raising Agricultural Productivity and Making Farming Remunerative for Farmers.* (N. Aayog, Producer) Retrieved September 15, 2018, from niti.gov.in: http://www.niti.gov.in/writereaddata/files/document_publication/Raising%20Agricultural%20Productivity%20and%20Making%20Farming%20Remunerative%20for%20Farmers.pdf

23. Paradkar, S. (2000). India's Computer Revolution. *Britannica Book of the Year*.

24. Peters, T. (2018). *System level thinking to meet our cooling demands sustainably.* Heriot Watt University.

25. Peters, Toby; University of Birmingham. (2017). *Retail Refrigeration Making the transition to clean cold.* Edgabaston: University of Birmingham.

26. Sims, R., Flammini, A., Puri, M., & Bracco, S. (2015). *OPPORTUNITIES FOR AGRI-FOOD CHAINS TO BECOME ENERGY-SMART*. Washington: POWERING AGRICULTURE: An Energy Grand Challenge for Development.

27. Singh, J., & Pandey, K. (2018). Why India Remains Malnourished? In Down to Earth. *(S. Narain, Ed.)*. New Delhi, India.

28. Small Farmers Agribusiness Consortium Haryana. (2018, February). *Crop Cluster Deveopment Program (CCDP)- implementation norms and guidelines.* Retrieved September 26, 2018, from hortharyana.gov.in: http://hortharyana.gov.in/sites/default/files/Final%20CCDP%20Booklet.pdf

29. Small Farmers Agribusiness Consortium Haryana. (2016). *Haryana Cluster: Agriculture, Horticulture, Animal Husbandry, Dairy, Fisheries.* Panchkula: SFACH.

30. Surange, A. (2018, November 13). Technology Assessment for Clean Cold Chain. (M. Patankar, R. Yehuda, & C. Chhatbar, Interviewers)

31. Tat, J. (2018, August 2). Top 5 best android apps for Indian farmers/agriculture – 2018. India.

32. UNICEF. (2017). *Countdown to 2030 - Maternal, Newborn and Child Survival - country profiles.* New York, USA.

33. University of Biringham; Birmingham Energy Institute. (2016). *Clean Codl and Global cities*. Edgabaston: University of Birmingham.

34. University of Birmingham; Birmingham Energy institute. (2017). *India'a Third Agricultural Revolution Doubling farmers' income through clean cold chain.* Edgabaston: University of Birmingham.

35. University of Brimingham; The Institute for global intervention; Birmingham Energy Institute. (2018). *A Cool World – Defining the Energy Conundrum of Cooling for All.* Edgabaston: University of Birmingham.

ANNEXURE

A. List of Technology Providers/ Consultants and Related Institutions

Table 10: **List of Technology Providers/ Consultants and Related Institutions**

Company/ Organization	Name of Contact Person	Designation	Telephone/ Email ID/ Web address.
IIT Bombay	Dr. Milind Rane	Professor - Department of Mechanical Engineering	ranemv@iitb.ac.in
Kehems Technologies Pvt. Ltd	Rohit Yadav	Senior Engineer	rohityadav141@gmail.com
IIT Bombay	Vikash Jha	Assistant Project Manager - CTARA (Center for Technology Alternatives for Rural Areas)	cae188vikashkumarjha@gmail.com
India Insulation Forum	Amol Desai		isaac.emmanuel@covestro.com; indiainsulationforum@gmail.com; amol_desai@spl.co.in
POLFROST air - con Pvt Ltd	Parth Thakkar	Director	parth@polfrost.com
Huntsman International India Pvt. Ltd	Chandra Kumar Patel	Technical Platform Manager -Polyurethane	Aseem_Nirula@huntsman.com; Chandra_kumar_Patel@huntsman.com
Panasia Engineers	Surendra Shah	Founder Chairman	mail.surendrashah@gmail.com
Small Farmers Agriculture Consortium Haryana (SFACH)	Yoginder Singh	State Consultant	
United Nations Industrial Development Organisation	Pankaj Kumar	National Technical Expert (Solar)	P.KUMAR@unido.org
NABCONS	Mukesh Belwal	Assistant Manager	http://www.nabcons.com/
Pluss Advanced Tech	Vishnu Sasidharan		vishnu@pluss.co.in
World Bank	Karishma Gupte	Consultant 2030 WRG	
Llyod insulations / Refcold India	Mr. K K Mitra	National Steering Council Member of REFCOLD INDIA & Sr. Vice President	kk.mitra@llyodinsulations.com
Dasmesh Comprehensive Air Solution	Mr. Jaspreett Singh	Director - Dasmeshac air Conditioning	jaspreet@dasmetac.com
Carrier Transcold	Pankaj Mehta	Managing Director (India and South Asia)	Pankaj.Mehta@carrier.utc.com

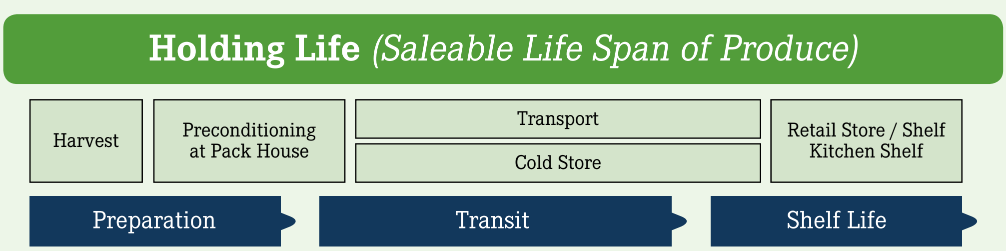
Company/ Organization	Name of Contact Person	Designation	Telephone/ Email ID/ Web address.
Tecumseh Products Company	Mr. Love Kumar	Regional Manager - North India; General manager sales	Love.Kumar@tecumseh.com
Bharat Innovations	Hemendra Mathur	Venture partner	hemendra@bharat.fund
Danfoss Industries Pvt. Ltd	Nagahari Krishna L	Director	Nagahari@danfoss.com; anupam@danfoss.com
Prompt Group	Mr. Shridhar Mehta	Director	smehta@promptgroup.co.in
Nexleaf Analytics	Anita Sircer	Project Manager	anita@nexleaf.org
National Institute of Food Technology Entrepreneurship and Management (NIFTEM)	Dr. Vinkel Arora	Assistant Professor, Mech. Engg	vinkelarora17@gmail.com
National Institute of Food Technology Entrepreneurship and Management (NIFTEM)	Dr. P.K. Nema	HoD (Food Engineering)	pknema@yahoo.co.in
ISHRAE	Vikram Murthy	National President Elect	presidentelect@ishraehq.in
Indian Society for Heating Refrigeration and Air-conditioning Engineers (ISHRAE)	Ashwini Mehra	Executive Secretariat, ISHRAE Headquarters.	mehrashwini@gmail.com
Association of Ammonia Refrigerants	Anand Joshi	Past President	anand@manikengineers.com
Association of Ammonia Refrigeration	Anil Gulanikar	Past President	ammoniaindia@gmail.com

B. Specific Terminologies Related to Cold-Chain

Table 11: Definitions and used in the sector

Terminology	Definition
CA enabled cold store (Controlled Atmosphere Technology):	This refers to a cold store fitted with technology to actively alter the atmospheric gaseous contents, in addition to controlling the temperature. This is affected by utilizing specialized equipment, generally involving molecular sieves (mechanical or chemical) to change the molecular composition of air. Used to purge the natural air in a cold storage space, an active and rapid change to atmospheric composition is done to maximize advantage of physiological slow down and for other benefits for specific fresh produce. Basically, in all cold stores there manifests a slow, passive, self-induced modification (from normal respiration and physiological activity) to atmospheric contents. In CA based cold stores, the atmospheric composition is heightened by active intervention. Globally, this add-on technology is commercially used in cold stores for long term storage of suitable quality of Apples, Kiwi and Pears. This technology is also used in certain transport modes.

Terminology	Definition
Cold-chain	An environment-controlled logistics chain, ensuring uninterrupted care from source-to-user, consisting only 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 or product handled.
Cold Storage (Bulk)	Environment controlled warehousing space with multiple chambers intended for the bulk storage of perishable produce. It is designed for long duration storage of produce to build an inventory buffer which will serve to smoothen the episodic production by stabilizing &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.
Cold Storage (Hubs)	Environment controlled warehousing space 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. Cold storage (Hubs) are key to effective distribution of perishable foods and essentially at the front end of the cold-chain, constructed close to consuming centers.
Cold Room (Staging)	An insulated and refrigerated chamber which serves as a transient staging space and is a necessary attachment to a Pre-Cooling Unit. Appended to pre-coolers, a staging cold room frees the pre-cooler space for the sequential batch of incoming freshly harvested produce. This component is typically installed at farm-gate as part of a modern pack house, and temporarily stores preconditioned fresh produce, awaiting transport link to a distribution point (a cold store close to market).
Fresh Food (Produce)	A produce of nature that is harvested by farmers and where the essential and natural attributes have not been altered. This includes all whole food that is a produce of nature and not a product of industrial process. The harvest may undergo cleaned, sorting, grading, trimming, de-sapping, fumigation, washing, waxing, packaging but does not undergo any process that modifies its natural characteristics. E.g., all fresh fruits and vegetables, raw milk, eggs, fresh fish, etc.
Holding cycle	The time for which a specific good is held in a storage or transport chamber. Also called inventory turnover, it is a long period in case of products like potato, apples and few days in case of tomato, milk, litchi, etc. The handling capacity of a space is in multiples of its size and the holding cycle or rotation of the inventory held.
Holding Life	Also called Product Life, refers to the Saleable Life Span of a product. In case of Fresh produce, this commences at harvest and extends until the produce perishes. In case of processed food products, this is initiated after the manufacturing process and extends up to the predetermined expiry date. Holding life is divided into time spent in each activity in the supply chain, with Shelf Life being the time spent in the front end, on shelf. The holding life of produce is extended with cold-chain, creating more opportunity to producers by expanding the range and accessibility to markets. The Holding Cycle in a space, should always a small part of the total Holding Life of a product.



Terminology	Definition
Packhouse	A modern infrastructure with facilities for conveyer belt system for sorting, grading, washing, drying, weighing, packaging, pre-cooling and staging. Modern packhouses are the first step in organized post-harvest management for horticulture and are in effect the first mile sourcing points for this sector. A modern integrated packhouse unit enables small lot sourcing of horticulture produce and should be built close to farm-gate.
Pre-Cooling Unit	A specialized cooling system designed to rapidly remove field heat from freshly harvested produce and thereby prepares the cargo for subsequent travel in the cold-chain. A Pre-cooling unit can be in the form of forced-air cooling, hydrocooling, vacuum cooling, room cooling, icing, etc. Pre-cooling or post-harvest cooling is the heart of a modern packhouse and is one of the key steps in preparing fruits and vegetables for the extended cold-chain.
Processed Food (Product):	A food product manufactured by transformative processes that may involve mincing or macerating, liquefaction, emulsification, cooking(such as boiling, broiling, frying, baking or grilling), dicing or slicing, pickling, preservation, canning or jarring, freezing or drying, refining, grinding, etc. – the natural attributes are altered, or ingredients added where the produce is transformed from its natural physical or chemical forms into a new product. E.g., pickles, flakes, ketchup, canned vegetables, juices, pulp, deep frozen goods, chocolates, beverages, etc. Processing industry may also use refrigeration technology (IQF, Blast freezers, etc.), such specialised production plants and product lines forming part of manufacturing equipment/components.
Reefer Vehicles	Road transport vehicles with a fixed insulated body equipped with active refrigeration designed for environment-controlled carriage of products. These are effectively cold rooms on wheels – or mobile cold stores. The refrigeration on long haul trucks is powered through integrated diesel driven motors, independent of the main truck engine. In case of small vehicles, the use of direct drive systems linked to the vehicle engine or battery powered refrigeration is the norm. Normally reefer trucks incorporate GPS based location tracking system and are installed with data logging temperature and humidity sensors.
Refrigerated Transport	The refrigerated transport system, with an insulated carrier and equipped with active refrigeration, designed for temperature-controlled carriage of perishable products. This can include refrigerated trucks (reefer trucks), vans, rail, containers and ships for transporting perishable products.
Ripening Unit	A front-end facility in the cold-chain, designed to function for controlled and hygienic ripening of certain fresh produce. Modern ripening units contain multiple ripening chambers, and these are used extensively for ripening bananas and other fruits like mangoes, avocadoes, kiwis, tomatoes, pears, etc.
Storage	Static infrastructure designed with insulated and refrigerated chambers for long term or transient storage of whole fresh, ready-to-retail, or processed forms of perishable products.
Storage Capacity	The handling capacity or the throughput measure of the goods that pass through a holding space over a specific period. This is also called the useful capacity of a space and assessed based on storage size and the product holding cycle. In case of a weekly holding cycle, the handling capacity of a space is "storage size x 52 weeks" or a 52x multiple of its holding size. The handling capacity of a storage unit depends on the product type being handled and is the proper characterization of the capability of a unit. The storage capacity of a cold store is a multiple of the space or storage size created.
U-value*	Heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Unit of U value is W/m2.K. (*Energy Conservation Building Code 2007, Bureau of Energy Efficiency)

Source: *NCCD Report on All India Cold-chain Infrastructure Capacity - Assessment of Status & Gap*

C. Commonly used refrigerants along with their environmental impacts

Table 12: 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 us after 1999	To be phased out of production in 2015. Their use is also regulated increasingly strictly
NH_3 Ammonia	R717	Zero	Very low	Used in Industrial systems since the birth of refrigeration	Toxic and flammable reacts 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, Iso-butane,** **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 very good refrigerants with few changes needed to a CFC/HCFC system
CO_2		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)

***ODP:** Ozone Depleting Potential; ** **GWP:** Global Warming Potential

***Source:** ASHRAE book of Fundamental*

D. Model Cold-chain Facility - Pack House with 250 MT Cold Storage

Design, Drawings and Specifications prepared by ACR Project Consultants Pvt. Ltd.

1. Background:

Through several schemes and projects, the Government of Haryana is promoting the development of cold-chain infrastructure to support farmers and prevent loss and wastage in the supply chain. Some of the measures undertaken by the Haryana State Infrastructure and Industrial Development Board (HSIIDC), the Horticulture Department and the Haryana State Agriculture Marketing Board (HSAMB) are note worthy.

The government schemes are not geared for 'clean' cold-chain and are likely to increase the energy demand through the addition of cold-chain infrastructure. The various departments and their schemes are briefly summarized below and a proposal to implement a model facility for 250 MT cold storage has been prepared for the Horticulture department of Haryana to incorporate at this stage.

The Haryana State Agriculture Marketing Board (HSAMB), set up inAugust, 1969, has the objective of "setting up a marketing infrastructure for better regulation of the purchase, sale, storage and processing of agricultural produce within the framework of Punjab Agricultural Produce Markets Act, 1961 and Punjab Agricultural Produce Markets (General) Rules, 1962." The Boardregulates the marketing of agricultural produce and provides infrastructure for facilitating marketing of agricultural produce. As part of its ongoing activities, the Board has set up several Kisan Mandis (Farmer Markets) facilitating direct farm to consumer linkage and guaranteed higher prices for farmers as compared to the Minimum Sales Price (MSP). Alongside the Mandis, the Board has set up integrated state-of-the-art pack houses throughout the State with sorting, grading and packing facilities.

The Horticulture Department (previously part of Agriculture department) of Government of Haryana, established in 1990-91 has a budget of Rs. 832 crore (US$ 118.86 million). Horiticulture, including fruits, vegetables and flowers, have a net worth of 7.5% of total agriculture produce in the state. The aim of the Horticulture department is to modernize and diversify agriculture production in the state, doubling horticulture production, optimizing natural resource use, nutritional security, dissemination of technology to farmers, improvement in productivity, yield and quality of horticulture produce, and creation of export potential.

The Crop Cluster Development Program (CCDP) promoted by the Horticulture Department has the goal of creating farmers' collectives especially small producers at various levels across the state, to disseminate technology, improve productivity, empower farmers by improved access to services and thereby increase income. The scheme focusses on forward and backward integration by creating on-farm infrastructure required for organized marketing of fresh fruits and vegetable by Farmer Producer Organizations / Companies (FPO/ FPC) completing the supply chain from production to market.

The Program supports cold-chain development by way of cold-rooms and integrated pack houses closer to the farms so the holding capacities vis-a-vis the pricing is leveraged and the farmers do not get exposed to anomalous market pricing. This is expected to reduce post-harvest losses, which are currently estimated by the Department at 30 – 40%. Following are key aspects of CCDP implementation:

- Launched in February 2018
- The Program is implemented through the Small Farmers Agribusiness Consortium Haryana (SFACH)
- Horticulture Department has identified 140 crop clusters across the state for the implementation of the Scheme
- Eligibility to the scheme requires farmers to be registered collectively in a Farmer Producer Organization (FPO) with more than 150 shareholders having collectively 500 acre under horticulture crops and minimum financial strength of ₹10 lakh (US$ 14,190)
- To date 87 FPOs have applied to take part.
- Horticulture Department has issued Letter of Intents (LOIs) to 20 FPOs from among the applicants
- TheProgram has a budget of ₹510 Crores (approx US$73 million)to subsidise the first costs of setting up cold-chains.
- Detailed implementation guidelines to be followed are available at http://hortharyana.gov.in/sites/default/files/Final%20CCDP%20Booklet.pdf.

Financial assistance to Farmer Producer Organizations (FPOs) from the project ranges from 70 – 90% on the following components:

Table 13: Financial assistance to Farmer Producer Organizations (FPOs)

S.No.	Component	Percent (%) Assistance
1.	Collection centre/ pack house including packing/ grading machines, cold rooms and reefer vans	90
2.	Primary Processing Centers	70
3.	Packing and Packaging Material	70
4.	Solar Power and Waste management	70
5.	E-platforms and related infrastructure	70
6.	Retail outlets	70
7.	Mobile retail vehicle and non-refrigerated vehicle	70

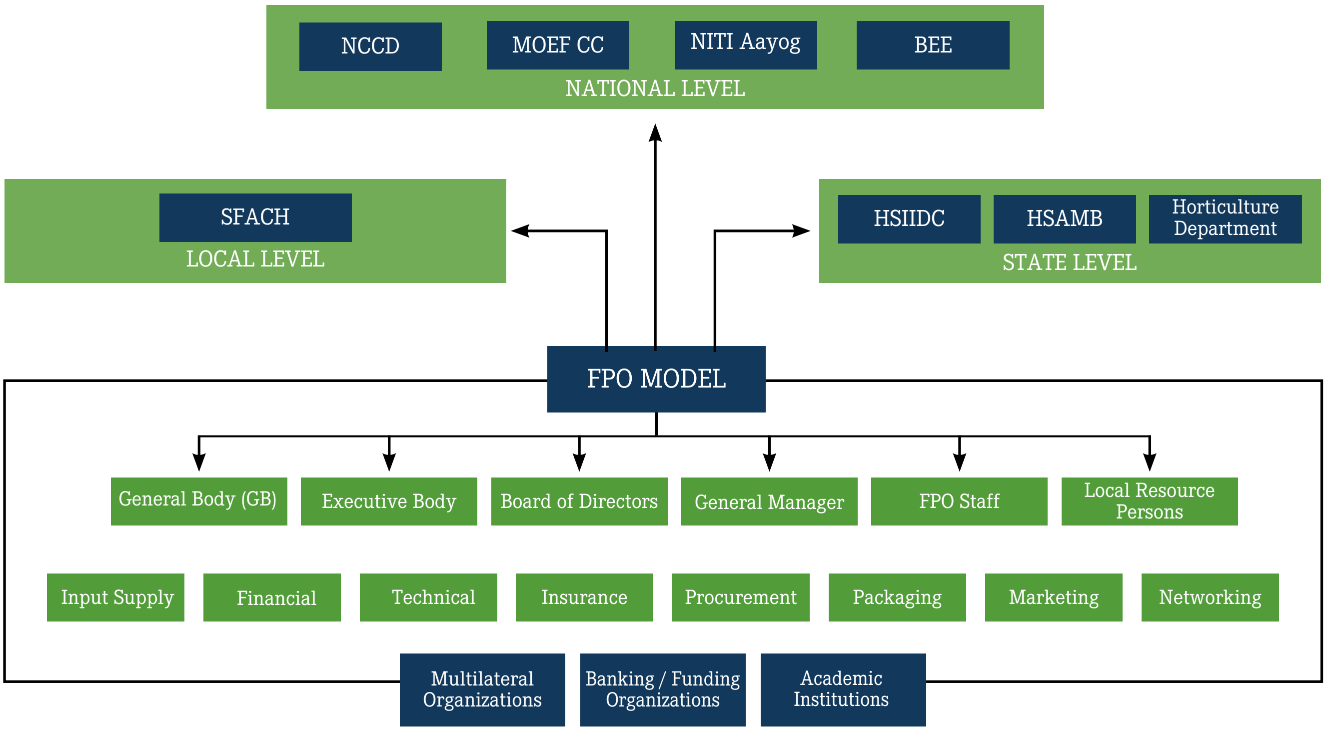
2. Cluster Production of Horticulture Produce using Farmer Producer Organization (FPO) Model

The **Farmer Producer Organization (FPO) Model** promoted in the CCDP scheme has the objective of overcoming the barrier of small land holdings and fragmented farming practices typical throughout the country, to be aggregated and bring in the economy of scale. In addition, crop cluster formation as has been identified in Haryana, will be more effective in connecting farmers to markets by proper analysis and management of the crop cycle, harvesting time and demand mapping. Besides, contiguous cultivation of crops will allow for easy analysis of soil, water and nutrition analysis, management of crop-wise volumetric demand and planning of cold-storage facilities. Cumulatively, the FPO model and the Crop Cluster Scheme will have the objective of reducing wastage during post-harvest handling and transportation, bridging the gap between demand and supply and create effective market links through IOT, improve production by building technical capacity of farmers, modern cultivation practices (including organic produce) and improving logistical capacity (National Cold Chain Development, 2017).

3. Organizational, Governance and Operational Framework:

The management and long-term sustainability of the FPO model will depend on inputs from various stakeholder organizations, each with its roles and responsibilities. The network of organizations and their roles is given in Fig. 14.

Figure 16: Network of organizations and their roles



Based on recommendations from literature, a sequential procedure for an ideal FPO model is presented below:

Box 3: FPO Model & Clean Cold-Chain

Selection

- Contiguous cultivation and with crop wise focus
- Existing Land under vegetable cultivation
- Existing volume of sales in vegetables
- Available technology to manage long distant markets
- Available professional management capacity

Formation

- R&D on aspects such as soil analysis of contiguous cultivation, daily production per hectare, daily throughput for pre-conditioning (sizing and design of pack house), minimum lot size for market dispatch, identify target markets, mapping consumption at target markets, evaluate distance from FPO location to target markets, evaluate produce selling cycle, minimum and maximum
- Assessment of collective Inputs at farm gate such as fertilizer, planting material, farm mechanization, combined harvester, labour, etc.
- Assessment of infrastructure gaps – collection centers, pack houses, cold stores, primary processing, ripening chambers, pre-coolers, mobile vending cart
- Formation of committee and work distribution
- Develop vision, goals and objectives for farming excellence and target for growth

Management& Marketing

- Technical support from Resource and Academic Institutions
- Develop scientific and specific crop plan for minimum 3 years
- Financial Management – loans, subsidies and schemes
- Improving value chain across all sectors in farming – soil, seeds, saplings, irrigation, pest-control, fertilizers, greenhouses,
- Integration with IOT for direct link to consumers and getting fair price for produce
- Cold-chain infrastructure requirement assessment and development – location, sizing and design of pack houses, cold storage and ripening chambers
- Clean cold-chain – use of renewables, closed loop systems and thermal storage systems
- Linkages with mega food parks and processing units
- Packaging and transport links
- Capacity building of Human Resources in specific areas
    - o Increasing technical know-how
    - o Demand mapping, sourcing markets and commercial negotiation
    - o Project Management o Best practices in handling produce
    - o Post-harvest management
    - o Clean Cold-Chain
    - o Operation and maintenance of infrastructure
- Large scale branding

Evaluation

- Capacity utilization and annual increase in output from use of post-harvest infrastructure
- Increase in income of farmer members
- Utilization of common clean / renewable facilities
- Nutritional value of produce
- Developing high value products

Proposed Model Cold-Chain Facility for CCDP scheme, Govt. of Haryana

3.1 Crops considered

Based on the crop clusters developed by the Department of Horticulture, Govt. of Haryana, the following vegetables have been considered for the Model Cold-Chain facility.

Primary vegetables:

Secondary vegetables:

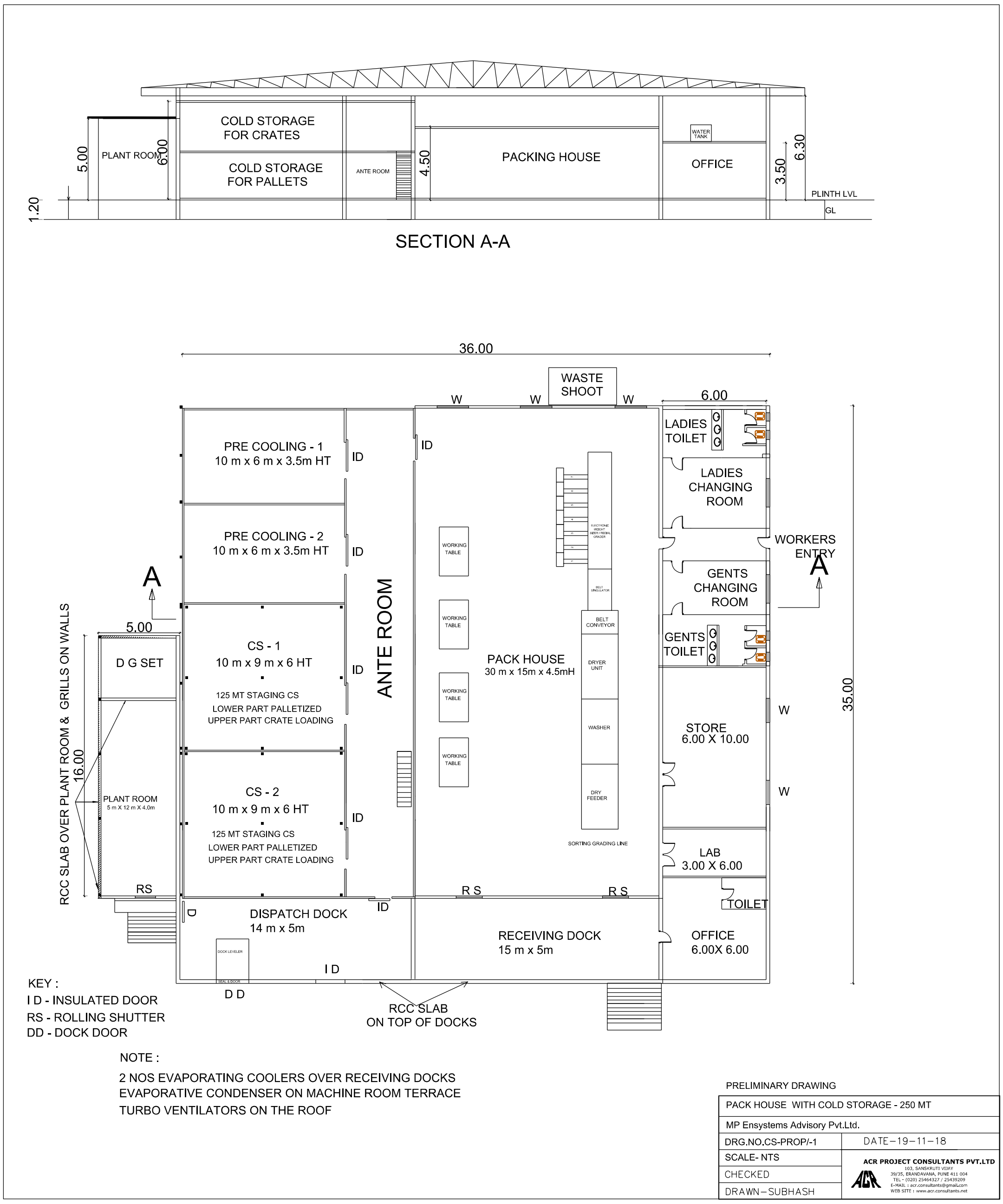
3.2 Cold-Chain Infrastructure

1. Integrated pack house with automatic sorting, grading and packing of fruits and vegetables for round fruits and vegetables (2 MT per hour)
2. Additional manual processing line for other vegetables
3. Two Nos. of pre-cooling unit of 6 MT each; handling 2 batches of precooling per day
4. Two Nos. cold rooms of 125 MT each designed for a temperature range of 0 to 80C to suit the requirement of variety of products.

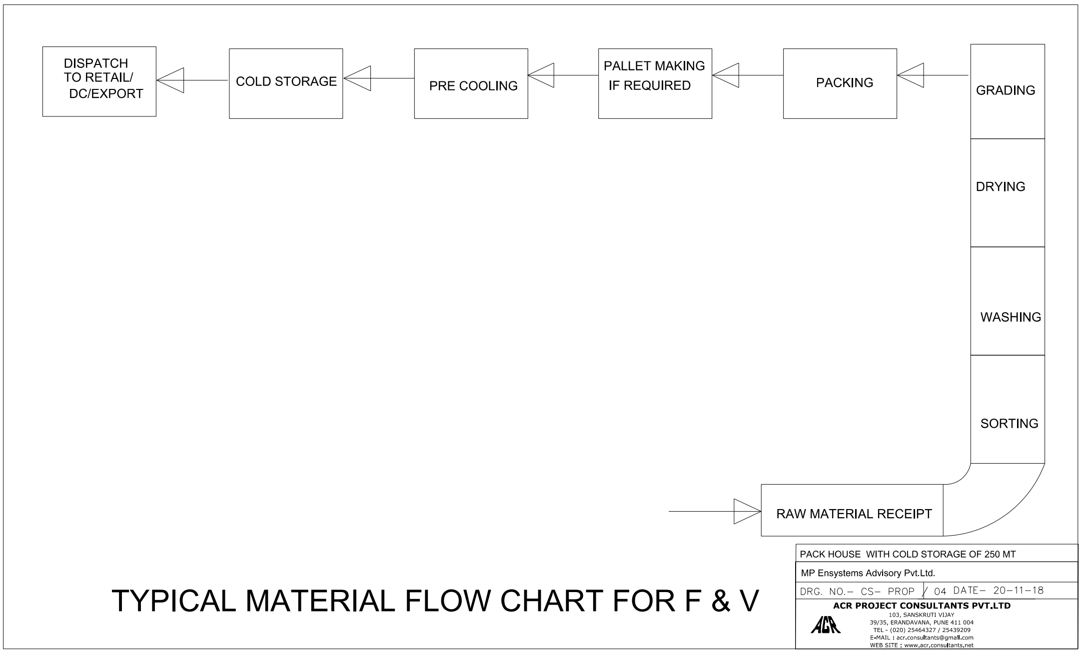
3.3 Requirement of Land & Building

Total plinth area of the building:	1260 Sq.m. (Approx.)
Building Envelope:	PEB steel structure with insulated panel
Other requirements:	Ante room of adequate size for precooling unit and cold rooms
	Provision for electrical hoist in the ante chambers.
	Fire norms and fire escape

3.4 Drawing of the proposed infrastructure:



3.5 Material Flow Chart:



3.6 Refrigeration System

Two types of refrigeration schemes can be used; keeping in mind the use of natural refrigerants. First option is use of Ammonia for entire cold-chain facility. Other option is use of Ammonia DX system for pre-cooling and use of ammonia Brine chillers and thermal storage for cold rooms.

Temperature in cold rooms shall be maintained in the range of 0 ^{0}C to 8 ^{0}C suitable for the storage of fruits and vegetables. The chambers shall have ceiling suspended AC units. The Pre-cooling chamber shall have a specially designed floor mounted air handling unit suitable for the required cooling capacity and high RH. The high RH cold chamber shall have ceiling mounted cooling units.

The machinery shall be available indigenously. The controls shall be provided for the regulation of temperatures in different chambers. Adequate safety devices and alarms shall be provided as per standard cold storage practice. The plant shall include standby compressor units and a water pumpset as per standard practice.

3.7 Insulation

The insulation shall be so selected that the heat gains by transmissions are reduced to minimum and the temperatures are maintained at low level for many hours.

As per the current international practice the cold chambers can be constructed with sandwich insulation panels. Sandwich panels shall be 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. PIR panels have better fire resistance as compared to PUF panels. However the structure has to be designed for proper wind loads, inclement weather conditions and leak-proofness.

3.8 Packing, Sorting and Grading

A mechanized line with facilities of washing drying and grading shall be provided. The fruit line shall have mechanized conveyor belt and tables for weighing, packing, etc.

The line shall include Dry Feeder cum inspection conveyor for gentle feeding of fruits for manual sorting of fruits according to quality. The Cull belt conveyor shall be used to eliminate the bruised or cull fruits.

The Washer Unit shall be used for

a) Foam cleaning of fruits to remove dirt and dust,

b) Fresh water rinsing with flood jet nozzles,

c) Damp drying using donut rolls,

d) Removal of fruits at the end of the run with clean out bar.

The dryer unit shall be used to dry the coating on the fruits to form a microscopic film without increasing the fruit pulp temperature. The mechanical weight grader shall be used for sizing the fruits in different sizes. Water supply, power supply and drain arrangements shall be made for various operations in the grading and packing hall.

3.9 Electrical Installation

Electrical power supply shall have 415 V, 50 Hz 3ph. AC and may come under LT supply. DG set, shall have to be provided for standby power supply.

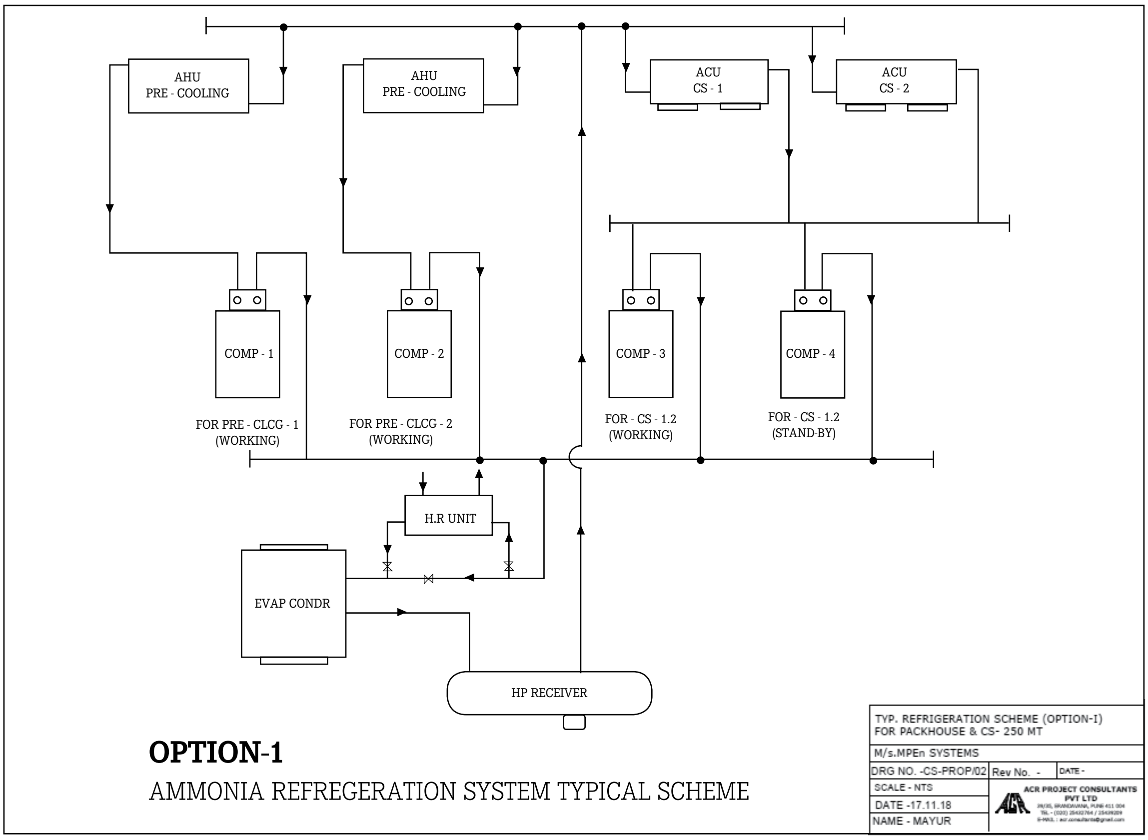
3.10 Miscellaneous Items

This includes fire-fighting equipment, water softening unit, rack structure in cold chambers, material handling equipment (if applicable), ventilation fans, office equipment, computers, etc.

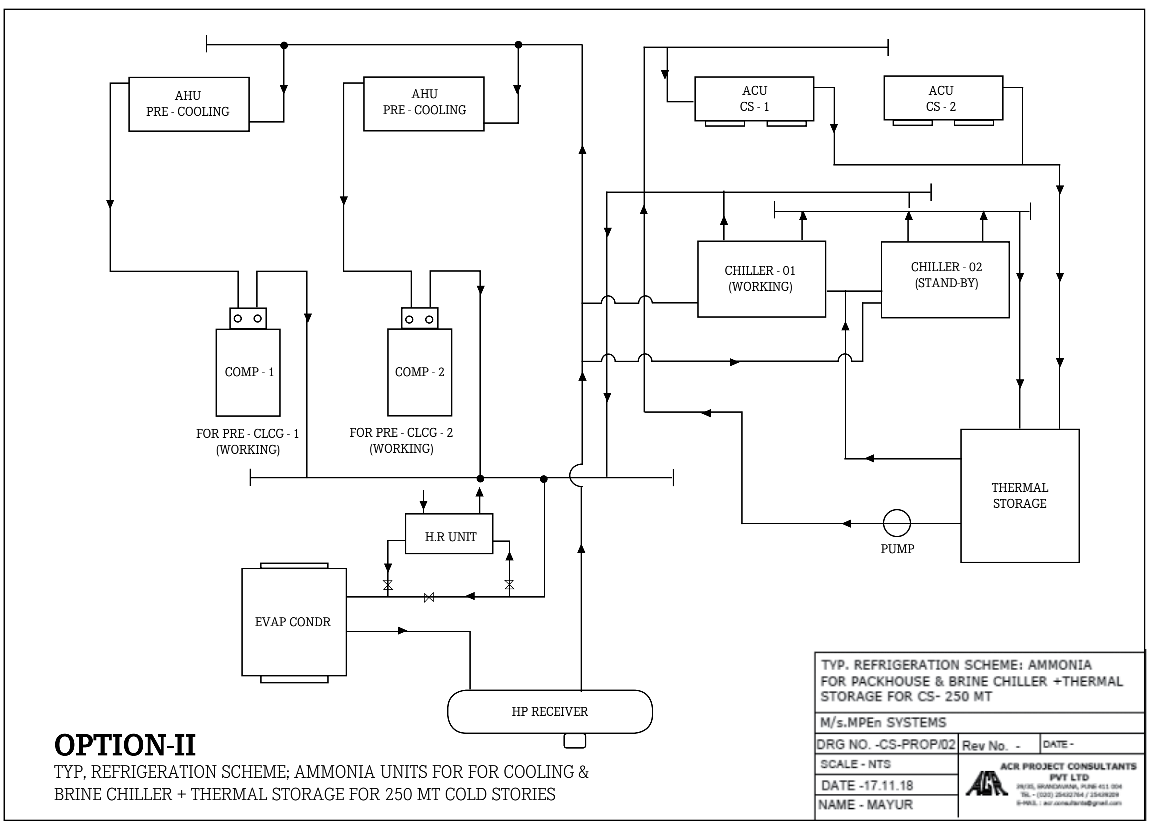
3.11 Refrigeration System Designs

The refrigeration system can be fully Ammonia based system for precooling units, cold rooms or can be split into Ammonia for pre cooling units and Brine chiller and thermal storage for cold rooms. The refrigeration scheme for both the option is given below:

AMMONIA REFRIGERATION SCHEME FOR PACK HOUSE AND COLD STORAGE (OPTION 1)



REFRIGERATION SCHEME - AMMONIA FOR PRECOOLING UNITS AND BRINE CHILLER + THERMAL STORAGE FOR COLD STORAGE (OPTION II)



3.12 Comparison of Proposed System against Baseline System Based On HFC

Comparative Energy Requirement for Pre Cooling / Cold Stores / Pack House / Equipment etc:

Table 15: Comparative Energy Requirement for Pre Cooling /Cold Stores /Pack House / Equipment etc:

		Base Line	Proposed
1	Pack House Lighting	With 40W TL - 9.2 kW	With 9W /12W LED Lights - 2.3 kW
2	Sorting Grading Line	31.0 kW	31.0 kW
3	**Refrigeration System**	**HFC System**	**Ammonia system**
a)	For Precooling & Cold Store	**Baseline System based on HFC**	**Option I: Entirely Ammonia Based System**
		With Air Cooled Condensing Units for Pre Cooling and Cold Storage AH Units for Pre-Cooling for Cold Stores - 16 kW AC Units for Cold Stores, Power 1.2 kW	Integrated system including stand by compressor common evaporative condenser, Pre Cooling AHU's & Cold Store AC Units.
		Power 76 kW	Power 40.5 kW
			Option II: Ammonia + Brine
			Ammonia DX System for Precooling & Ammonia Brine Chiller for Cold Stores with thermal storage for night 10 hr operation
			Power 49.3 kW
		HFC Based Air Cooled Units - 12 kW	HFC Based Air Cooled Units - 12 kW
b)	For Ante Room	Electrical Heating /gas for hot water heating	Waste heat recovered from Refrigeration system
c)	Heat Recovery System		Approx. - 20 kWh per hour Total Approx. - 240 kWh/day

E. Existing Agricultural Applications – List of free apps related to agriculture provided by the Ministry of Agriculture, Government of India

Name of App	Purpose	Developed by
AGRICULTURE		
KISAN SUVIDHA	Information on weather of current day and next 5 days, dealers, market prices, agro advisories, plant protection, IPM Practices etc. Unique features like extreme weather alerts and market prices of commodity in nearest area and the maximum price in state as well as India have been added to empower farmers in the best possible manner.	Ministry of Agriculture and Farmers Welfare
Pusa Krishi	Promotes Agribusiness Ventures through technology development and commercialization for everyone from a corporate to an individual farmer	ZTM&BPD Unit; ICAR-IARI, New Delhi
MKisan Application	It enables farmers and all other stakeholders to obtain advisories and information being sent by experts and government officials at different levels through mkisan portal without registering on the portal	
Shetkari Masik Android App	Main purpose of the magazine is to provide information about agriculture and modern technology to readers (mainly farmers)	Department of Agriculture, Maharashtra
Farm-o-pedia	Application is a multilingual Android application targeted for rural Gujarat. The app is useful for farmers or anyone related to agriculture. It is available in English and Gujarati languages. The main functionalities of the app are: • Get suitable crops as per soil and season • Get crop wise information • Check weather in your area • Manage your cattle	CDAC, Mumbai
Bhuvan Hailstorm App	Developed to capture crop loss happened due to hailstorm. Agriculture Officer will go to the field with mobile or tablet loaded with this mobile app. This mobile app is able to capture following parameters: • Photograph of field with latitude and longitude. • Name of Crop • Date of sowing • Date of likely harvesting • Source of irrigation This captured data will automatically be plotted to Bhuvan Portal and analysis can be done easily	Information not available

Crop Insurance mobile app	To calculate the Insurance Premium for notified crops based on area, coverage amount and loan amount in case of loanee farmer. It can also be used to get details of normal sum insured, extended sum insured, premium details and subsidy information of any notified crop in any notified area.	Information not available
AgriMarket	To get the market price of crops in the markets within 50 km of the device's location.	Information not available
ANIMAL HUSBANDRY		
Sikkim Allotment Of Breeding Bull	Used for making request for allotment of breeding bull under Animal Husbandry department of government of Sikkim	Information not available
Application for Poultry	With the help of this app, an applicant who wants to obtain assistance under Poultry Chick and Backyard Poultry Schemes of Govt. of Himachal Pradesh can apply online.	CDAC, Mumbai
Pashu Poshan	With the help of this software balanced ration is formulated while optimizing the cost considering animal profile	NDDB
OTHER USEFUL APPS FOR FARMERS		
MSCS (Multi State Cooperative Societies)	With the help of this app Cooperative Societies know the status of their registration and people can search the registered society in their location	MSCS
Digital Mandi India	Enables farmers, traders and all others to know the updated Mandi price from anywhere. Its main features are: • Browse through various commodity categories • Browse prices in different states • Simplified flow to reach the selected commodity's mandi price • Copy the mandi price of a commodity • Sync data from the Indian government portal Agmarknet.nic.in	Information not available
MNCFC	Useful for field data collection for crop assessment using satellite data under FASAL project of Ministry of Agriculture. The application can be used for collecting Field Photographs (640x480 resolution), GPS coordinates and Field information, such as crop type, condition, sowing date, soil type, etc	National Remote Sensing Centre, ISRO
Karnataka Bhoomi	Bhoomi (meaning land) is the project of on-line delivery and management of land records in Karnataka. Farmers of Karnataka know the status of their application through this app.	
HP Soil Testing	With the help of this app farmers can submit soil health samples of their land to the concerned soil health testing lab of their district / Block.	C-DAC Mumbai
Intelligent Advisory System for Farmers	Farmers can get different farming season details, month based atmospheric and ideal conditions for variety of crops	CDAC, Mumbai
Crop Info	Provides Production Technology of commercially important Horticultural & Agricultural crops on your smart phone. It provides production aspects, post-harvest technology, processing possibilities and market information.	Nirantara Livelihood Resources Private Limited, Bangalore, Karnataka.

Annexure F: Stakeholders Consultation

Summary of workshops organized in Delhi, Haryana and Mumbai with different stakeholders

S.No.	Workshop	Organized by	Date	Venue
I	Clean Cold-chain	Government of Haryana UK Trade Initiative, Shakti Sustainable Energy Foundation, MP Ensystems Advisory Pvt. Ltd.	10 September 2018	The Taj Mahal Hotel, Chandigarh

1. Background and Objectives

To discuss the opportunities in Clean Cold-Chain, the Haryana State Industrial and Infrastructure Corporation (HSIIDC), in collaboration with the Deputy High Commission Chandigarh, convened a meeting on 10 September 2018 at the TajMahal hotel, Chandigarh.

2. Some Facts about Haryana with respect to Cold-Chain

1. Geographically, and climatically, Haryana has similar regime throughout
2. Subsidy does not work. Market demand drives growth. Example, there is no subsidy for floriculture, mushroom and strawberry but there is demand and hence increase in growth.
3. Water table is going down due to excessive pumping of ground water – since electricity is free.
4. Horticulture produce comprises of Cabbage, cauliflower, tomato, Okra, carrot, cucumber. Leafy vegetables, baby corn and mushroom (mostly supplied to cities).
5. There is minimal or no food grain wastage or food loss in Haryana

3. Concern Areas

1. On the demand side, capturing the time value of agricultural produce
2. Take into consideration cost, environmental issues and technology
3. Lack of crop diversity in agriculture production in Haryana
4. There are many Silos in government structure
5. Pack houses have been constructed but they are not being used because farmers have not been trained
6. Sustainable cold-chain development has to take into consideration staple food of Haryana – meat and fish not consumed; major produce is grains
7. Identification of places where more vegetables and fruits are to be grown
8. Traditional farming practicing and cropping cycles with respect to shelf life and storage of fruits and vegetables to be taken into consideration; reducing demand for storage;
9. Imparting knowledge about shelf life / holding life and importance of pre-cooling harvest to farmers;
10. It is a matter of supply chain and issue of scale – a minimum acreage of land is desirable for crop output to sustain the scale of operations;
11. Selection of crops that are agro-climatically relevant to Haryana is important;

12. For development of model clean cold-chain, selection of a crop that can be exported and that will double farmers' income is important.

4. Opportunities

1. IESHaryana State Industrial and Infrastructure Development Corporation (HSIIDC) setting up food Park at Baddi and Ropar
2. Horticulture Department of Haryana State has set up cold-chain facility including Pack Houses and handed it over to FPOs in Kurukshetra which have aggregated a cluster of 7 to 8 villages
3. HSIIDC and Marketing board can help in implementation of a model cold-chain facility – supported by UKTI in Kurukshetra
4. Horticulture department has identified 140 clusters where potato, tomato, cauliflower are grown for 9 months. Project involves involvement of 87 FPOs, funding of Rs. 500 crore from Government; LOI for starting crop-facilitation centers issued.
5. Theses 87 FPOs could be provided with social capital – training, micro financing, aggregating and introduction to technologies
6. For the study purpose and model development, Horticulture department can provide 20 FPOs with crop cluster centers
7. In Gurgaon, several pack houses developed by Marketing Board. One or two of these can be made available for the purpose of the model.

5. Summary of Discussions

1. Create **Institutional design** to enable farmers to utilize cold-chain infrastructure such as pack houses and cold storage;
2. Reduce government involvement
3. **Increase involvement of NGOs, cooperatives and private sector.** Forming of clusters such as the Small Farmers Agribusiness Consortium, should be encouraged. On the positive side, Haryana has huge number of clusters, organized as FPOs
4. **Basis of excellence should** be profit – **increasing farmer's income.**
5. **In order to make FPOs successful, Social capital** needs to be infused in the form of institutional framework, training, etc.
6. Cold-chain or crop diversity - chicken or egg situation; however, **opportunities are huge**
7. **Create a platform** in which **HSIIDC along with UKTI will act as facilitator**, other organizations such as **marketing board and horticulture department** will play major role
8. This **platform** will be base to bring in new ideas of **branding and marketing, microfinance**
9. Include one person from each department as a coordinator:
   a. HSIIDC - Ms. Deepika Handa,
   b. Horticulture Department - Dr.Ranbir Singh
   c. HSAMB - Mr. Ajay Kadian
   d. MP En through SSEF – Dr. Mahesh Patankar
10. British support will bring in **branding**

6. Glimpses of the Workshop:

Mr. Shubhashis Dey, Program Manager (Energy Efficiency) (Shakti Sustainable Energy Foundation) giving an introduction to Shakti Foundation's Project on Clean Cold-chain

Dr. Mahesh Patankar, Managing Director (MP Ensystems Advisory Ltd.), presenting on the Clean Cold-chain Challenges

Participants interacting during the workshop

Group photo of the participants at the end of the workshop

7. List of Attendees

PARTICIPANTS			
S.No.	Organization	Name of Participants	Designation
1.	Haryana State Industrial and Infrastructure Development Corporation (HSIIDC)	T.L. Satyaprakash	Managing Director
		Ms. Deepika Handa	Assistant General Manager
2.	Haryana State Agricultural Marketing Board (HSAMB)	Dr. Hardeep Singh	Chief Administrator
		Mr. Prem Singh	Technical Advisor
		Mr. Ajay Kadian	
3.	Haryana State Horticulture Department	Dr. Ranbir Singh	Jt. Director
4.	University of Birmingham, UK	Prof. Toby Peters	Professor in Cold Economy
5.	British Deputy High Commission Chandigarh	Andrew Ayre	Deputy High Commissioner
		Dipankar Chakraborty	Senior Sector Manager - Agri-Tech & Chemicals and Head of Trade for Northwest India
		JavaidMulla	Prosperity Adviser, Energy & Low Carbon Growth
6.	Shakti Sustainable Energy Foundation	ShubhashisDey	Program Manager (Energy Efficiency)
		Chetna Nagpal	Programme Assistant
7.	MP Ensystems Advisory Ltd.	Dr. Mahesh Patankar	Managing Director
		Dr. Roshni Udyavar Yehuda	Head - Operations
		Chinmay Chhatbar	Program Manager
		Shirish Deshpande	Energy Expert

S.No.	Workshop	Organized by	Date	Venue
II	India-UK Framing Workshop to deliver Sustainable and Energy Efficient Cold-chain	**University of Birmingham India Institute, Shakti Sustainable Energy Foundation, MP Ensystems Advisory Pvt. Ltd.**	**12 September 2018**	**The Taj Mansingh Hotel, New Delhi**

1. Background and Objectives:

The Government of India has put forward substantial emphasis on doubling farmers' income by 2022. In India, up to 50% of food can be lost post-harvest primarily because of lack of cold-chain. We cannot address rural poverty without cold-chains extending the life of crops while connecting farmers to markets.

A seamless cold-chain will reduce food loss to raise farmers' income and give them bigger markets, whilst expanding their selling range. But at the same time, it must be clean and sustainable cooling; we must not replace a social crisis with an economic catastrophe.

The University of Birmingham in collaboration with the Shakti Sustainable Energy Foundation organized this workshop to kick-start a programme for advancing the use of new technology, initially in Haryana and Punjab, and help meet rising demand for cooling sustainably. The programme will help India achieve nutrition security and help boost farmers' incomes, with Shakti Foundation providing funding to allow researchers (MP Ensystems) to carry out the vital first phase of work in creating a roadmap to clean cold success.

Following the workshop on 10 September 2018 in Chandigarh engaging with government officials and the regional agricultural community, hosted by the State Government of Haryana, this second workshop **for industry and financiers**, was hosted by the University of Birmingham Institute for Global Innovation, in Delhi.

The aim of this first phase of discussions was to deliver the evidences and recommendations to make technologies affordable, financeable and implementable by the small and large implementation partners from warehousing, haulage and bulk-processing/storage options, to seek their input in terms of expertise on technology, processes, cost economics and financing options.

Working with Indian partners, the National Centre for Cold-Chain Development and the State Governments, the full ambition is to develop a Centre of Excellence through which to demonstrate innovative and integrated solutions for delivering affordable cold-chain solutions without compromising climate goals. The programme aimed to facilitate deliberation on:

- A roadmap identifying the actions needed to deliver clean cold goals in India;
- A cooling services model that outlines the new technology needed
- In-country ‘living labs’ to test and demonstrate new technologies

2. Introductory Session by Prof. Toby Peters:

Prof. Toby Peters, Professor of Cold Economy from the University of Birmingham, provided an overview of the challenges and need for developing a methodology and tool-kit for clean cold-chain Indian markets - from farm to fork. He explained the idea of developing ‘Living Labs’ with centers of demonstration and the introduction of appropriate technologies including renewables and thermal systems integrated end to end.

He stated that the three major challenges that have been accepted by countries globally - the Paris agreement, the Kigali Convention and the United Nations’ Sustainable Development Goals (SDGs) – all deal with clean cooling. Considering the status of cold-chains in India at present, he put forth the opportunities for India to leapfrog to green technologies.

3. What is A Clean Cold-Chain?

Clean cooling is the provision of cooling through efficient and sustainable means that contribute towards achieving society's goals for greenhouse gas emissions reduction, climate change mitigation, natural resource conservation and air quality improvement. Clean cooling must be affordable, accessible, financially sustainable, scalable, safe and reliable to help deliver our societal, economic and health goals.

Through the session, Prof. Toby Peters put forth the idea of Living Labs and use of liquid nitrogen as a technology for cooling. Beyond technology demonstration, he expressed various aspects and aspirations related to clean cold-chain including:

- **Cooling as a service** extending beyond cold-chain to play multiple roles
- Clean cold-chain needs as a **good business model rather than a technology**
- Setting up a **LIVING LAB** as an integrated bundling of technologies taking into consideration **Policy interventions, Business Models, Data and Awareness.**
    - For example, if the Indian government is planning to introduce 20,000 pack houses, what is the energy that will be consumed? What is the funding model? What is the right business model?
    - Challenges in planning first and last mile transportation with cooling. For example, rail instead of road, etc.; while we have a lot to learn from Vaccines in this area, the challenge with cold-chain in agricultural produce lies in the volumes.
    - Developing cold-chain piecemeal – while the aspiration is to start with clean cold-chain right through it may not be practical due to non-availability of technology; beginning may be with partial measures.
    - Timeline for the 'Living lab / Demonstration Project' is early next year - starting with system design of the centers of excellence – perhaps, for different climates, specifying a portfolio of sustainable and energy-efficient technologies along the cold-chain.
    - System level energy design and introduction of cutting edge technologies for waste to energy, absorption chillers, solar thermal, ice cooling, phase change materials and liquid nitrogen

4. Barriers in Clean Cold-Chain

- Diverse demographics and specific local issues, moderate literacy levels, and conventional ideas related to food and agriculture.
- Operation and maintenance of efficient cooling services
- First and last mile challenges - limited capacity for storage at farm end (for millions of farmers with limited income of 1200 to 1500 USD per year) and lack of space and infrastructure at the retail end.
- Lack of knowledge on post-harvest care of produce
- Unit economics of cold-chain - from farm to fork.
- No direct incentives to farmer of clean cold-chain (in comparison with MSP or Minimum Sales Price of a produce, which insures farmers against contingencies).

- Loss due to use of regular haulage (For example, Jain Farm Fresh processes 2500 MT of mango in May/ June; the top layer in the regular haulage is usually lost due to heat)

5. Support extended by participating organizations

The following organizations extended their support to the clean-cold-chain project:

- ISHRAE to support in creating awareness
- YES Bank to support viable business models
- Carrier, Polfrost and other technology providers and consultants, to collaborate on demonstration of newer technologies

6. Summary of Discussions

- Mapping the performance of existing technologies and equipment with respect to clean refrigeration and energy efficiency
- Techno-commercial-financial feasibility of new technologies
- The role of IT in enhancing connections in the cold-chain
- Involvement of government stakeholders that are related with energy efficiency and clean/ green technologies- Ministry of Environment Forests and Climate Change (MOEF CC), Bureau of Energy Efficiency (BEE), State Agricultural Marketing Boards;
- Analysis of Life Cycle Costing (LCC) of clean cold-chain
- Study existing successful models such as that of cargo ships.
- Study international models for clean cold-chain
- Mapping the energy consumption at each stage of the cold-chain – from farm gate to retail outlet.
- Need to develop successful integrated cold-chain before introducing clean/ green aspect.
- Lessons from experience in last mile for clean cold-chain in vaccination in 12 states of India using insulated boxes with temperature sensor to ensure potency of vaccine at the time of inoculation.
- Lessons from India - there is predominant use of insulated ice boxes (a phase change material) in the preservation and transportation of fresh fish produce to markets.
- Training, capacity building, institutional set-up and deployment of personnel for maintenance of cooling systems (clean cold-chain).
- Study existing value chain and document existing handling practices
- Study of different business models such as the FPO model, the private entrepreneur model, the cooperative model, etc.

7. Glimpses of the Workshop:

Dr. Toby Peters, Professor of cold economy (University of Birmingham Institute for Global Innovation) during a discussion session

Dr. Toby Peters, Professor of cold economy (University of Birmingham Institute for Global Innovation) during a presentation

Dr. Toby Peters providing an overview of use of liquid nitrogen for cooling

Dr. Toby Peters, Professor of cold economy (University of Birmingham Institute for Global Innovation) in discussion with participants

8. List of Attendees

PARTICIPANTS			
S.No.	Organization	Name of Participants	Designation
1	Indian Society for Heating Refrigeration and Air-conditioning Engineers (ISHRAE)	Vikram Murthy	National President Elect
	Tropical air conditioning & Refrigeration		India Representation
2	Jain Farm Fresh Foods Ltd	V.P Patil	Sr. Vice President
3	Jain Farm Fresh Foods Ltd	Homaji Bhangale D.	Manager
4	Jain Farm Fresh Foods Ltd	P. V. Gunjal	Automation Head
5	Association of Ammonia Refrigeration	Anil Gulanikar	Past President
6	Indian Society for Heating Refrigeration and Air-conditioning Engineers (ISHRAE)	Ashwini Mehra	Executive Secretariat, ISHRAE Headquarters.
7	Refcold India	Mr. K K Mitra	National Steering Council Member of REFCOLD INDIA & Sr. Vice President
8	POLFROST Air - con Pvt Ltd	Parth Thakkar	Director
9	Dasmesh Comprehensive Air Solution	Mr. Jasprit Singh	Director - Dasmeshac air Conditioning
10	Carrier Transcold	Pankaj Mehta	Managing Director (India and South Asia)
11	Tecumseh Products Company	Mr. Love Kumar	Regional Manager - North India; General manager sales
12	Shakti Foundation	Shubhashis Dey	Program Manager (Energy Efficiency)
13	Shakti Foundation	Nandini Sharma	Programme Associate
14	Shakti Foundation	Chetna Nagpal	Programme Assistant
15	UKTI	Dipankar Chakravarthy	Senior Sector Manager - Agri-Tech & Chemicals and Head of Trade for Northwest India
16	University of Birmingham Institute for Global Innovation	Dr. Toby Peters	Professor of Cold Economy
17	University of Birmingham Institute	Aparajita Kalra	Country Manager
18	MP Ensystems Advisory Pvt. Ltd.	Dr. Roshni Udyavar Yehuda	Head – Operations
19	MP Ensystems Advisory Pvt. Ltd.	Chinmay Chhatbar	Program Manager

PARTICIPANTS			
S.No.	Organization	Name of Participants	Designation
20	MP Ensystems Advisory Pvt. Ltd.	Shirish Deshpande	Energy Expert
21	Bharat Innovations	Hemendra Mathur	Venture partner
22	Danfoss Industries	Nagahari Krishna L	Director
23	Prompt Group	Dr. SudhindraTatti	Director Innovation
24	Prompt Group	Mr. Shridhar Mehta	Director
25	Confederation of Indian Industries (CII)	Pragya Nehru	CII-FACE
26	Yes Bank	Mr. NitinPuri	Senior President & Global Head, FASAR
27	National Institute of Food Technology Entrepreneurship and Management (NIFTEM)	Dr. P.K. Nema	HoD (Food Engineering)
28	World Bank	Dr. Ashok Sarkar	Sr. Energy Specialist
29	Agricultural Specialist	Dr. R. K Sharma	Consultancy
30	Nexleaf Analytics	Anita Sircer	Project Manager
31	National Institute of Food Technology Entrepreneurship and Management (NIFTEM)	Dr. Vinkel Arora	Assistant Professor, Mech. Engg

S.No.	Workshop	Organized by	Date	Venue
III	Sustainable and Energy-Efficient Technologies for Clean Cold-Chain in India	University of Birmingham India Institute, Shakti Sustainable Energy Foundation, MP Ensystems Advisory Pvt. Ltd.	29 October 2018	Kasliwal Board Room, MACCIA, Oricon House, Mumbai

1. Background and Objectives:

It is envisaged that a seamless cold-chain will reduce food loss, thereby raising farmers’ income and expand their selling range – in line with the Government of India’s goal of doubling farmers' income by 2022. However, it is imperative that we develop practical and affordable cold-chain solutions without compromising climate goals.

In this context, the workshop on ‘Sustainable and Energy-Efficient Technologies for Clean Cold-Chain in India’ was organized as part of a project on ‘Promoting Energy Efficient and Clean Cold-chain' by MP Ensystems Advisory Pvt. Ltd. under contract from Shakti Sustainable Energy Foundation (SSEF) and with technical support from the University of Birmingham (UoB). The workshop was held on **29 October 2018 at the Kasliwal Board Room, MACCIA, Oricon House, 6th Flr., Maharashtra Chamber of Commerce Lane, Kala Ghoda, Fort, Mumbai – 400 001, from 1000 to 1600 hours.**

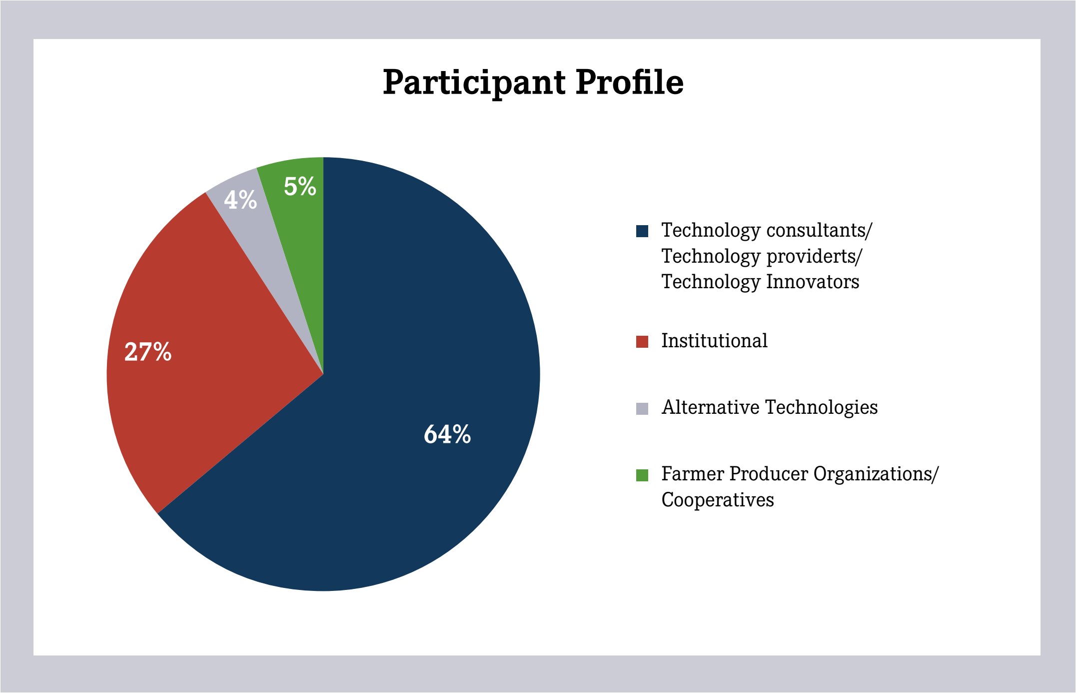
The objectives of this workshop were:

- To assimilate knowledge-base in efficient and clean cold-chain technologies
- To create a list of appropriate technologies available or imported in India by project developers/contractors
- To compare and contrast technologies throughout the cold-chain considering costs, localization, efficiency, technology transfer, O&M, scale-up opportunity, GWP/ ODP range, skills required for servicing, and specific energy consumption (thermal/electricity)
- To create a database of best-practices and technologies prevalent in cold-chain in India

The workshop aimed to assess technologies throughout the cold-chain including first and last mile transportation, Packhouses, Cold rooms, Ripening chambers, Bulk and sub-zero storage, envelope and infrastructure design requirements. The focus was on efficient and clean technologies as closed loop systems, clean refrigerants, waste heat recovery options, IoT based remote monitoring techniques and integrated system design.

2. Program Outline and Participants

The workshop/ round table was attended by 23 participants including representative from the Government of Haryana, Technology Consultants and Providers, Institutional bodies such as ISHRAE, Association of Ammonia Refrigerants and India Insulation Forum, FPOs as well as experts from Academic Institutes such as IIT Bombay and United Nations Industrial Development Organization (UNIDO). A profile of participants is given below:



The program of the workshop was divided into 4 sections:

1. Background and introduction to participants
2. Presentation by Technology Providers and Consultants on Clean Cold-Chain Technologies of Present and Future

3. Presentation and discussion session lead by Prof. Toby Peters on 'Cold Economy Vision and Integrated Design'
4. Discussion on Appropriate Technologies for Indian Cold-Chain

The detailed program outline is attached in the annexure.

3. Technology Data Sheet and Technology Assessment Template (Radar Diagram)

In order to systematically document the details of the clean cold-chain technologies from all the technology consultants and providers, a technology sheet was prepared and circulated. About 8 technology providers provided the completed data sheets before the program. These will be compiled and assessed.

For technology assessment, which will be done by MP Ensystems Advisory Pvt. Ltd, a template was developed on spreadsheet – a copy of which is attached. Based on the technology data sheets submitted, the template will be filled to create the radar diagrams – which will assist in selection of technologies and identification of best practices.

4. Summary of Discussions

- Dr. Mahesh Patankar introduced participants to the project of 'Promoting Clean and Energy Efficient Cold-Chain in India' and the objectives of the workshop. He facilitated the discussions and connected each of the technology presentations to the contribution it could make to the cold-chain particularly under the Govt. of Haryana's Crop Cluster Development Project (CCDP) under which 21 FPOs have been issued Letter of Intents (LOIs) by the Govt. with subsidy up to 90% for the cold-chain development.
- Prof. Toby Peters engaged with the participants throughout the workshop and provided a global overview on clean cold-chain– emphasizing on integrated design. He stated that while there are plans by the Government to develop the Cold-Chain in India with an objective of 'doubling farmer's income', delivering cold-chain would not be difficult. What we need, he stated, is to see that the cold-chain is delivered with zero climate impact. He summarized the discussions that followed his presentation on 'Cold Economy Vision and Integrated Design' in the post lunch session as follows:
    - While developing the cold-chain, system level thinking is important. We need to find out the potential of energy saving and energy efficiency throughout the cold-chain
    - We need to identify what we are throwing away in the cold-chain – that waste must be recovered and used.
    - Aggregation is important to see that we deliver a bundle of technologies with end-to-end cold-chain for the Govt. of Haryana
- Mr. Arvind Surange, who kick-started the technology discussions with 'integrated system design' provided an overview of cold-chain in India, definition of cold-chain and its components and case studies of some of their projects in Maharashtra. He summarized his presentation and subsequently his discussion in the cold economy vision session as follows:
    - Cold-Chain has to transform into value chain – for the farmer, aggregator, retailer and finally consumer

- India has the largest cold-chain related to milk supply and the second largest in the world related to fruits and vegetables. The current loss of fresh vegetables in India is about 20 – 25% - in the absence of cold-chain.
- NCCD estimates that we need 34 million metric tonnes of cold storage (10% more than current), 69000 pack houses (as against the current 800 – 900), 15,000 to 20,000 ripening chambers (as against current 1000) and 15000 reefer vehicles (as against the current 10,000). The potential is huge. Therefore, we must consider the environmental impact of this cold-chain in terms of energy usage, water usage and disposal of waste
- Considering that a large number of existing cold storage units are using outdated technology, there should be a scheme for modernization with financial incentive to retrofit existing facilities with better insulation and more energy efficient and clean refrigeration systems.

- Mr. Milind Rane, who presented on various technologies including super heat recovery water heater, cooling from vehicular exhaust and air compressor technologies, provided his inputs in the discussion as follows:
  - We must identify opportunities to save energy in the cold-chain. For eg. Can we bring down the size and cost of cold storage by effective pre-cooling using evaporative cooling technology? Waste heat from engine exhaust and radiator hot water can take care of entire requirement of energy for reefer vehicles in the chain.
  - We need to have systems which are sustainable with respect to environment and are cost-efficient as well. For example, use of waste heat is both environmentally and economically sustainable. We should also consider using surplus from renewable grid to charge PCM banks.
- Mr. Amol Desai who presented on the potential energy savings from use of insulation for cold-chain stated the need for norms and mandatory checks post-installation
- Mr. Anand Joshi who presented on technologies using ammonia as refrigerant, stated that the AAR will be coming up with Ammonia based technologies for smaller units of cold storage in a few months.
- Mr. Surendra Shah, Founder Director of Panasia Engineers presented on technologies for dehydration to increase the quality and value of the product.
- Mr. Vishnu Shashidharan from PLUSS technologies made an elaborate presentation about the use of phase change materials and eutectic plates for different applications throughout the cold-chain.
- Mr. Shirish Deshpande, Energy Expert from MP Ensystems Advisory Pvt. Ltd. suggested the use of solar concentrator technology for DC compressor using VAM (Vapour Absorption Machines)
- Mr. Vikram Murthy representing ISHRAE (Indian Society for Heating, Refrigeration and Air Conditioning Engineers) talked about the lack of organized sector in the first mile and to have a more well-defined ecosystem which is economically viable to the farmer. Even through India has the second largest arable land in the world after USA, farmers still get 10 – 15% of value for products as compared to the world average of 50 – 55%. While subsidies are good, they do not incentivize farmer or farmer groups to run cold-chains profitably. Hence, government and private sector must make efforts for the whole business to be cost effective otherwise clean cold-chain will remain aspirational only.

- Mr. Pankaj Kumar, National Technical Expert (Solar), United Nations Industrial Development Organization (UNIDO), presented on the opportunities in concentrated solar thermal (CST) technologies for the cold-chain and the incentives being offered by MNRE.
- Mr. Homaji Bhangale from Jain Farm Fresh, Jalgaon, spoke about the energy efficient technologies and waste heat recovery that is being already followed in their 800 MT/ day Mango Processing Plant and 600 MT/ day onion processing plant. Onion and mango peels are processed in the biogas plant from which 1.6MW/ hour of electricity is generated. The waste heat recovered from biogas engine is passed through absorption chiller producing 450 TR of cooling which is used to store 25000 MT of raw onion for a period of 6 months from March to August. In terms of challenges, he stated about the losses due to lack of cold-chain for both onions and mangoes in the first mile and the price fluctuation affecting farmers.
- Mr. Yoginder Singh representing the Govt. of Haryana, concluded with an appreciation for all technology providers / consultants for sharing their new and innovative technologies, which he felt was much needed in the upcoming CCDP projects promoted by the Govt. of Haryana. He suggested to form a team which will guide the government in creating a model clean cold-chain.

5. Glimpses of the Workshop:

Dr. Milind Rane, Professor, IIT Bombay and Mr. Pankaj Kumar, National technical expert (solar),UNIDO during the discussion session

Mr. Arvind Surange, Chairman and Managing Director, ACR Project Consultants Pvt. Ltd presenting on integrated system design

Dr. Mahesh Patankar, Managing Director, MP Ensystems Advisory Pvt. Ltd. during the introduction session.

Mr. Yoginder Singh, State Consultant, Small Farmers Agriculture Consortium Haryana (SFACH) during the conclusion session

Participants at the workshop

6. List of Attendees

PARTICIPANTS			
S.No.	Organization	Name of Participants	Designation
1	ACR Project Consultants Pvt. Ltd	Arvind Surange	Chairman and Managing Director
2	ACR Project Consultants Pvt. Ltd	Aditi Surange	Head - Business Development
3	IIT Bombay	Dr. Milind Rane	Professor - Department of Mechanical Engineering
4	Kehems Technologies Pvt. Ltd	Rohit Yadav	Senior Engineer
5	Kehems Technologies Pvt. Ltd	Subodh Kawale	

6	Kehems Technologies Pvt. Ltd	Amey More	
7	Danfoss Industries Pvt. Ltd	NeerajNarula	Manager - Business Development
8	Danfoss Industries Pvt. Ltd	Amit Chaurasa	Manager
9	IIT Bombay	Vikash Jha	Assistant Project Manager - CTARA (Center for Technology Alternatives for Rural Areas)
10	India Insulation Forum	Amol Desai	
11	India Insulation Forum	Rajesh Gaonkar	
12	POLFROST air - con Pvt Ltd	Parth Thakkar	Director
13	Huntsman International India Pvt. Ltd	Chandra Kumar Patel	Technical Platform Manager -Polyurethane
14	Panasia Engineers	Surendra Shah	Founder Chairman
15	Small Farmers Agriculture Consortium Haryana (SFACH)	Yoginder Singh	State Consultant
16	National President Elect	Vikram Murthy	ISHRAE
17	Association of Ammonia Refrigerants	Anand Joshi	Past President
18	United Nations Industrial Development Organisation	Pankaj Kumar	National Technial Expert (Solar)
19	NABCONS	Mukesh Belwal	Assistant Manager
20	Pluss Advanced Tech	Vishnu Shashidharan	
21	Jain Farm Fresh Foods Ltd	Homaji Bhangale N.	Manager
22	MP Ensystems Advisory Pvt. Ltd.	Dr. Mahesh Patankar	Managing Director
23	MP Ensystems Advisory Pvt. Ltd.	Dr. Roshni Udyavar Yehuda	Head - Operations
24	MP Ensystems Advisory Pvt. Ltd.	Shirish Deshpande	Energy Expert
25	MP Ensystems Advisory Pvt. Ltd.	Chinmay Chhatbar	Program Manager
26	Shakti Sustainable Energy Foundation	Chetna Nagpal	Program Assistant, Energy Efficiency
27	World Bank	Karishma Gupte	Consultant 2030 WRG

Annexure 1 – Program Outline

PROGRAMME OUTLINE

TIMINGS	SESSION
10:00 – 10:30	Registration
INTRODUCTION SESSION	
10:30 – 10:00	Background and Introduction of Participants
Section 1: Presentation by Technology Providers and Consultants	
10:00 –11:30	Integrated System Design – physical Infrastructure
11:30 – 12:00	Cold-chain Logistics & First / Last Mile Technologies
12:00 – 12:30	Technologies relevant to pack Houses, Cold Rooms and Ripening Chambers
12:30 – 13:00	Bulk Storage and Sub-zero storage
13:00 – 13:30	Design and Planning - Infrastructure and Building Envelope
Lunch: 13:30 – 14:30	
Session II: Cold Economy Vision	
14:30 – 15:15	'Cold Economy Vision' by Prof. Toby Peters, Professor of Cold Economy, University of Birmingham
15:15 – 15:45	Moderated discussion on Cold-chain **Integrated Designs** led by Prof. Toby Peters
Session III: Appropriate Technologies for Indian Cold-Chain	
15:45 – 16:15	Discussion on Appropriate Technologies for Indian Cold-Chain
16:15 – 16:30	Summing up and next steps

DETAILED PROGRAM

TIMINGS	SESSION
10:00 – 10:30	Registration
	INTRODUCTION SESSION
10:30 – 11:00	Background and Introduction of Participants • Welcome Remarks and Overview by Dr. Mahesh Patankar, Managing Director, MP Ensystems Advisory Pvt. Ltd. • Welcome remarks by Mr. Yoginder Singh, State Consultant, Small Farmers Agribusiness Consortium, Haryana (SFACH) • Practical Challenges in Clean Cold-chain – Remarks by Mr. Vikram Murthy, National President Elect, ISHRAE and Mr. Homaji Bhangale, Manager, Jain Farm Fresh Foods Ltd.
	Session I: Clean Cold-chain technologies of Present and Future
11:00 –13:00	1. **Integrated System Design** by Mr. Arvind Surange, MCD, ACR Project Consultants 2. **Super Heat Recovery Water Heater** by Dr. Milind Rane, Professor Department of mechanical Engineering, IIT Bombay 3. **Thermal Energy Storage for Low Temperature Applications** by Rohit Yadav, Senior Engineer, Kehems Technologies Pvt. Ltd. 4. **Innovations & Technologies** by Neeraj Narula, Manager, Business Development HVACR, Danfoss Industries Pvt. Ltd. 5. **Solar Thermal Applications for Cooling** by Prof. Vishal R. Sardeshpande, Associate professor, Centre for Technology alternatives for Rural Areas, IIT Bombay 6. **Zero Energy Vegetable Storage using Evaporative Cooling in First Mile** by Vikash Jha, Assistant Project Manager, Centre for Technology Alternatives for Rural Areas, IIT Bombay 7. **Innovative technologies for First Mile** by Surendra Shah, Founder Chairman, Panasia Engineers 8. **Innovations & Technologies** by Sagar Sethi, Senior Sales Engineer, Carel ACR Systems India Pvt Ltd. 9. **Innovative Thermal Energy Storage Technology** by Vishnu Shashidharan, Pluss Advanced Tech 10. **Insulation Design for cold-storage** by Amol Desai, India Insulation Forum 11. **Future Trends for Ammonia Refrigerants in the Cold Chain** by Anand Joshi, Past President, Association of Ammonia Refrigerants 12. **Opportunities in Concentrated Solar Themal (CST) Technologies** by Pankaj Kumar, National Technical Expert (Solar), United Nations Industrial Development Organisation
	Lunch: 13:30 – 14:30
	Session II: Cold Economy Vision
14:30 – 15:15	'Cold Economy Vision' by Prof. Toby Peters, Professor of Cold Economy, University of Birmingham
15:15 – 15:45	Moderated discussion on Cold-chain **Integrated Designs** led by Prof. Toby Peters
	Session III: Appropriate Technologies for Indian Cold-Chain
15:45 – 16:15	Discussion on Appropriate Technologies for Indian Cold-Chain
16:15 – 16:30	Summing up and next steps

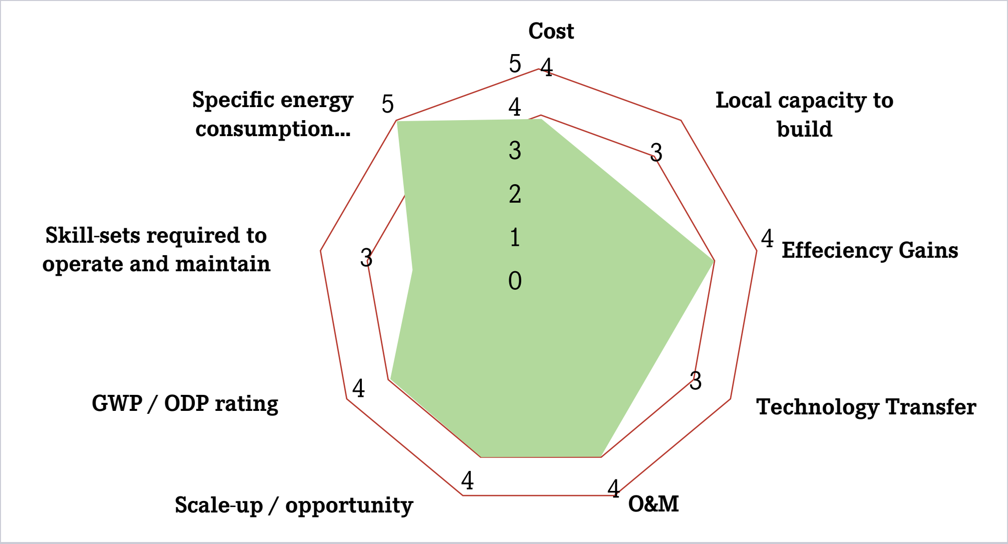
Annexure 2 – Technology Data Sheet

TITLE OF TECHNOLOGY	
Technology Description	
Block/ Schematic of the technology (a picture of schematic can be pasted)	
Technology Applied in (Stage of Cold-chain)	☐ First mile transportation (Farm to Pack House or first storage/ processing facility) ☐ Last mile transportation (Last storage/ processing/ marketing/ retail facility to end consumers) ☐ Transportation in between first and last mile (throughout cold-chain) ☐ Packhouses ☐ Cold rooms ☐ Ripening chambers ☐ Bulk and sub-zero storage ☐ Envelope and infrastructure design requirements
Specific Process for which the technology is applicable in the above Stage	
Technology Application Results in Reduction of	☐ Greenhouse Gas Emissions ☐ Ozone Depleting Potential ☐ Energy Consumption ☐ Air Pollution ☐ Cooling Load ☐ Wastage/ Loss of Produce
Description of Reduction achieved (in absolute figures or % as compared to conventional)	
Applicable environment conditions	Temperature (^{0}C) : ___________ RH (%) : ___________ Others : ______________________
Capacity range (MT)	
Compatibility with previous and next stage of the cold-chain	
Exclusive technology or add-on	☐ Yes ☐ No
If Yes, Process or Equipment modifications required	

What is the type of energy source used during operations? **Thermal / Electrical / Waste heat / Process heat**	☐ Electricity – Grid Connected ☐ Battery Operated (Battery Type _________) ☐ Diesel, Coal, Bio Fuels ☐ Waste to Energy/ cogeneration ☐ CNG, LPG, BioGas ☐ Hydro Energy ☐ Solar PV ☐ Solar Thermal ☐ Geo Thermal ☐ Wind Energy ☐ External energy source is not required Waste/ Process Heat_______________			
Energy consumption data (kWh per unit)				
Global Warming Potential& Ozone Depletion Potential Data				
Economic Benefits of using your product / technology				
Other Benefits of using your product / technology				
Health/ Occupational or Environmental Hazards				
Have you published Environmental Product Declaration (EPD)?				
Life of the technology / product (years)				
Capital cost (Rs./ unit or size)				
Operating cost (Rs./ unit or size)				
Skill sets required				
Man Power requirements				
Readiness for adoption of technology		Low	Medium	High
	Scale of operations			
	Infrastructure availability			
	Skill sets required			
Operational issues (if any)				
Key parameters for operation of the technology (SOP) and standard Values.				
Is there a policy support for your technology?	☐ Yes		☐ No	
What are the various government policies supporting your technology?				
Do you foresee any threat to your technology?	☐ Competing Technologies ☐ Environmental regulations ☐ Availability of resources			
Contact data of Suppliers				
Contact data of Users				

Annexure 3 – Technology Assessment for Clean Cold-chain

Technology Assessment					
Factors	1	2	3	4	5
Cost					
Local capacity to build					
Efficiency Gains					
Technology Transfer					
O&M					
Scale-up opportunity					
GWP/ ODP rating					
Skill-sets required to operate and maintain					
Specific energy consumption (kWh/MT)					



S.No.	Workshop	Organized by	Date	Venue
IV	Clean and Energy-Efficient Clean Cold-Chain in India	Process Division, IMECHE.	2 February 2019	The Beattle, Powai, Mumbai

1. Background and Objectives:

Objectives: The objective of the workshop was to discuss the outputs of the high-level study on 'Clean and Energy Efficient Cold-Chain in India' by MP Ensystems Advisory Pvt. Ltd., Mumbai, supported by Shakti Sustainable Energy Foundation (SSEF), New Delhi and University of Birmingham, UK. The study aimed at enabling the farm to fork value chain sustainably.

The Program convened by Dr. Milind Atrey, Institute Chair Professor, Ex-Professor-In-Charge of SINE(Society for Innovation and Entrepreneurship) & Professor, Department of Mechanical Engineering, IIT Bombay, was organized by the Process Division, Institution of Mechanical Engineers (IMECHE), India on the occasion of their first anniversary celebration. The workshop was chaired by Dr. Tim Fox, Chair IMechE Process Division, UK and anchored by Dr. Milind Atrey. Dr. Mahesh Patankar, Managing Director, MP Ensystems Advisory Pvt. Ltd., was the lead speaker providing an overview of the Clean Cold-Chain study and prospects.

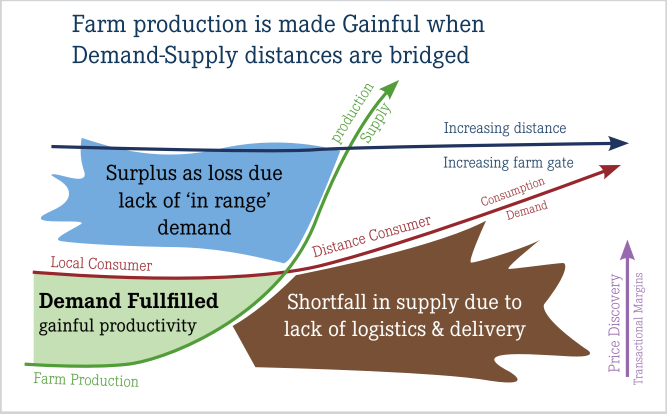
Background: Up to 90% of food loss in developing countries is caused by losses in the supply chain with major consequences for poverty, hunger and health, as well as the environment and natural resources. In India, despite sufficient and surplus production, rural poverty and under-nutrition prevails and hunger is as yet not eradicated. Perversely, compared with the start of the 1960s, India now harvests 40 times as much tomato; 14 times more potato; 8 times more wheat; 3 times as much in poultry and meat; 13 times more fish; 8 times more milk and almost 40 times more eggs.

Dr. Mahesh Patankar, Managing Director, MP Ensystems Advisory Pvt. Ltd. during the session.

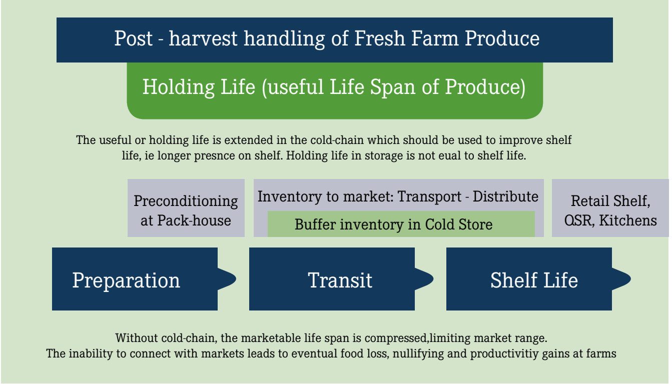
Two underlying problems

- Historically, efforts were made to correlate population (or demand) with production (or supply). Production alone is not sufficient to ensure supply of food - the missing condition is physical and effective market reach.
- Cold-chain has colloquially been interpreted as cold warehousing, to store surplus agricultural produce, to meet delayed or deferred demand.

A cold-chain is not *a cold store*. It is an integrated, seamless and resilient network of refrigerated and temperature-controlled pack houses, cold storage, distribution hubs and vehicles used to maintain the safety, quality and quantity of food produce, while moving it swiftly from point of harvest to consumption point.



It should enhance economic wealth, cash flow and security for farmers and improve food quality, safety and value to the consumer; it can allow farmers to expand their portfolio of products "fork to field", as well as enable them to diversify into processing food, thereby creating value add and jobs.



Cold-chains are an essential contributor to food security and prosperity building. However, while recognising these important benefits, to cope with desired demand growth in a sustainable way, systems need to be designed to maximise final energy efficiency and harness renewable and waste energy sources; currently cold-chains are reliant largely on fossil fuel based electricity grids and diesel for both transport refrigeration and off-grid power. Accelerated deployment of clean cold-chains is an urgent, significant, but currently not prioritised, local, national and global challenge if we are to meet our commitments under the Sustainable Development Goals, Paris Climate Agreement and the Kigali Amendment to the Montreal Protocol.

Clean cold-chains deliver on the three core pillars of food:

Our research with farmers, FPOs, state and national Governments, industry and the finance community has identified clear challenges and routes forward:

Cold-Chain Development Challenges

- Focus on storage; not system
- Not paired with education and training
- Lack of understanding of the business case and model
- Lack of skilled capacity to design, deploy, maintenance
- Focus on storage with little regard for the chain (esp. first and last mile)
- Return on investment needs to be clearly calculated and understood

Clean Cold-Chain Specific Challenges

- Nascent technologies
- Current focus on green electricity;
- Energy storage
- End to end system incl. transport
- Business model – TCO versus Caped
- No knowledge base
- Risk embedding old technology

Clean Cold-Chain Development Requirements

- System design – end to end
- "Fork to field" flow of information as well as "field to fork" flow of produce
- Access and understanding of "fit for market" cooling, cold storage and cold chain technologies
- Vetted business models for small, medium and large scale enterprises
- Demonstration of impact: flow of money back to farmers
- Trained technicians for design, installation and maintenance
- Enabling support – finance options, basic infrastructure
- Incentive such as duty free imports, low interest rates, corporate tax breaks

➜ **Robust methodology for "fit for market" design**
➜ **Demonstration**
➜ **Education, training**
➜ **Incubation hubs**
➜ **Finance**

Potential technologies are on the point of commercialisation, but it is not enough simply to demonstrate that each of the new clean cold technologies works individually. Instead we need to test, evaluate and demonstrate bundles of technology working from end to end rather than as a series of isolated facilities. We also need to demonstrate affordable business and funding models and show economic value back to the community as well as replication of "fit for market".

The study proposes a trailblazer project to deliver needs-driven end to end clean cold-chain system design. It will be driven by meeting cooling and logistics needs in both an environmentally sustainable (including refrigerants), energy efficient and economically affordable manner, harnessing available sources of waste, free and renewable energy to meet the multiple cooling service needs of end to end cold-chains.

2. Program Outline

The workshop was attended by about 50 engineers, members of IMECHE (Institute of Mechanical Engineers,) India. The program outline was as follows:

1700 HRS to 1715 HRS – **Welcome (Tea/coffee)**

1715 HRS to 1720 HRS – ***Introductory Address***

1720 HRS to 1735 HRS – *Fireside Discussion* (Dr. Patankar, Dr Tim Fox &Dr. Atrey)

1735 HRS to 1835 HRS – **Workshop with Q & A** – Dr Mahesh Patankar (lead)

1835 HRS to 1845 HRS – **Summary & Vote of Thanks**

1845 HRS to 2130 HRS – **Networking cocktails & Dinner**

3. Summary of Discussions

- **Sustainable cooling** has been a major theme at the IMECHE since the last 7 years.
- **Under-utilization of newly constructed cold storage units** by government agencies due to:
  - Lack of stakeholder consultation with farming community;
  - Failure of economics of cold storage;
  - Operational inefficiencies and high cost of electricity;
  - Geographic siting and location of the pack houses and cold storage facilities.
- **Role of Cold-chain in improving nutritional value of food**, going beyond the objective of increasing farmers' incomes and reducing food loss. Recent WBCSD report pointed out the low nutrition value of agricultural output in India.
- **Cold stores in UK being used as thermal storage** -This is done by reducing temperatures to -32^{0}C when excess energy is available and then reducing the temperature to -18^{0}C releasing stored energy.
- **Living Labs as Business Incubation** beyond display of clean cold-chain technologies, providing outreach, training and support to farming community.
- **Use of IoT for market connectivity and quality control.** Example of Sahayadri Farm Fresh which is a cooperative of more than 6000 farmers; each produce is geo-tagged providing information about its origin, handling, storage temperature, etc.
- **Availability of Technologies is not a key concern.** Clean cold-chain technologies are available. What is needed is feasibility and applicability in local context and harnessing human resources through skill training for maintenance and operation of cold-chain.
- **Dissolving Silos in India for better utilization of thermal resources** – India has the largest quantum of thermal storage in the form of cold storage. They need to be geographically tagged with attributes to improve usability and linked with grids of biomass, biogas, solar, wind, micro-hydel, etc.
- **Training and capacity building** will be key to setting up clean cold-chain – increasing awareness among farmers about the temperatures required to store different agriculture produce and enhance life span.

G. Imparting Knowledge on High-value Products

Box 4: Imparting Knowledge on High-value Products – the Case of Elle Farms

Cordyceps militaris,.

Source: http://en.gobizkorea.com

Elle Farms, specializing in exotic mushrooms, is a success story of private entrepreneurship. Currently supplying specialized mushrooms called Cordyceps militaris, Elle was started by Seema Gulati and Amit Gupta in Karnal, Haryana over 12.5 acres of land growing staple horticulture produce such as potato, carrots, onions, iceberg lettuce, and sweet corn.

In 2014, after participating in two international workshops on cold-chain facilitated by the National Center for Cold-chain Development (NCCD), Elle invested in a pre-cooling chamber, a 200 T cold store, a ripening chamber, and equipment for grading, washing, drying, and packaging their produce. They also bought four small three-wheeler insulated vans used now to directly sell their produce to urban customers. All this was paid for through the lease on 37 acres they had previously farmed, bank loans and some government support (Birmingham Energy Institute, 2017).

Despite the high interest charged on a loan for cooling equipment at 12.5% compared to 4–6% for a tractor and trailer, Elle Farms farm's revenue has tripled and its net income doubled. Elle further continued to make investments in cooling, such as blast-freezing, to add further value to their produce. Now, with their expertise in growing specialized mushroom with the aim of exports, Elle Farms have grown to include training to their portfolio, imparting knowledge on a high-end product which could be marketed directly by farmers or through the use of their cold-chains. For more information, visit https://www.ellefarms.in/cordyceps-training

Seema Gulati and Amit Gupta of Elle Farms (first and third from left) along with MP Ensystems Advisory Team of Shirish Deshpande and Chinmay Chhatbar.

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