Requirement and Availability of Cold-Chain for Fruits and Vegetables in the Country

Chandra S.R. Nuthalapati
Rajeev Sharma

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Institute of Economic Growth
Delhi University Enclave, North Campus
New Delhi- 110 007, www.iegindia.org
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Acronyms

AMI	Agricultural Marketing Infrastructure
APEDA	Agricultural and Processed Food Products Export Development Authority
CA	Controlled Atmosphere
CCS	Cold-Chain Scheme
CIS	Capital Investment Scheme
CSs	Cold Storages
CWC	Central Warehousing Corporation
DMI	Directorate of Marketing and Inspection
ECS	Evaporative Cooled Structure
FCI	Food Corporation of India
FPC	Framer Producer Company
FPI	Food Processing Industry
GCCA	Global Cold Chain Alliance
GOI	Government of India
IQF	Individually Quick Frozen
ISAM	Integrated Scheme for Agricultural Marketing
LMT	Lakh Metric Tonnes
MA	Modified Atmosphere
MFPS	Mega Food Park Scheme
MIDH	Mission for Integrated Development of Horticulture
MMT	Million Metric Tonnes
MoFPI	Ministry of Food Processing Industries
MT	Metric Tonnes
NABARD	National Bank for Agriculture and Rural Development
NCCD	National Centre for Cold-chain Development
NCDC	National Cooperative Development Corporation
NE	North East
NGOs	Non-Governmental Organizations
NHB	National Horticulture Board
NHM	National Horticulture Mission
NWRs	Negotiable Warehousing Receipts
PEB	Pre-Engineered Buildings
PMKSY	Pradhan Mantri Kisan SampadaYojana
QSRs	Quick Serving Restaurants
SFAC	Small Farmer Agri-Business Consortium
SWCs	State Warehousing Corporations
WDRA	Warehousing Development and Regulation Authority
WFLO	World Food Logistics Organization

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Executive Summary

The issue of food loss and waste has emerged as a major policy issue in recent times in the world in general and developing countries like India in particular. Though horticulture production outpaced food-grains production since 2012-13 and made India the second largest producer of fruits and vegetables worldwide, its distribution suffers significant post-harvest losses in the supply chain primarily due to the perishable nature of fresh produce and its sensitivity to handling damages. This study examines the pathways for food security by reducing the losses by cold-chain network; examines the losses and works out potential welfare gains from loss reduction; analyses the build-up of cold-chain over the last two decades; works out the investment needs of the industry; and analyses the policy support measures to give some policy suggestions.

Improving the cold-chain has a crucial bearing in driving down food loss and waste in developing countries, where supply-side factors are important in reducing the consumable food. There are direct and indirect causes of food loss and waste. Direct causes associated with actions (or lack thereof) of individual actors in the food supply chain that directly cause food loss and waste; whereas indirect causes refer to the economic, cultural and political environment of the food system under which actors operate. Reductions in food losses or waste may improve the food security and nutrition status of food-insecure groups, depending on where these groups are located and where the reductions are made. The food loss is a supply side problem and most often happens in developing countries like India where the post-harvest technology and cold chains are primitive. Therefore, this study looks at the likely impacts of reducing food loss in the country from a supply-side perspective and

Review of literature establishes clearly the relationship between cold-chain network development and benefits to all stakeholders in the chain including farmers, middlemen, processors, wholesalers and retailers. While the protecting the margins and improving the volume of trade is the main benefit for most of the stakeholders, farmers in the country stands to gain by means of higher prices and profits. However, development of cold-chain is only a necessary condition, and subject to the fulfilment of the sufficient condition that is participation by the farming community in harnessing the facilities with awareness.

India produced 282 million tons of fruits and vegetables from 16.77 million hectares at a trend growth rate per annum of 1.2% during the last decade. The losses of fruits and vegetables using the proportion of losses by ICAR- CIPHET constitute 3.5% of gross value added in agriculture (GVA) as a whole and 1.52% for fruits and vegetables. However, several scholars including government agencies questioned these estimates. A realistic estimate using FAO figures reveal losses to the tune of 3.5% of GVA from fruits and vegetables alone. Also, we argue that the food loss and waste is a dynamic concept and the estimates may go up as households may prefer to eat food with higher sanitary and safety standards as their income increases. An endeavor is made to calculate the welfare gains through feeding additional people by loss reduction. A large numbers of additional people can be fed reducing losses by half in the case of mango, papaya, guava, green peas, citrus, grapes, tomato, cabbage, onion, cauliflower and potato. A noteworthy finding from this exercise is that the additional welfare gains from reducing losses in fruits and vegetables are relatively high and far outweigh from those in food crops.

Across the crop groups, large quantities are wasted in vegetables followed by fruits and then the food crops. Potato, onion, tomato, cabbage, green peas and cauliflower from UP, MP, West Bengal, Maharashtra, Bihar and AP need particular attention in view of the seriousness of the problem. Among fruits, the major losses are in mango, grapes, apples, guava, and papaya from AP, UP, MP, Bihar, Maharashtra and J&K.

The top five states in terms of total installed cold storage capacity are Uttar Pradesh (14.71 million tons), West Bengal (5.95 million tons), Gujarat (3.82 million tons), Punjab (2.32 million tons) and Andhra Pradesh and Telangana (1.57 million tons) and these 5 states together contribute to an overall 76.73 per cent of the total storage capacity. While cold storages are mostly single commodity and near production sites, there is a need for multi-commodity and market hub cold storages with additional services. However, the other components of the cold-chain like integrated pack houses, reefer trucks and ripening chambers are almost non-existent and need urgent action.

The cold-chain industry has been emerging as a sunrise industry because of several positive and promotional policies of the central government and active support of some of the fast-growing state governments. The cold-chain in India is currently a 62000 crore industry with high growth rates (Arora, 2018) and is expected to grow at 13-15% during 2017-2022. Nearly two-thirds of the existing cold stores are used for potato in the country leaving a huge gap in meeting the cold preservation requirements of other fruit and vegetables. On the other hand, the cold-chain for frozen products captures most of the refrigerated transport and peri-urban storage capacities for market linkage (GoI, 2018). India's 37 million ton cold storages are in the hands of 3500 entities, while 125 million ton capacity of the USA is in the hands of 20 companies. Therefore, consolidation is round the corner for this industry, while some startups have already started aggregating the services by means of digital platforms. The scope of modern cold storage is increasing to provide related services. Given the recession free nature of this industry, new entrants from both India and abroad are coming forward to invest. The industry needs huge investments and our calculations show that there is a need of 18.51 billion USDollars worth of investment in the short-run to make integrated cold chain operational for the fruits and vegetables along with others. While this will make available more fruits and vegetable to additional people and enable welfare gains through food security, this can also create an employment of 2.5-3.0 million in the coming years, provided the right impetus is given.

Several innovative startups have been coming up with novel solutions for improving the cold-chain and several others have been building cold-chain on their own or creating market for third party logistic services (3 PLS). Solar-powered cold storages at field level by *Ecozen*, storage-cum-transporter named *Sabjikothi* by *Saptakrishi*, cold storage build up by *Godaamwale*, cold storage aggregator model of Arya Collateral and Oregon are some of the exciting innovations worth policy support to scale up. There are also some innovative solutions from the public sector institutions that deserve support for commercialization. The unicorn status received startups like *BigBasket, Zomato, Swiggy, Grofers,* and *Udaan* have been building their own cold chain by using the large funds mobilized to the tune of 5.5 billion US Dollars in the last few years.

The government, especially the central government, has been pro-active in supporting the rise of this sunrise industry, though the evolution of the cold-chain ecosystem has been propelled basically by demand side factors. The government support until recently was to start cold storages in production site and things started changing with the explicit recognition for an integrated cold-chain in the last few years. Our analysis shows that the central government released a subsidy of Rs.3794 crores during 2006-07 to 2020-21 by various agencies. This level of support, at Rs.252 crores per annum over the last 15 years, is too small in relation to the cold-chain building requirements of the country. Nevertheless, these grants have played catalytic role in the emergence of the cold-chain industry. Moreover, the value of the tax incentives and tariff deductions have been helping the industry, apart from the articulation of enabling environment and promotional campaigns. Establishment of the National Centre for Cold Chain Development (NCCD) in 2013 as a PPP model was a major milestone in developing integrated cold chain.

Several of the ongoing schemes course corrections to make them more helpful in upgrading the existing cold-chain and build up large capacities. The Pradhan Mantri Kisan Sampada Yojana grants were found to be skewed in favour of the fast-growing western and southern states. Schemes like Operation Greens, one-lakh crore Agricultural Infrastructure Fund (AIF) have to be made more concrete with detailed guidelines for operationalization. Though it is a good initiative to provide support to farmers, FPOs, PACS and MCS through AIF with interest subvention, the actual operationalization is fraught with procedural difficulties in view of their lack financial muscle. The electronic Negotiable Warehousing Receipt system could not take off much because of lack of registration to the cold storages, lack of awareness and complicated procedures. The government may take steps to make registration of warehouses mandatory so that post-harvest loans with lower interest rates become accessible to resource poor farmers.

Some more limitations of the study are reiterated here so that future research can address them. These are as follows. The conceptual framework leaves out the drivers for the trends, though it brings all the actors and process together. Also, it is important to understand that sum of all parts is greater than mere addition in some instances. Finally, as already mentioned, the issues of cold-chain have to be examined from the perspective of a typical small farmer to gauge the ground realities through field surveys.

To conclude, the promotional policies of the government have succeeded in creating critical mass for the cold-chain industry and some level of understanding among the stakeholders. It is now time to have long-term policies, strategies and action plans from the private and public sectors, commercial financing at low interest rates and subsidies to encourage local and international cold chain investment, greater education about food handling, cold chain technology and post-harvest activities to increase the efficiency of logistics processes throughout the food supply chains. Crucial point is that short and medium-term investment by manufacturers should be coupled with government grants, subsidies or investment to allow the supply chains to grow and benefit manufacturers, consumers and governments (Sachdeva, 2020).

Adoption of cold-chain technology needs interventions in both the demand and supply side. The India Cooling Action Plan of the Government of India takes a technological view without addressing these issues (Gorthi and Waray, 2019). Enabling equitable access of cold-chain facilities to resource poor farmers in contrary to the exclusive use of these facilities by export-oriented and resource rich farmers. There is a need to provide incenstives to enable SHGs, farmer producer organizations and resource poor farmers to get cold storage services at affordable rates through government support. Also, the government needs to mandate an integrated clean cold chain from production to consumption as in Europe for harmonised food system. That can create demand for the cold-chain. There is also a need for large-scale, strategic pilots across the country are needed for enhancing demand and flowing in of investments. The study highlights the future research agenda for equitable access development of cold-chain across all stakeholders including farmers in all regions of the country.

1. Introduction

Cold-chain can have the greatest socio-economic impact when used as a logistics medium that empowers the farmers to directly connect with multiple markets, across country. Without facilitation of cold-chain, the average farmer or growers of perishable produce has no counter to produce perishability and no other recourse but is constrained to selling off the harvested produce to the closest intermediary. This in effect, disconnects farmers from scope of increased value realisation directly from consumers of fresh produce. Moreover, innovations in packaging, fruit and vegetable coatings, controlled ripening, and other techniques would reduce the deterioration of food products, which in-turn help the shippers to extend the reach of perishable products across other parts of the country in a timely fashion while maintaining the quality of the products and increasing their shelf-life.

It is well recognized that an integrated cold-chain embraces the management of the movement of the product, from the field through diverse nodes in the chain: harvest, collection, packing, processing, storage, transport and marketing, until it reaches the end-users (NCCD-NABCONS, 2015; Kitinoja, 2013; Singhal and Saksena, 2018). A cold chain break signifies a disruption in cold chain management, causing food safety issues. This assumes added significance in India where fruits and vegetables forms 18% of gross value added in agriculture of the country.

It is unacceptable that, in a world that produces enough food to feed its entire population, more than 1.5 billion people cannot afford a diet that meets the required levels of essential nutrients and over 3 billion people cannot even afford the cheapest healthy diet. People without access to healthy diets live in all regions of the world; thus, we are facing a global problem that affects us all. Currently, nearly 690 million people are hungry or 8.9 percent of the world population – up by 10 million people in one year and by nearly 60 million in five years. In 2019, close to 750 million (nearly one in ten people in the world), were exposed to severe levels of food insecurity. Considering the total affected by moderate or severe food insecurity, an estimated 2 billion people in the world did not have regular access to safe, nutritious and sufficient food in 2019. The pandemic of COVID-19 wrecked havoc in the lives of millions in developing countries like India with meagre incomes and scarce livelihoods. Nutritious diets for them is difficult to come by and it is estimated that their malnutrition problems will have accentuated with reduced

diversity in foods. If recent trends continue, the number of people affected by hunger would surpass 840 million by 2030. Low-income countries rely more on staple foods and less on fruits and vegetables and animal source foods than high-income countries. Only in Asia, and globally in upper-middle-income countries, are there enough fruits and vegetables available for human consumption to be able to meet the FAO/WHO recommendation of consuming a minimum of 400 g/person/day. India has seen growth in the past two decades. GDP has increased 4.5 times and per capita consumption has increased 3 times. However, 189.2 million people are undernourished in India (14% of the population) (FAO, IFAD, UNICEF, WFP and WHO, 2020).

Globally, around 14 % of food produced is lost from the post-harvest stage up to, but excluding, the retail stage (FAO, 2019). India is the 2nd highest grower of fruits and vegetable, and at the other hand 25-30 per cent of it are food losses and damages due to insufficient transportation and distribution facilities such as cold storage, dedicated fleet, cold trucks, etc. In the Asian developing nations such as India, an estimated 20‑30 per cent fruits and vegetable food is lost due to lack of cold logistics infrastructure available. The knowledge of criteria can help 3PL provider to focus on essential facilities to be provided to customers. Understanding the selecting criteria will improve the service quality of 3 PL. This may be beneficial to the food industry to reduce loses (Raut et al., 2019).

Approximately one-third of all produced foods (1.3 billion tons of edible food) for human consumption is lost and wasted every year across the entire supply chain. In less-developed countries, food loss and waste (FLW) occurs mainly in the post-harvest and processing stage, which accounts for approximately 44% of global FLW. This is caused by poor practices, technical and technological limitations, labor and financial restrictions, and lack of proper infrastructure for transportation and storage. In the developed countries, it is 56% of the world FLW. Of this, 40% of FLW in developed countries occurs in the consumption stage, which is driven mostly by consumer behavior, values, and attitudes. Food wastage at the consumption stage in developing regions is significantly lower due to limited household income and poverty. Households in developing countries purchase less and smaller amount of food, and they have a tendency to buy food on a daily basis.

Possible causes of food loss and waste in different stages vary. At the production stage, loss of food happens because of infrastructural limitation, over production, economic problems, harvesting method (mechanical versus manual), harvesting timing, quality standards. On the other hand at the stage of handling and storage, losses arise due to degradation and spillage according to product characteristics, transportation from farm to distribution, and storage infrastructure. At processing and packaging stage, there are unavoidable losses, technical inefficiencies, legislation restrictions, packaging system, and overproduction. During the distribution and marketing stage, losses are due to contamination of transportation, transportation and market facilities, road and distribution vehicles, business rule, commercial conditions. Finally, losses occur at the consumption stage due to household size and composition, household income, household demographics, household culture, individual attitude, cooking process and method, storage in household, and over cooking. Mostly for developing countries, solutions should first consider the farmer perspective (i.e., farmer education, harvest techniques, and storage and cooling facilities) and then need to improve social infrastructures (Ishangulyyev et al., 2019).

The latest available horticultural statistics indicates that the production of horticultural crops have outpaced the production of food-grains since 2012-13 in India. For instance, the horticultural production was 145.8 million tons in 2001-02, which increased to 268.8 million tons (2012-13) and further increased to 311.7 million tons during 2017-18. On the other hand, food-grains production was 212.9 million tons in 2001-02 and increased to 257.1 in the year 2012-13. This further increased to 284.8 million tons in 2017-18. Specifically, the production of fruits and vegetables has increased from 152.1 million tons to 281.8 million tons during the period 2004-05 to 2017-18, which made India at second rank in fruits and vegetables production in the world, after China. Moreover, the percentage share of horticultural output in agriculture has increased to 33 per cent (2015-16) from 29.2 per cent in 2011-12 (GOI, 2018). The trend growth rates (2010-11 to 2017-18) in the production of fruits and vegetables further substantiate this increase (Table 1).

Table 1: Trend growth rate (%) of fruits and vegetables production across States for 2010-11 to 2017-18

States	Area 2017-18 (Mn Ha)	Production 2017-18 (Mn tons)	Growth rates		
			Fruits	Vegetables	Total
Andhra Pradesh	0.89	22.12	2.0	-4.5	-0.8
Assam	0.45	5.42	0.9	1.0	1.0
Bihar	1.12	20.98	1.1	-0.1	0.2
Chhattisgarh	0.73	9.67	3.6	3.2	3.3
Gujarat	1.04	21.25	1.3	2.1	1.7
Haryana	0.51	7.95	4.8	2.4	2.6
Himachal Pradesh	0.32	2.38	-0.2	1.3	0.7
Jammu & Kashmir	0.38	3.58	0.3	-0.9	-0.1
Jharkhand	0.39	4.56	1.9	-1.4	-0.7
Karnataka	0.91	15.53	0.9	0.0	0.4
Kerala	0.42	4.56	-0.7	-3.9	-2.4
Madhya Pradesh	1.24	24.96	4.8	7.5	6.5
Maharashtra	1.48	24.04	0.7	2.4	1.5
Odisha	0.98	11.17	1.0	0.1	0.3
Punjab	0.34	6.83	2.1	1.9	2.0
Rajasthan	0.22	2.44	1.6	4.6	3.5
Tamil Nadu	0.53	12.08	-3.0	-2.0	-2.5
Uttar Pradesh	1.93	38.86	5.0	3.4	3.8
Uttarakhand	0.28	1.66	-1.0	-0.6	-0.8
West Bengal	1.66	31.55	1.6	0.2	0.4
Total	15.84	271.56	1.4	1.1	1.2

Source: Computed from the data provided by Horticultural Statistics at a Glance (2015, 2018), Ministry of Agriculture & Farmers Welfare, Govt. of India.
Note: 1. States total excludes Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. AP consists of Telangana too.
2. Trend growth rates are computed by employing Log-Lin Model.

The main points from Table 1 may be noted: first, positive rate of growth in production has been observed in overall situation for fruits (1.4%), vegetables (1.1%) and their total (1.2%). Majority of the states followed similar pattern of growth. Second, dis-aggregated analysis showed negative rate of growth for fruits in four states (Himachal Pradesh, Kerala, Tamil Nadu and Uttarakhand) out of 20 states; whereas, negative trend growth rate has been seen in case of vegetables for seven states.

However, increasing production of crops is one aspect of fulfilling food demand. Delivering food to the consumers by saving produced commodities from losses in the fields, transport, storage, retailing, processing etc. in a sustainable manner seems to be much better option. Here comes the importance of well integrated cold-chain.

Many studies conducted at India and outside highlighted the fact that after production, agricultural produce undergoes a series of post-harvest unit operations, handling stages and storage before they reach to the consumers. Each operation and handling stage results some

losses. Food wastage is a global phenomenon. At global level 35 per cent of fruits and vegetables production is wasted every year, it is 40 per cent for developing countries as compared to developed counties (15%). Moreover, 23 per cent of perishables foodstuffs lost due to lack of refrigeration in developing countries, which is 9 per cent for developed countries (Kitinoja and Alhassan, 2012; Kitinoja, 2013). These losses were much higher at the immediate post-harvest stages in developing countries and higher for perishable foods both in industrialized and developing economies (Parfitt et al., 2010). A recent study by Minten et al. (2020) analysed post-harvest losses in the context of rapidly growing rural–urban value chains in Ethiopia. They found that post-harvest losses vary between 2.2 and 3.3 percent in the teff value chain depending on assumptions on storage facilities and losses during transportation on the farm.

There can be various causes of food losses. World Food Logistics Organization (WFLO) project measured post-harvest losses for 26 perishable crops in four countries, and documented losses from 30-80% due to poor quality packages, poor temperature management, and delays in marketing (Kitinoja and Alhassan, 2012). For China, food waste and losses were about 20-30 per cent for vegetables and fruits at the storage and transportation stages, which are caused partly by the incomplete cold-chain facilities (Zhao et al., 2018). The lack of infrastructure in many developing countries and poor harvesting/growing techniques are likely to remain major elements in the generation of food waste (Parfitt et al., 2010).

India is no exception in this regard. About 30 per cent of fresh fruits and vegetables production is wasted through lack of a cold-chain (Mittal, 2007). More disaggregated study by Nanda et al. (2012) showed that 5.8-18.1% fruits and 6.9-13.0% vegetables are lost during harvest, post-harvest operations, handling and storages in India. Similar kind of study by Jha et al. (2015) showed that these losses were in the range of 6.70-15.88% for fruits and 4.58-12.44% for vegetables, respectively.

Food waste may be reduced with a better temperature management in food cold-chains (Ndraha et al., 2018); the application of proper refrigeration in developing countries would reduce the amount of perishable food wasted annually by more than 200 million tons, which is approximately 14 per cent of their consumption (Mercier et al., 2017); and the expansion of modern retail is likely to reduce post-harvest losses in food value chains, at least at the retail

level (Minten et al., 2020). From food security view-point in the context of Tanzania, improved on-farm storage has reduced the proportion of severely food insecure households by 38 per cent on average in the lean season, and by 20 per cent in the full seasonal cycle (Brander et al., 2019). These findings demonstrate that a simple and inexpensive technology could contribute strongly to reducing seasonal food insecurity and improving smallholder farmers' year-round access to food.

On the basis of empirical analysis, Kumar and Das (2020) suggests that farm households which are likely to have access to storage facility are more likely to take part in market transaction, sell more number of crops, and are more likely to have higher number of market transactions in India. The other main points are as follows: one, having outstanding credit affects farmer's decision to participate in the market and sale ratio. Two, agricultural power availability shows a U-shaped relationship with farmer's selling decision, sale ratio, and number of sales. Third, the presence of smaller urban centers has an inverted U-shaped relationship with selling decision, sale ratio, and number of sales. Finally, capital and total expenditure in agriculture significantly affects farmer's market participation.

As per International Institute of Refrigeration (IIR), the carbon footprint alone of food produced and consumed (either lost or wasted) is estimated to be 3.3 giga tons of carbon dioxide equivalent. There is also a need to look at the green logistics for supply chain solutions in view of the climate concerns and rising consumer awareness about these issues. Energy efficiency by switching from hydroflurocarbons to natural refrigerants (with low-CWP) is important in taking care of the consumer end of the food value chain as well as infrastructure applications as well as supermarkets and convenient stores (GoI, 2017).

It is clear that the cold storage infrastructure constitutes important backward and forward linkages in the farm-to-fork model of integrated food production, processing, distribution and consumption. Therefore, an efficient cold chain helps in addressing the problem of post-harvest losses, thus reducing the supply-side constraints for critical food supplies, especially perishable items such as fruits and vegetables. It also ensures greater prospects of reasonable returns to farmers as they would not be under pressure to sell their produce immediately in the post-harvest period, when the prices tend to be low.

With above background, it is pertinent to understand the status of cold-chain in India. It would be more revealing to understand the policy framework and their challenges pertaining to strengthen the cold-chain in the country. This kind of exploratory analysis helps us to understand the problems associated with cold-chain and the way in which horticultural growers harness the opportunities (or affected) created by the cold-chain industry and shape their livelihood for sustainable economic development.

Objectives of the Study: This study tries to understand the cold chain infrastructural issues for fruits and vegetables in the country and the welfare losses in the absence of a modern cold chain. What are the various stages in the supply chain of perishables of Indian cold-chain industry? What are the main challenges with respect to the promotion of cold-chains in the country? Does existing infrastructure deter useful application of cold-chain? How efficient cold-chain reduces losses in perishables and is expected to increase welfare to the society? It is worthwhile to mention here that some other questions which we will undertake in the later stages of the study are listed in the last section of the report.

Given these questions, the specific objectives of the present study are as follows:

- To develop a conceptual framework for understanding the links between food security in the country and cold chain;
- To ascertain the economic losses due to food losses and wastage and the additional welfare gains by reducing these losses;
- To analyse the status of cold-chain in terms of its requirement and availability of infrastructure in the country; and
- To examine the growth prospects of cold-chain industry and the policy framework.

This report is organised as follows. After the introduction with background and objectives of the study in Section 1, conceptual framework is given in Section 2. Section 3 brings out the review of studies, while the extent of losses in value terms across crops in different states has been discussed in Section 4. The status of cold-chain in India is analysed in Section 5. The gaps in different components of cold-chain are discussed in Section 6. The investment needs and policy measures for the cold-chain industry are analysed critically in Section 7. Section 8 summarizes main findings of the study along with policy implications.

2. Conceptual Framework

It is necessary to have a conceptual framework that forms the lens through which the object of study is to be analysed. It is clear from the introductory chapter and literature review that an efficient cold-chain not only provides possible solution to post-harvest losses in case of perishables but also extend its saleable life cycle in far-away markets. From farmer's point of view (especially small and marginal growers), it ensures greater prospects of reasonable returns and encourages them to diversify towards high-value crops and benefit from prevailing market conditions. Cold-chains also improve food quality, safety and value to the customer by providing last mile delivery of fresh produce.

A major part of an efficient cold-chain lies in having an equivalently good backward integration. This, in-turn, is a potential source of generating growth opportunities in rural areas; improve living standards and reducing migration to urban areas. It will also substantially increase the employability in the rural areas offering tremendous opportunities for both men and women in this sector.

An efficient cold-chain is extremely critical to the growth of the agriculture in general and food industry in particular. This is also important to facilitate the movement of the produce to the market-place in the best possible condition. In this regard, pertinent question arises: how to use the integrated components of storage (static infrastructure) and transport (mobile infrastructure) for cross-geography access in India. The well-connected cold-chain improves availability of diversified foods, makes them affordable and accessible and most importantly creates growth opportunities and employment (Chintada et al., 2017). These aspects are discussed in little more detail in the following paragraphs.

Availability: India has a wide range of climate and physio-geographical conditions which restrict the availability of fruits and vegetables all over the year. An efficient cold chain ensures delivery of produce throughout the year. Agriculture is a seasonal activity which results in surplus production in peak season whereas a lacuna in off-season. The presence of temperature controlled environment facilitates storage of the processed and fresh products, the products are processed (packed) in bulk during peak season and stored in the controlled atmosphere so as to supply in the off-season. Perishable foods, like fruits, vegetables, meat, poultry and dairy, require

an uninterrupted cold-chain. Moderating parameters like temperature, humidity, and atmospheric composition, along with utilizing proper handling procedures, cold-chain can significantly increase the product life of fresh foods for days, weeks or even months. These services allow fresh products to hold their value longer, increasing their transportability and providing opportunities that expand their market reach.

Affordability: Vegetable and fruits production in the country has increased over the years but still the prices are not normal across the country. Normalizing price of the crops throughout the year and locations is possible through the holistic development of integrated cold-chain. It holds the key to reducing post-harvest losses, ensuring uninterrupted supply and thereby minimizing food inflation.

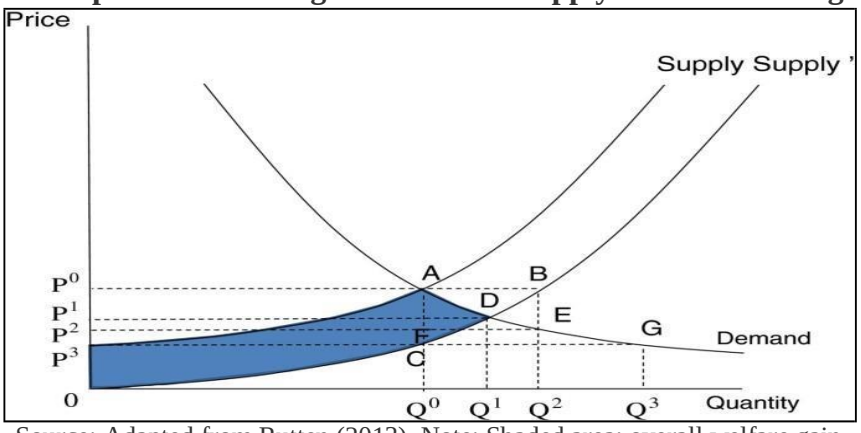
Accessibility: Availability across various parts of the country can be guaranteed if the crop produced can be supplied to areas where it is not cultivated. The cold-chain will considerably help farmers to reach far away markets. It empowers them with the ability to capture a larger buyer base and helps to bring their harvest to more valuable end use. Also, the consumer will now have access to the products of his choice and at desirable time and place. In the proposed vision 2022 "for doubling farmers income, the components to strengthen agricultural supply chains is an important aspect. Extending the cold-chain network is one of the key solutions to bridge the existing gap and strengthen these supply chains.

Cold chain and its linkages to food loss and waste: Improving the cold-chain has a crucial bearing in driving down food loss and waste in developing countries, where supply-side factors are important in reducing the consumable food. There are direct and indirect causes of food loss and waste. Direct causes associated with actions (or lack thereof) of individual actors in the food supply chain that directly cause food loss and waste; whereas indirect causes refer to the economic, cultural and political environment of the food system under which actors operate. The socio-economic and demographic characteristics of a household also influence the level of food waste it produces. Small households and high-income households generally waste more food, because the amount of food they buy and prepare is usually larger than the amount they can consume. Culturally, food may also be used as a symbol of prosperity. Households with a higher socio-economic status may purchase more, and more varied, food especially if this is visible to

others (for example, at social events); such behaviour leads to more food waste. In developed countries, most food is believed to be wasted at the retail and consumption stages of the food supply chain, while in developing countries; it is mainly lost in the earlier stages of the chain. In developing countries where post-harvest losses account for an important share of overall food loss and waste, efforts to promote improved growing and post-harvest technologies and practices might prove more effective in reducing food losses.

Reductions in food losses or waste may improve the food security and nutrition status of food-insecure groups, depending on where these groups are located and where the reductions are made. But positive food security impacts are not guaranteed, and in certain cases impacts may be negative for some groups, such as farmers. Reductions in food losses or waste in high-income countries have a limited impact in terms of overall food security. However, food recovery and redistribution programmes may increase access to food and improve diets of food-insecure individuals. The reduction in food losses through better on-farm storage can improve the food security status of farming households. Smallholders are often compelled to sell all their grain soon after the harvest, because traditional storage facilities cannot guarantee protection against pests and pathogens. This may force them to buy grain for their own consumption later, at possibly higher prices. The likelihood that a reduction in losses or waste will improve the food security status of groups located far away from the point of reduction is small (FAO, 2019).

Figure 1: Impacts of reducing food losses in supply of fruits and vegetables



Source: Adapted from Rutten (2013). Note: Shaded area: overall welfare gain

As explained above, the food loss is a supply side problem and most often happens in developing countries like India where the post-harvest technology and cold chains are primitive[1]. Therefore, we look at the likely impacts of reducing food loss in our country. Let us assume that there are losses in the production and supply of this food commodity. In such a situation, the socially optimal supply curve, or the supply curve of this food commodity that would not have these losses, lies below the original supply curve, as depicted by Supply' in Figure 1; given the original price, P^0, more can actually be produced and supplied to the market (Q^2 at point B), or the original quantity, Q^0, can actually be produced at a much lower cost (P^3 at point C) if losses were to be absent.

If food losses in supply are reduced, it would result in a lower price, P^1, and a higher equilibrium quantity, Q^1, in the market, as given by point D. At this new equilibrium consumers can buy more food at a lower price, resulting in a welfare gain to consumers as measured by the change in the consumer's surplus of P^0ADP^1. Similarly, producers can sell more, but at a lower price, resulting in a change in the producer surplus of P^1D^0 - P^0AP^3, which is also positive. The overall welfare gain equals the sum of the change in the producer and the consumer surplus, which amounts to the area P^3AD^0, the blue shaded area between the new and old supply curve and under the demand curve.

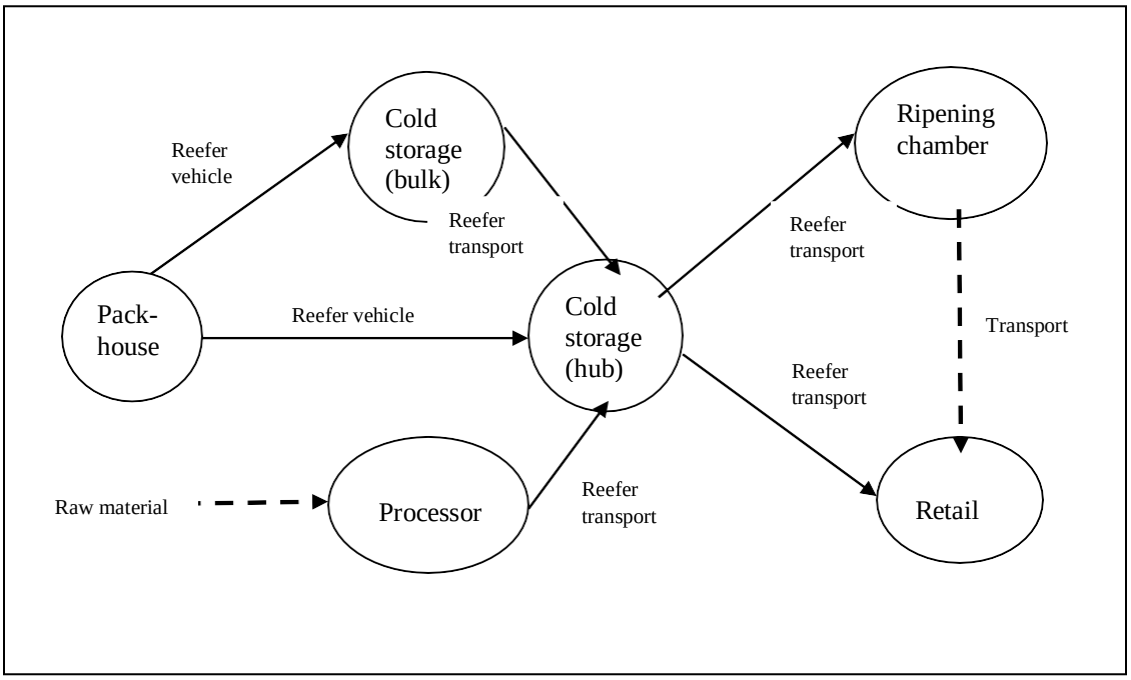
The entrepreneurial problem can be written as a profit maximization problem where the final output is proportional to the volume of feedstock and the entrepreneur must determine the allocation between in-house production and external sources of feedstock (Zilberman et al., 2019). Once these variables are determined, the total output can be calculated. There are three types of solutions – vertical integration, purchasing from external sources, and a combination of the two. The implementation of innovations leads to non-competitive behavior or market structure. Over time, market power changes with obsolescence and emerging competition. Firms may reestablish their market power by expanding and improving their innovation. Innovations are more likely to be implemented and on a larger scale in an economy where entrepreneurs have more access to credit, insurance, complementary assets that enhance their own human capital, and lower cost of transport and other costs of doing business. Many of the agrifood innovations that we considered increased the value-added of agricultural resources either by identifying non-

[1] Rutten (2013) and FAO (2019)

food uses of agricultural products and residues as part of the bioeconomy, or producing differentiated products by increasing their convenience and quality. Dynamics and risk considerations need to be taken into account when analyzing and designing supply chains and to develop mechanisms for adapting the supply chain in response to changes. Policy making should take into account the behavior of entrepreneurs as they implement innovations and introduce supply chains.

The conceptual framework shows linkage between the institutional environments that influences the structure on which economic activities such as selling, buying, and negotiation are conducted within the market arrangements in the supply of perishable produce (Figure 2). Some of the main actors in these arrangements are middlemen, brokers, farmer producer's organizations, aggregators, transporters and marketing organizations.

Figure 2: Schematic depiction of the flow of produce in a typical cold-chain



Source: GoI (2018a)

Generally, farmers are associated with production and marketing related constraints, which arises due to multiple determinants. On the production side, input related factors include the use of pesticides, fertilizers, irrigation, and seed, and all other inputs used in production of crops; institutional factors such as the extension department and the access of credit related institutions; climatic factors, including rainfall patterns, severe temperatures, smog, and humidity, etc.; and economic factors, including farmers' income related issues. On the marketing side, output related factors such as any quality issues of the produce, output packaging and grading; distribution to the consumers, etc. Horticultural growers may adopt different strategies for marketing of perishable produce, as depicted in Figure 2. Adoption of different marketing strategies among farmers also varies due to differential access to livelihood asset endowments (such as, natural, physical, human, financial and social capital). In other words, decisions of the farmer in a given point of time are assumed to be derived from the maximization of expected profit subject to land availability, credit and other constraints. The particular strategy will decide the expected outcomes which will finally affect their consumption/income expenditure, reduce vulnerability conditions, and improve well-being (or welfare outcomes).

It is to be noted that the presence of marketing margin reduces market efficiency leading to the low welfare of the whole community. In the Indian agricultural sector, especially horticultural sector, the role and existence of intermediary agents are dominant. Based on the harvested areas, wholesale traders set the prevailing market price at end-user. Farmers have low bargaining power, and they play as price takers. Marketing margin exists because of intermediaries (or middlemen) in the market.

The level of marketing margin is hypothesised to be affected by the dimension of distribution channels. The longer the distribution channel, the higher the applicable marketing margins since every channel collects a reasonable margin based on the current market condition. Thus, the level of marketing margin varies, and every channel receives a different level. Farmers indirectly perceived the effect of distribution channels on the marketing margin as the prevailing farm-gate price when the farmers sell the products.

3. Cold chain for fruits and vegetables: Necessity and benefits

This section brings out insights from the review of extant literature to understand the issues related with cold-chain in perishable commodities and tried to identify existing research gaps. The efficient supply chain is very important in fruits and vegetables sector and it will lead to increase the profit of the stakeholders involved in the chain and most importantly reduce the losses and wastages in this sector, as we noted in the introductory chapter. It will also reduce the chances of deterioration in the quality of perishable produce and help to enhance the value and makes a reliable delivery to the consumer at the right time with right quality and at the right prices.

There is a immediate need to create community type pre-cooling and cold storage facilities at district and block level to enhance the share of tomato growers in Kolar mandi area from the meagre producer share of 30% in consumer Rupee (Hegde and Madhuri, 2013). They recommended that there is a need to train the farmers on scientific post-harvest management techniques such as good cultural practices, harvesting at maturity, grading, pre-cooling, packaging and storage practices.

Some studies in Bihar showed that a large number of even relatively small farmers participated and directly benefited from the cold storages in terms of better storage conditions of their seeds and were also able to sell their produce directly after the harvest (Minten et al., 2014). They documented the rapid emergence of cold storages in the potato supply chain in two poor districts of Bihar viz., Vaishali and Samastipur. This benefited most of them in terms of getting higher prices of their produce. They suggested that there is need to increase investment in cold storages to ensure more competition so as to drive down the cost of storage.

The investments in cold-chain infrastructure (especially in pre-cooling and transport refrigeration equipment) can reduce food loss from 32% (sell in open truck) to 9 % (sell in refeer truck) and CO_2 equivalent emissions by 16% (Sodhi et al., 2016). Kinnow aggregator's profit margin jumped 20% from out-of-season sales and access to distant markets; distributors and retailers margins also improved significantly. The payback for pre-cooling equipment was around 2.3 years, while it takes 4 years to pay back refrigerated trucks. Their interviews with farmers clearly pointed to price and its volatility as a major challenge. However, they reported that the cold

chain has the potential for increasing volume of flows, which resulted in better returns for farmers. This study has clearly shown how the cold-chain is used intelligently to counter the inherent limitations of perishability to connect farms-to-consumers, both over large distances or over extended periods of time.

It is argued that one of the crucial factors behind the worsening structural and technical coefficients for the food processing industry is the existing capacity gaps in the infrastructural components constituting integrated cold-chain and their lopsided development (Singhal and Saksena, 2018). The study highlighted the limitations of the prevailing policy perspective that uses scheme-based incentives for securing private sector participation in the cold-chain sector. There is need for a holistic policy framework and a national blueprint for the long-term development of cold-chain sector given its far reaching implications for the dynamics of a primarily agrarian rural economy in general, and in promising reasonable returns to the small and marginal farmers in particular.

There are very few papers have considered the issue of sustainability in the transportation of perishable products for the last many years (Vrat et al., 2018). Their analysis used bibliometric analytics and network analytics to study different dimensions involved in the evolution of the cold-chain for perishable food products. From the analysis, it is evident that the publishing trend is now gaining momentum and is steadily rising since 2015. They highlighted that the most contributing country in the area of sustainable logistics for perishable food products is Italy.
The analysis of case studies from Haryana demonstrate the need for cold chain to be able to market fruits and vegetables to new and rewarding markets (MPEnsystems et al., 2019). The summaries of four case studies are given below.

Case study 1: Crown Fruits and Vegetables Producer Company Ltd., Kurukshetra, Haryana: A multi-crop Farmer Producer Company (FPC), its major produce comprises potato, tomato, onion, capsicum and cucurbit. It has more than 500 acres of farm land with 700 farmers clustering land and production throughout the year. Presently, most farmers in the FPC sell their produce (tomato) at local markets at average price of Rs. 5 per kg. In new identified markets, the same produce will fetch up to Rs. 40 per kg. The annual sales are expected to increase from Rs. 245 lakhs to Rs. 2584 lakhs. Wastage is reduced to 5%. The likely cost of additional supply

chain components would be around Rs. 17 to 20 per kg. The investment is expected to increase income of individual farmers substantially.

Case Study 2: AHA LLB, Shahbad, Haryana: AHA LLB is a private company run by a progressive farmer and entrepreneur. Through contract farming it produces 3500 tons 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 15 ton integrated pack house is estimated at Rs 20 lakhs and operational cost at Rs 1 lakh 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 tons.

Case Study 3: Elle, Karnal, Haryana: Elle Farms (7 acres leased farm land) is a proprietorship company located at Karnal, Haryana. It produces about 60 tons of button mushrooms annually. The production is climate-controlled mechanized process. It has an integrated postharvest management unit with equipment for sorting, grading and packaging, a pre-cooling unit, a 30 ton 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. At 5% material loss (2 Tonnes), sales of 24 tons, sell at Rs. 100/Kg. Future market sales is expected to Rs. 150/Kg.

Case Study 4: Optimal Agro Producer Company Ltd., Ambala, Haryana: This is a farmer producer organization (FPO) with 160 farmers (500 acres of Land), 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 support, the FPO is

investing in commissioning an integrated pack-house with processing lines for grading, sorting, packaging; seven ripening chambers with capacity of 16 to 20 tons each; one cold storage with capacity of 20 tons; and one pre-cooling chamber with capacity of 16 to 20 tons. 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 Rs. 1971 lakhs (at Rs 40 per kg) from Rs 256 lakhs (at Rs 5 per kg) 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 likely to fetch Rs. 400 per kg.

In addition to the case studies above, a study based on field surveys at Azadpur mandi concluded that proper supporting infrastructure like cold storage facilities, packing houses to perform operations, technological advancement and adequate resources to handle produce is the need of the hour in fruits supply chain (Negi and Anand, 2019). They identified three factors for high cost, namely, operational charges, labour and resources; four factors for high lead time, namely, operational issues, labour, resources and infrastructure; and four factors for poor quality, namely, operational issues, infrastructure, resources and poor ambience.

The key obstacles for the limited use of cold-chains in developing countries: deficient professional skills, lack of quality and safety-control measures, high concentration of intermediaries, poor infrastructure, lack of information systems, high cost of installation and operation, inadequate education and training at farmer level, deficiency of standardization, lack of government support for local businesses and social norms (Gilgor et al., 2018). However, government rules and regulations were the main key success factors that companies have adopted in both their own operations and in their supplier's operations from sustainability point of view in cold-chains (Shashi et al., 2016). Study suggests that there is a strong need for the government and NGOs to work in a unified manner to promote training programs to achieve the objectives of sustainability in cold-chain.

A cost–benefit analysis for the maize, bean and cowpea supply chains in Benin and Mozambique found the investment in hermetic bags and metal silos to be beneficial for farmers. Results suggest that farmers in both countries may realize an up to 11-fold return on investment. Extending shelf life without plastics or cold storage. Apeel is an innovative natural technique to

coat fresh fruits and vegetables with a thin peel of edible plant material that slows down water loss and oxidation. The start-up that developed the technique was launched in 2012 in the United States of America. It claims Apeel extends the lifespan of avocadoes by almost a week and doubles their ripeness window from two to four days by reducing water loss by 30 percent and slowing down softening by 60 percent, relative to untreated avocadoes. The developers also claim that their technique results in a fivefold reduction in mechanical damage (FAO, 2019).

It is clear that the developing of cold storages alone cannot mitigate the losses incurred by domestic perishable produce, unless other infrastructure like pack-houses and transport are also associated to avail connectivity with consumption areas. This assumes its significance because cold-chain follows a process of providing fresh produce to the last mile consumers from the producers. Despite the benefits associated with the efficient cold-chains, little is known about the factors that impede cold-chain implementation in India. Such gaps need to be minimized. Getting insights from the review of studies, the proposed conceptual framework is discussed in next sub-section.

4. Economic losses and potential welfare gains from loss reduction

Estimates of harvest and post-harvest losses of crops/commodities provide the information about the range of losses in different operations and market channels. It helps in identifying the operations and channels where losses are high and whether the losses may be avoided.

Economic value of harvest and post-harvest losses: Table 2 shows the economic value of quantitative loss of 39 crops was found to be in the tune of Rs 114403 crores at average annual prices of 2018 in India. While this Rs. 1.14 trillion estimate of food losses is from relatively conservative loss estimates of Jha et al., (2015) study, the losses are in fact much higher with Rs.3.77 trillion if we take the FAO (2019) gives an estimate of 21% across all crops. Highest contribution (37.1%) towards economic loss was from fruits and vegetables followed by plantation and spice crops (27.1%); and cereals (21.8%). The more loss in fruits and vegetables is primarily due to its perishable nature. Thus, it requires post-harvest management of fruits and vegetables to reduce losses.

Table 2: Estimates of the monetary value of harvest and post-harvest losses for different crops in India at production of year 2017-18 and prices of 2018

Sr. No	Crop	Production (Million tonnes)	Price (Rs./ tonne)	Overall total loss (%)*	Value of the losses (Rs. Crores)as per Jha et al (2015)	Monetary value of loss (Rs.Cr) as per FAO#
	Cereals				**24941**	**100586**
1	Paddy	112.76	19381	5.53	12085	45893
2	Wheat	99.87	19336	4.93	9520	40553
3	Maize	28.75	15505	4.65	2073	9361
4	Pearl millet	9.21	14381	5.23	693	2781
5	Sorghum	4.80	19817	5.99	570	1998
	Pulses				**6902**	**18839**
6	Pigeon pea	4.30	45483	6.36	1244	4107
7	Chick pea	11.23	46700	8.41	4411	11013
8	Black gram	3.56	47319	7.07	1191	3538
9	Green gram	0.16	53945	6.6	57	181
	Oilseeds				**9070**	**31162**
10	Mustard	8.43	38693	5.54	1807	6850
11	Cottonseed	11.62	33802	3.08	1210	8248
12	Soybean	10.93	33789	9.96	3678	7756
13	Safflower	0.06	28979	3.24	6	37
14	Sunflower	0.22	32442	5.26	38	150
15	Groundnut	9.25	41808	6.03	2332	8121
	Fruits				**25083**	**57478**
16	Apple	2.33	78850	10.39	1909	3858
17	Banana	30.81	19794	7.76	4732	12807
18	Citrus**	11.52	33475	9.69	3737	8098
19	Grapes	2.92	57930	8.63	1460	3552
20	Guava	4.05	28598	15.88	1839	2432
21	Mango	21.82	51645	9.16	10322	23665
22	Papaya	5.99	18563	6.7	745	2335
23	Sapota	1.18	29455	9.73	338	730
	Vegetables				**17374**	**43218**
24	Cabbage	9.04	10843	9.37	918	2058
25	Cauliflower	8.67	16848	9.56	1396	3068
26	Green pea	5.42	37555	7.45	1516	4275
27	Mushroom	0.49	108493	9.51	506	1116
28	Onion	23.26	18857	8.2	3597	9211
29	Potato	51.31	13843	7.32	5199	14916
30	Tomato	19.76	15267	12.44	3753	6335
31	Tapioca	4.95	21540	4.58	488	2239
	Plantation				**31033**	**126208**
32	Arecanut	0.83	185504	4.91	759	3233
33	Black	0.07	351404	1.18	27	517
34	Cashewnuts	0.82	363514	4.17	1238	6260
35	Dry Chillis	2.15	84154	6.51	1177	3800
36	Coconut	16.41	274455	4.77	21487	94580
37	Coriander	0.71	31893	5.87	133	476
38	Sugarcane	379.90	1941	7.89	5818	15485
39	Turmeric	1.13	78260	4.44	393	1857
				Grand total	**114403**	**377490**

Source: Compiled data from Horticultural Statistics at a Glance (2018), Agricultural Statistics at a Glance (2019) and www.agmarknet.gov.in (Accessed on 27.12.2020).

Note: * See Jha et al (2015), ** includes Lemon, Mousambi and Orange.
FAO (2019) estimated food losses and waste in the South Asia region to be of the order of 21% across all crops

Table 3: Food loss estimates in vegetables in remote areas by Small Farmers Agribusiness Consortium (In per cent)

Vegetables	Farmers level	Wholesale level	Retail level	Total
Potato	5	2	2	9
Carrot	6	2	2	10
Knol-khol	5	5	5	15
Radish	5	5	5	15
Ridge gourd	5	5	5	15
Cowpea	5	5	5	15
Ladyfinger	5	5	5	15
Ash gourd	5	5	5	15
Tomato	7	5	4	16
Brinjal	5	6	6	17
Spine gourd	5	6	6	17
French bean	5	7	7	19
Cucumber	10	5	5	20
Onion	-	15	5	20
Bottle gourd	4	15	5	24
Chilli	5	15	5	25
Pumpkin	5	15	5	25
Bitter gourd	5	15	5	25
Ginger	5	15	5	25
Cabbage	10	8	8	26
Pointed gourd	5	15	7	27
Sweet gourd	5	15	7	27
Garlic	7	15	5	27
Capsicum	5	15	8	28
Cauliflower	10	10	10	30
Pea	10	15	7	32

Source: GoI (2017)

The comparison of loss estimates for meta-analysis is problematic in view of the differences in methodologies and definitions of loss across all the developing countries including India (Kitinoja and Kader, 2015). The High Level Committee on Doubling Farmers' Income of the government questioned the estimates of the ICAR-CIPHET and felt there were too low to be representative in far-flung areas of the country. The loss estimates among vegetables range from 9-30% in remote areas as per the estimates of Small Farmers Agribusiness Consortium of the central government (Table 3). It concluded that these losses represent losses of vegetables in most parts of the country. (GoI, 2017). There is a unique problem in India of the proportion of unsold produce with the farmers, especially of fruits and vegetables[2] that has to be stored for longer periods in anticipation of marketing later.

[2] The Report on Doubling Farmers' Income by GoI (2017) identifies this unsold produce as a major problem in India and needs policy attention.

Table 4: Expected crop-wise food loss reduction in monetary terms through cold chain efforts under different scenarios in India for 2018

Crop	Overall total loss	Monetary loss	Scenario 1 (up to 40% reduction & 40% monetary value saved)			Scenario 2 (up to 70% reduction & 70% monetary value saved)		
	%	Rs cr	IR	RFL (%)	MVS (Rs. cr)	IR	RFL (%)	MVS (Rs. cr)
Paddy	5.5	12085	H+P+T	2.2	4834	H+P+T+TH	3.9	8460
Wheat	4.9	9520	H+P+T	2.0	3808	H+P+T+TH+C	3.5	6664
Maize	4.7	2073	H+P+T	1.9	829	H+P+T+TH+C+W	3.3	1451
Bajra	5.2	693	TH	2.1	277	TH+H+F	3.7	485
Sorghum	6.0	570	TH+P+T	2.4	228	TH+P+T+H+C	4.2	399
Pigeon pea	6.4	1244	TH+P+T	2.5	498	TH+P+T+H+F	4.5	871
Chick pea	8.4	4411	TH+P+T	3.4	1764	TH+P+T+H+W	5.9	3087
Black gram	7.1	1191	H+C	2.8	476	H+C+TH+D	5.0	834
Green gram	6.6	57	H+C	2.6	23	H+C+TH+W	4.6	40
Mustard	5.5	1807	TH+C	2.2	723	TH+H	3.9	1265
Cottonseed	3.1	1210	H	1.2	484	H+C	2.2	847
Soybean	10.0	3678	TH+C+W+WS+PU+P	4.0	1471	TH+C+W+WS+PU+P+R+T+G+F+D	7.0	2575
Safflower	3.2	6	H+T	1.3	2	H+T+C+TH	2.3	4
Sunflower	5.3	38	TH+C	2.1	15	TH+C+H+W+D+P	3.7	26
Groundnut	6.0	2332	H+W	2.4	933	H+W+TH+D	4.2	1632
Apple	10.4	1909	S+PU	4.2	764	S+PU+WS+T+R+C+G+P+F	7.3	1336
Banana	7.8	4732	H+S	3.1	1893	H+S+T	5.4	3313
Citrus	9.7	3737	S	3.9	1495	S+H+T	6.8	2616
Grapes	8.6	1460	S	3.5	584	S+H+T	6.0	1022
Guava	15.9	1839	H+T	6.4	736	H+T+S	11.1	1287
Mango	9.2	10322	S+C	3.7	4129	S+C+H+T	6.4	7226
Papaya	6.7	745	S+H	2.7	298	S+H+T+C+P	4.7	521
Sapota	9.7	338	S+T	3.9	135	S+T+H	6.8	237
Cabbage	9.4	918	S+C	3.8	367	S+C+H+T	6.6	643
Cauliflower	9.6	1396	S	3.8	559	S+H+T	6.7	977
Green pea	7.5	1516	S	3.0	607	S+H+T	5.2	1062
Mushroom	9.5	506	R+H+T	3.8	202	R+H+T+F	6.7	354
Onion	8.2	3597	H+C+P	3.3	1439	H+C+P+S	5.7	2518
Potato	7.3	5199	S	2.9	2080	S+H	5.1	3640
Tomato	12.4	3753	S+C+P	5.0	1501	S+C+P+H	8.7	2627
Tapioca	4.6	488	H+T	1.8	195	H+T+S+F	3.2	342
Arecanut	4.9	759	H+TH	2.0	303	H+TH+W+D	3.4	531
Black pepper	1.2	27	H	0.5	11	H+TH	0.8	19
Cashewnuts	4.2	1238	H	1.7	495	H+TH	2.9	867
Dry chillis	6.5	1177	S	2.6	471	S+H+C	4.6	824
Coconut	4.8	21487	H+W	1.9	8595	H+W+TH+D	3.3	15041
Coriander	5.9	133	H	2.4	53	H+TH+W	4.1	93
Sugarcane	7.9	5818	H+S	3.2	2327	H+S+WS+R+T+P+C+F+PU	5.5	4073
Turmeric	4.4	393	S+WS+D+C+P	1.8	157	S+WS+D+C+P+F+R+PU+T	3.1	275
Total		**114402**			**45761**			**80082**

Note: 1. Intervention is required at different stages of farm operations for different crops: H= Harvesting, C= Collection, TH= Threshing, S=Sorting/grading, W=Winnowing, D=Drying, P= Packaging, T=Transport, F=Farm storage, G=Godown, WS= Wholesaler, R=Retailer and PU=Processing unit

2. IR= Intervention required; RFL= Reduction in food loss; MVS= Monetary value Saved, Mn t= Million tonnes

Table 4 shows how different levels of saving will reduce losses and gain to the economy. For all crops, Rs 45761 crores has been saved if loss is reduced up to 40 per cent. It increased to Rs 80082 crores, if loss is reduced to 70 per cent. Similar pattern is observed in individual crops as well.

Welfare gains with loss reduction: The real question that arises in this debate on food loss and waster is whether there can be net welfare gains if the losses are reduced. *A priori*, the net gains are ambiguous and depends on the kind of loss (Rutten, 2013). The outcomes will be vvery different with supply-driven food loss and demand-driven food waste. While reducing losses in developing countries like India where the food losses are mainly at the post-harvest stage, the net gains can be substantial. There are hungry people who can consume these foods, especially because the consumption of fruits are vegetables is too low. An effort was made to calculate the additional people that can be fed with a likely food savings with 50% loss reduction by taking the per capita consumption of these foods from the NSSO (Table 5). The results are presented hereunder in brief and the detailed tables in Appendix tables 1 to 20.

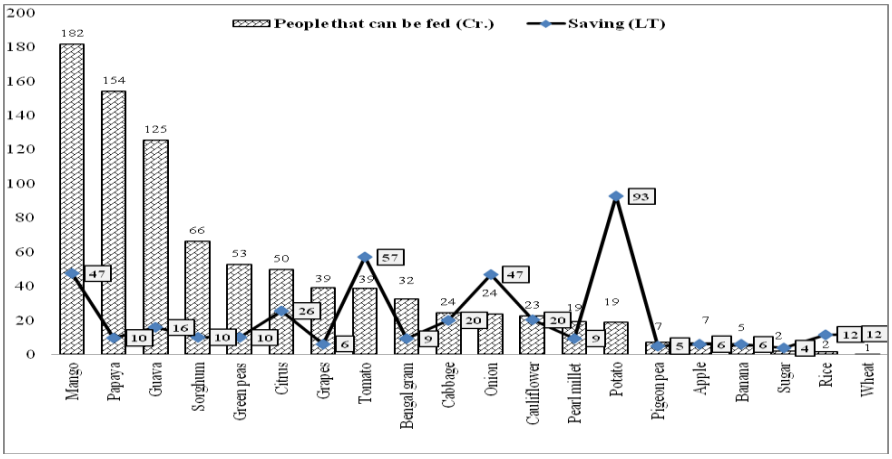
Table 5: Crop-wise total savings and additional number of people that can be fed in 2018

Crops	Total saving/annum (50%) Lakh tonnes	Per capita consumption Kg/annum	Additional people that can be fed/annum Crores
Mango	47.48	3.20	181.71
Papaya	9.77	1.09	153.98
Guava	15.83	1.58	125.37
Sorghum	10.13	10.17	66.23
Green peas	9.93	1.98	52.54
Citrus	25.54	6.84	49.63
Grapes	6.23	1.57	39.02
Tomato	57.05	16.11	38.62
Bengal gram	9.27	2.65	32.33
Cabbage	20.09	7.68	24.23
Onion	46.85	19.54	23.64
Cauliflower	20.29	8.79	22.50
Pearl millet	9.36	9.80	19.16
Potato	92.65	34.33	18.93
Pigeon pea	4.94	6.95	7.06
Apple	5.99	4.77	6.70
Banana	5.87	12..91	4.71
Sugar	3.71	21.29	2.05
Rice	11.70	160.43	1.63
Wheat	12.03	156.73	0.69
Total	424.71		870.73

Note: * indicates the consumption given in numbers.

A synthesis of the findings on the additional people that can be fed with a 50% reduction of losses are provided in Table 4 and Figure 3. Even if we reduce food losses by half, we can save large quantities of food much of it in potato (93 lakh tons) followed by tomato (57 l.t), mango (48 l.t), onion (47 l.t), citrus (26 l.t), cabbage (20 l.t), and guava (15 .t). Crop-wise savings and additional people are calculated and given in the Appendix tables 1-20.

Figure 3: Crop-wise total savings and additional number of people to be fed in 2018



Note: Cr. = Crores and LT= Lakh tons

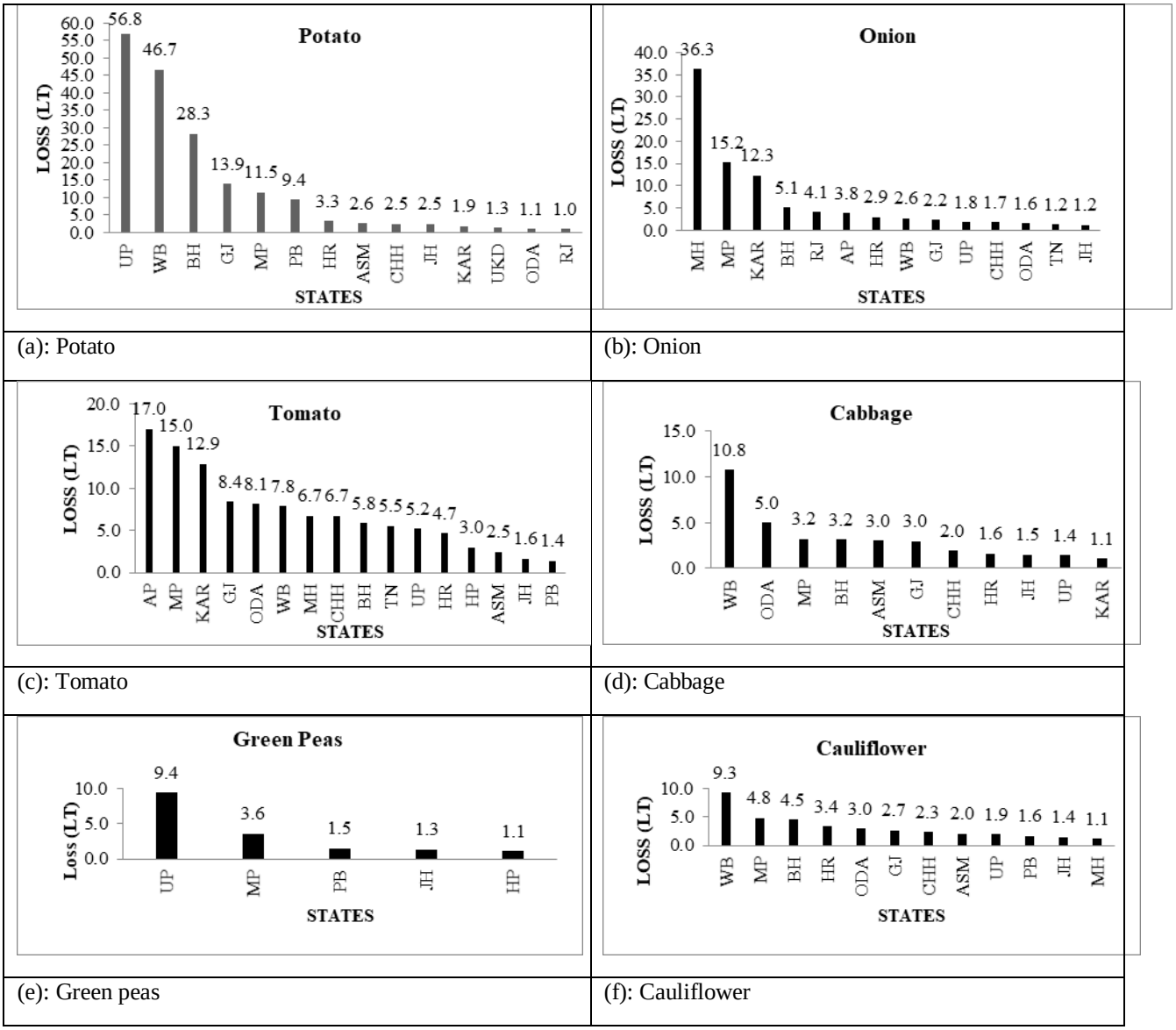
Table 5 gives another startling finding. Even reducing food losses by half can enable feeding an additional population of 848 crores. The substantial gains are possible in case of loss reduction in mango, papya, guava, sorhum, green peas and grapes. It is important here to mention that the per capita consumptions of these commodities are very low and are likely to go up incomes rise. Nevertheless, NSSO data provide a benchmark to asses the numbers of people who can be fed with the savings generated by reducing food losses.

Food loss and waste across states and crops: Food loss and waste among states' estimations across various states show the staggering figures and the enormity of this problem. The states with highest losses are brought out for vegetables (Figure 4), fruits (Figure 5) and food crops (Figure 6), while the full details of losses across all states are given in the Appendix Tables 1-20. These figures reveal that the losses are more in vegetables and followed by fruits and food crops.

Losses in vegetables: The losses in case of vegetables are found to be more in the states of UP, MP, West Bengal, Maharashtra, Bihar and Andhra Pradesh (Figure 4). Further, the losses are more in potato followed by onion, tomato, cabbage, green peas and cauliflower. The states with the highest losses for

individual vegetable crops are also given in the Table. The losses of vegetables are more in UP (57 lakh tons), WB (47 l.t) and Bihar (28 l.t); in Maharashtra (36.3 l.t) and MP (15.2 l.t) for onion; in AP (17 l.t) and MP (15 lt) for tomato; in WB (11 l.t), and Odisha (5 l.t) for cabbage; in UP (9.4 l.t), and MP (3.6 l.t) for green peas; and in WB (9.3 l.t), and MP (4.8 l.t) for cauliflower.

Figure 4: Loss (lakh tonnes) in vegetables across states in India: 2018



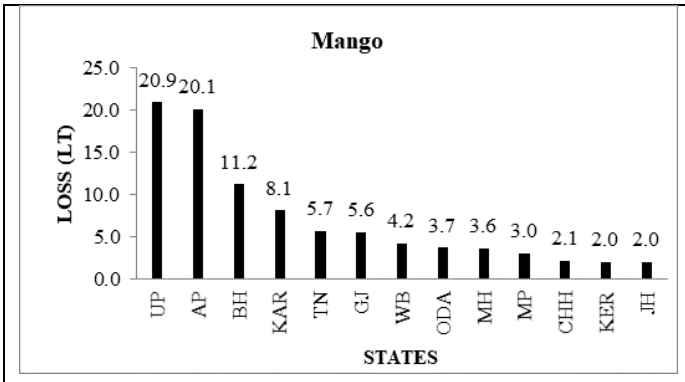
(a): Potato (b): Onion

(c): Tomato (d): Cabbage

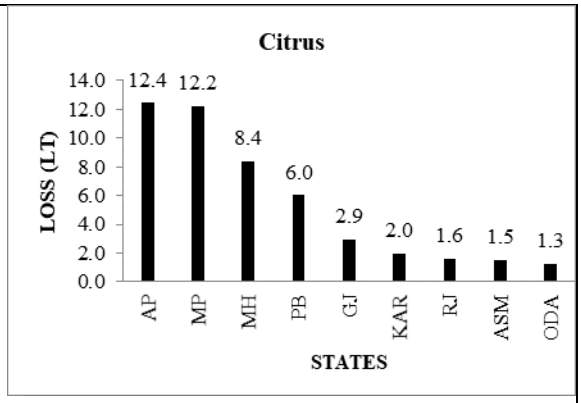
(e): Green peas (f): Cauliflower

Note: LT=Lakh tones, UP= Uttar Pradesh, WB=West Bengal, BH=Bihar, GJ=Gujarat, MP= Madhya Pradesh, PB=Punjab, HR=Haryana, ASM=Assam, AP= Andhra Pradesh, CHH=Chhattisgarh, JH=Jharkhand, KAR= Karnataka, UKD=Uttarakhand, ODA=Odisha, RJ=Rajasthan, TN=Tamil Nadu, HP=Himachal Pradesh, MH=Maharashtra

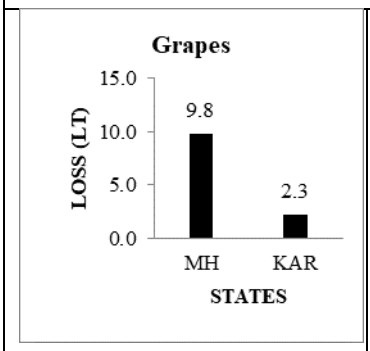
Figure 5: Loss (lakh tonnes) in fruits across states in India: 2018



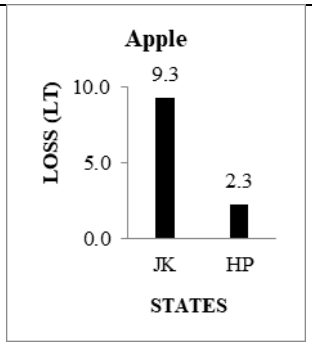
(a): Mango



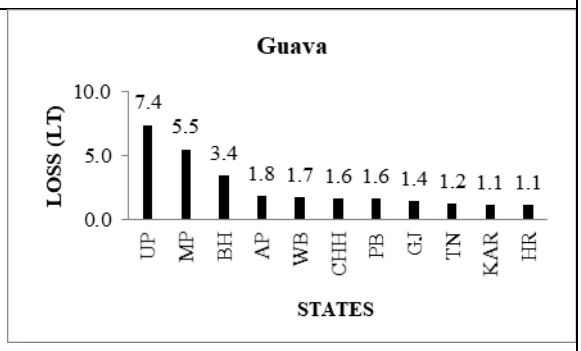
(b): Citrus



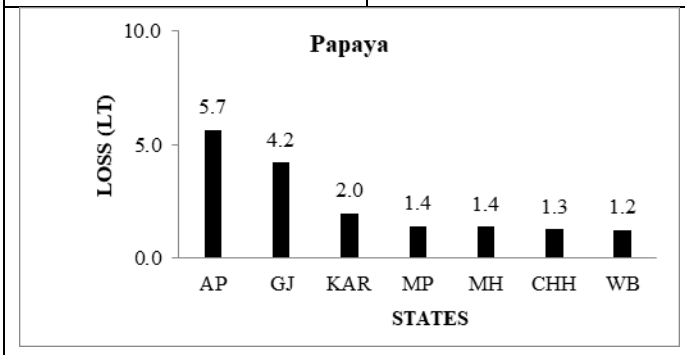
(c): Grapes



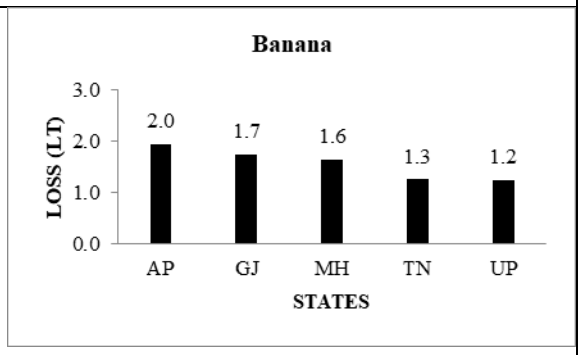
(d): Apple



(e): Guava



(f): Papaya



(g): Banana

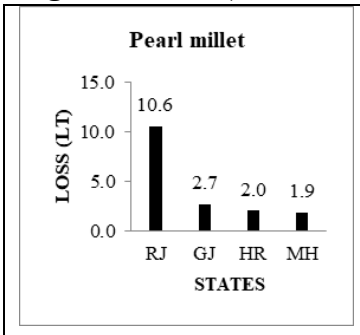
Note: LT=Lakh tones, UP= Uttar Pradesh, WB=West Bengal, BH=Bihar, GJ=Gujarat, MP= Madhya Pradesh, PB=Punjab, HR=Haryana, ASM=Assam, AP= Andhra Pradesh, CHH=Chhattisgarh, JH=Jharkhand, KAR= Karnataka, UKD=Uttarakhand, JK= Jammu & Kashmir, ODA=Odisha, KER=Kerala, RJ=Rajasthan, TN=Tamil Nadu, HP=Himachal Pradesh, MH=Maharashtra

Losses in fruits: Substantial losses of fruits seem to occur in the states of AP, UP, MP, Bihar, Maharashtra and Jammu and Kashmir (Figure 5). The fruit crops in the order of magnitude of food loss in descending order are mango, citrus, grapes, apple, guava, papaya and banana. While UP (21 lakh tons),

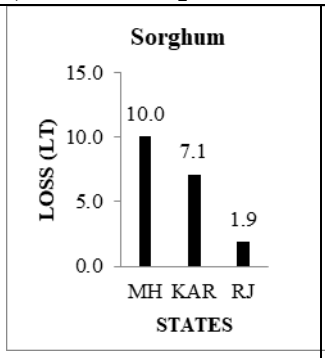
AP (20 l.t) and Bihar (11 l.t) are the states with the highest loss in case of mango, citrus fruits are wasted mainly in AP (12 l.t), and MP (12 l.t). Other leading states with major losses include- Maharashtra for grapes (10 l.t), J&K for apple (9.3 l.t), UP for guava (7.4 l.t), AP for papaya (6 l.t) and banana (2.0 l.t).

Losses in food crops: Paradoxically, more food wasted in minor millets and pulses than the largest cultivated rice and wheat in India (Figure 6). This indicates the lackadaisical manner in which these crops are treated, leading to proportionately higher loss. In other words, much of the post-harvest care is given to rice and wheat to the relative neglect of minor millets and pulses and therefore improving post-harvest handling can save a lot of food from these crops. The major states with large food losses in case of food crops are UP, Maharashtra, Rajasthan and MP. Substantial losses are found in case of pearl millet in Rajasthan (11 lakh tons); sorghum in Maharashtra (10 l.t) and Karnataka (7 l.t); wheat in UP (8 l.t); chickpea in Maharashtra (6 l.t) and Rajasthan (5 l.t); pigeon pea (5 l.t); and rice in West Bengal (4 l.t), UP (4 l.t) and Punjab (3 l.t).

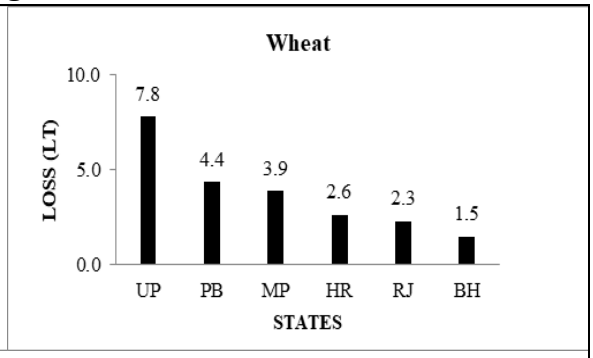
Figure 6: Loss (lakh tonnes) in cereals, pulses & sugarcane across states in India: 2018



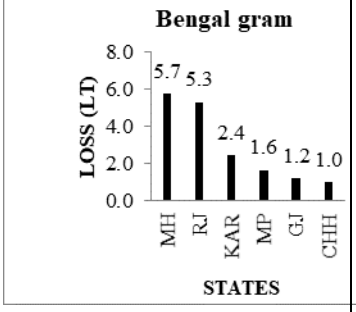
(a): Pearl millet



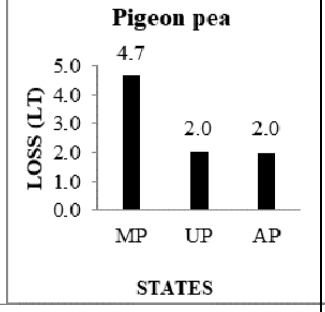
(b): Sorghum



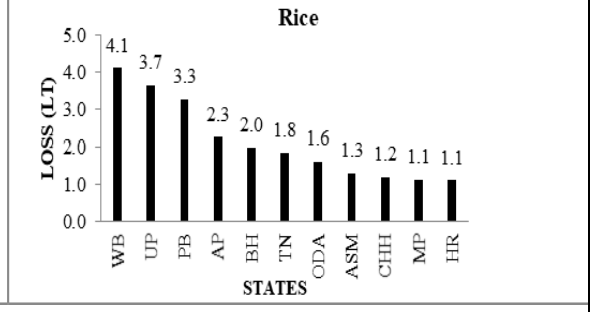
(c): Wheat



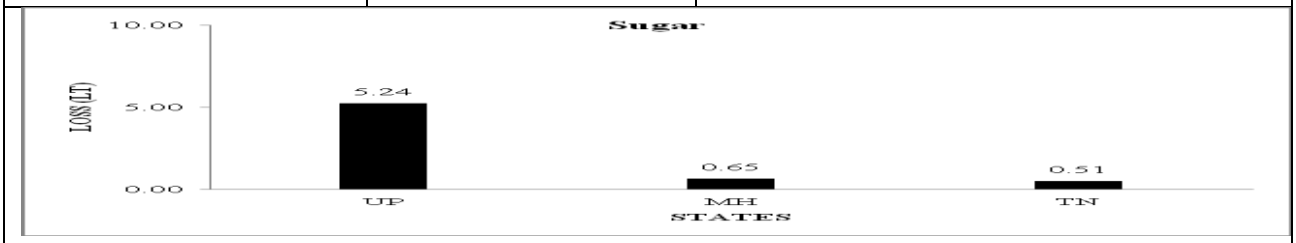
(d): Bengal gram



(e): Pigeon pea



(f): Rice



(g): Sugar*

Note: LT=Lakh tones, UP= Uttar Pradesh, WB=West Bengal, BH=Bihar, GJ=Gujarat, MP= Madhya Pradesh, PB=Punjab, HR=Haryana, ASM=Assam, AP= Andhra Pradesh, CHH=Chhattisgarh, JH=Jharkhand, KAR= Karnataka, UKD=Uttarakhand, JK= Jammu & Kashmir, ODA=Odisha, KER=Kerala, RJ=Rajasthan, TN=Tamil Nadu, HP=Himachal Pradesh, MH=Maharashtra

5. Status of Cold-Chain in India

This section deals with the overview and current status of cold-chain in the country in regard to the marketing of fruit and vegetables from the producer to the consumer.

5.1 Overview of Cold Storages: Before coming to the status of cold-chain sector in India, it is imperative to look at the number of cold storage units and their capacity expanded since

independence in the country. The available data suggests that there were only 4 cold storage units in India in the year 1947 with a capacity of just 0.031 lakh tons. The cold storage capacity increased to 3.055 lakh tons in 1960, 16.38 lakh tons in 1970, 39.65 lakh tons in 1980, 68.15 lakh tons in 1990, and 153.85 lakh tons in 2001 and further to 374.25 lakh tons in 2020. The total number of cold storage units in the country in 2001 has been 4199, which increased to 8186 in 2018 (GoI, 2020). There are several unique features of the cold storages in the country as revealed by several studies (For example NHB, 2014[3]).

Farmgate cold storages form 68% of the cold stores. But horticulture CSs account for 75 per cent of CSs, as there are CSs even in urban and distribution centres. Mean capacity is at 5003 tons. East zone has the highest mean capacity of 8543 tons mainly contributed by WB with 11113 tons. As the bulk of the CSs stock raw potatoes, the chamber temperature is between 0 to 100 Celsius. Frozen chambers are found more in animal husbandry CSs. While horticultural CSs stock mainly single commodities, processed food CSs and Pharma CSs, stock other products including horticultural products. 74 per cent of the CSs are having brick and mortar structures with West zone, while 17 per cent of the CSs have adopted Pre-Engineered Buildings (PEB) structures.

Overall average capacity utilisation (2010-2012, for 3 years) is 75 per cent which shows that the CS's catchment area is sustainable. Product wise capacity utilization shows that Type H (Horticulture /Agriculture) has 75 per cent, Type P (Processed food) has 71 per cent, and Type M (Animal Husbandry) has 74 per cent, 70 per cent for Type Q (Pharmaceutical) and 65 per cent for Type O (Other products). Single commodity cold storages are higher in number except in the stated of T.N, Jharkhand and Delhi where number of multi commodity cold storages outnumbers the single ones. Of the 87 per cent of Type H cold storages, 72 per cent only store single commodity. Raw potatoes are stocked by majority of horticultural CSs. Other products stocked are apples, bananas, spices, pulses, grapes, different vegetables and seeds.

The average distance to a highway- either national or state highway- is 4 kms for all CSs. As transport services are not provided by 79 % per cent of CSs, logistics companies lift the stock

[3] It is based on a survey of 5003 cold storages across the states.

and transport them to trading centres. The proximity to highways is facilitating this service adequately. The average distance from railways is over 10 kms. Distance to airports and seaports were higher at 45 kms and 35 kms respectively, though these are relevant for export trade.

Over 50 per cent have ante rooms and over 40% have sorting and grading facilities, and pack houses. Analysis of CSs built post 2009 shows that there is improvement in existence of these back end infrastructure. Importance of back end infrastructure needs to be educated to CS owners so that they can create the infrastructure. If required concessional rate of interest can be provided for the loans to facilitate the infrastructure in CSs.

Though bunker coil system is to be terminated, a third of CSs are still using bunker coil system. In fact over 40 per cent have refrained from answering the question as they are not sure of what system they are using. Analysis by age wise CSs reveal that post-2009 the percentage using bunker coil system has dropped. Only in North zone, usage of bunker coil system has significantly dropped post 2009. Likewise, there is a significant drop in usage of bunker coil in horticultural and pharma CSs. Multiple systems are used in every CSs to detect and fight fire in CSs. Gas based extinguishers are prevalent in majority – over 70 per cent - of the CSs. Though technology has improved, CSs also depend on manual rounds to detect fire. UP accounts for 27 per cent of CSs and accounts for 37 per cent of capacity. West Bengal though accounts for fourth in terms of number of cold stores (9 %), ranks second in capacity with 21 per cent share in all India capacity.

The total capacity of refrigerated warehouses worldwide was 616 million cubic meters in 2018, 2.67% greater than the capacity reported in 2016. India was the single largest country market, at 150 million cubic meters, followed by the United States at 131 million cubic meters, and China at 105 million cubic meters (Salin, 2018). India had 7,645 cold storages in 2018 and nearly all of them were owned by private sector companies and the products stored were mainly potatoes and other vegetables. Currently 68 per cent of the existing cold storage capacity is used for storing potato only.There is therefore an urgent need to upgrade the existing cold storage plant and machinery, and technology (Rawat, 2019).

The state-wise and zone-wise storage capacity during 2013-2019 along with percentage change is shown in Table 6. Two points may be noted from the table. Barring North-East Zone and South Zone, other zones have shown increase in storage capacity during 2013-2019. Within zones, states have shown mixed pattern of change in storage capacity. However, it is the north zone that possesses more than half of all the storage capacity in the country and Punjab and Haryana in this zone account for nearly 80% of this storage. In other words, the available storage capacities are mostly in the northern zone and west zone with practically no storage capacities in north-east zone and several states.

Table 6: Storage capacity for different States and Zones: 2013-2019 (Lakh tons)

State/UTs	2013	2014	2015	2016	2017	2018	2019	% Change (2019/2013)
Bihar	11.21	11.50	10.49	15.10	15.56	25.81	22.10	97.15
Odisha	15.33	14.09	13.57	11.63	13.57	12.10	13.15	-14.22
West Bengal	19.68	19.64	14.68	16.72	18.64	18.67	19.44	-1.22
Jharkhand	1.69	2.11	2.95	2.53	2.91	3.68	5.51	226.04
East Zone	47.91	47.34	41.69	45.98	50.68	60.26	60.20	25.65
Assam	6.07	6.25	5.76	6.29	3.98	4.68	3.98	-34.43
Arunachal	0.23	0.23	0.28	0.23	0.41	0.27	0.30	30.43
Tripura	0.76	0.83	0.37	0.83	0.43	0.44	0.99	30.26
Manipur	0.3	0.31	0.32	0.32	0.32	0.32	0.49	63.33
Nagaland	0.46	0.46	0.33	0.45	0.44	0.48	0.49	6.52
Mizoram	0.26	0.26	0.25	0.67	0.25	0.93	0.67	157.69
Meghalaya	0.4	0.42	0.28	0.23	0.23	0.22	0.22	-45.00
North East Zone	8.48	8.76	7.59	9.02	6.06	7.34	7.14	-15.80
Delhi	5.16	5.14	3.67	3.67	3.67	3.67	3.67	-28.88
Haryana	57.66	64.78	107.77	116.11	101.73	99.17	112.20	94.59
Himachal	0.45	0.45	0.51	0.49	0.35	0.51	0.53	17.78
Jammu and	1.41	1.75	2.10	2.49	2.59	2.79	2.46	74.47
Punjab	168.1	182.66	240.00	252.56	250.13	201.43	234.30	39.38
Rajasthan	38.78	39.88	25.49	23.24	21.42	19.90	27.83	-28.24
Uttar Pradesh	102.63	91.59	57.53	64.43	58.28	58.72	62.38	-39.22
Uttarakhand	2.73	2.84	3.67	3.80	0.21	3.93	2.94	7.69
North Zone	376.92	389.09	440.74	466.79	438.38	390.12	446.31	18.41
Andhra Pradesh	91.3	68.47	27.31	24.02	28.71	26.80	25.48	-72.09
Telangana	N.A	N.A	19.79	20.88	17.52	27.37	33.42	68.87
Kerala	9.06	9.00	5.89	5.89	5.55	7.17	7.62	-15.89
Karnataka	24.16	25.02	29.24	29.62	13.87	11.56	12.49	-48.30
Tamil Nadu	23.36	24.41	17.58	16.99	26.97	43.17	31.31	34.03
South Zone	147.88	126.90	99.81	97.40	92.62	116.07	110.32	-25.40
Gujarat	17.21	18.33	9.86	9.26	8.82	9.28	10.71	-37.77
Maharashtra	50.66	53.43	31.79	31.55	31.98	34.19	38.30	-24.40
Madhya Pradesh	59.2	68.63	59.17	129.66	124.29	210.73	157.80	166.55
Chhattisgarh	23.66	23.70	23.58	24.98	19.00	15.04	24.90	5.24
West Zone	150.73	164.09	124.40	195.45	184.09	269.24	231.71	53.73
All Zone	731.92	736.18	714.23	814.64	771.83	843.03	855.68	16.91

Source: Compiled from Agricultural Statistics at a Glance (2017, 2019), Ministry of Agriculture and Farmers Welfare Department of Agriculture Cooperation and Farmers Welfare Directorate of Economics and Statistics, GoI.

Note: 1. For Telangana, 2015 figure is used as data for 2013 and 2014 are not available.
2. Storage capacity pertains to FCI, CWC and SWC. It includes Owned and Hired, Covered and Cap Storage.

State-wise number of Godown projects and storage capacity for two points of time (2015 and 2019) along with percentage change is shown in Table 5. Improvement in the number and storage capacity of Godowns has been observed in most of the states (as indicated by positive change in percentages). However, reverse pattern is observed for number of Godowns in Haryana (-8.23%) and Kerala (-2.37%). For storage capacity, Haryana and Uttarakhand have shown negative change.

Table 7: State-wise godown projects (No.) and storage capacity sanctioned under Agricultural Marketing Infrastructure (AMI) Scheme

State	2015		2019		Change in 2019/2015 (%)	
	Godown (No.)	Storage Capacity (Mn tons)	Godown (No.)	Storage Capacity (Mn tons)	Godown	Capacity
Andhra Pradesh	1225	4.83	1 338	5.41	9.22	11.91
Assam	266	0.72	325	0.99	22.18	37.11
Bihar	990	0.49	1 000	0.50	1.01	2.80
Chhattisgarh	525	1.66	594	1.94	13.14	17.08
Gujarat	9908	3.39	11 663	4.47	17.71	31.93
Haryana	2198	6.75	2 017	6.56	-8.23	-2.85
Himachal Pradesh	78	0.02	87	0.03	11.54	37.43
Jammu & Kashmir	07	0.04	14	0.08	100.00	107.57
Jharkhand	18	0.09	26	0.16	44.44	74.80
Karnataka	4421	3.30	4 508	3.79	1.97	14.78
Kerala	211	0.09	206	0.09	-2.37	0.57
Madhya Pradesh	3283	7.81	3 828	10.63	16.60	36.05
Maharashtra	3153	5.26	3 581	6.67	13.57	26.82
Odisha	419	0.78	691	1.01	64.92	29.38
Punjab	1704	6.38	1 745	6.74	2.41	5.67
Rajasthan	1360	2.05	1 471	2.72	8.16	32.72
Tamil Nadu	1040	1.12	1 127	1.41	8.37	25.66
Uttar Pradesh	1081	4.94	1, 119	5.32	3.52	7.74
Uttarakhand	266	0.79	287	0.77	7.89	-2.24
West Bengal	2480	1.39	2, 552	1.58	2.90	13.78
Telangana	583	3.50	760	4.63	30.36	32.15
Total	35216	55.40	38939	65.50	10.57	18.22

Source: Compiled from Agricultural Statistics at a Glance (2017, 2019), Ministry of Agriculture and Farmers Welfare Department of Agriculture Cooperation and Farmers Welfare Directorate of Economics and Statistics, GoI.

Even cold storage capacity has shown improvement both in number and capacity across all the states of India (see Table 7). Andhra Pradesh has exception in this regard for storage capacity (-0.64%).

Table 8: State wise cold storage capacity:2015-2020

State	2015		2020 (23.09.20)		Change in 2020/2015 (%)	
	No.	Capacity (Lakh tons)	No.	Capacity (Lakh tons)	No	Capacity
Andhra Pradesh	404	15.8	405	15.7	0.3	-0.6
Assam	34	1.2	39	1.8	14.7	48.8
Bihar	303	14.1	311	14.8	2.6	5.2
Chhattisgarh	89	4.3	99	4.9	11.2	13.9
Delhi	97	1.3	97	1.3	0.0	0.0
Goa	29	0.1	29	0.1	0.0	0.0
Gujarat	560	20.3	969	38.2	73.0	88.2
Haryana	295	5.9	359	8.2	21.7	39.3
Himachal	30	0.4	76	1.5	153.3	280.7
J&K	28	0.6	69	2.5	146.4	286.3
Jharkhand	55	2.2	58	2.4	5.5	8.9
Karnataka	189	5.3	223	6.8	18.0	28.5
Kerala	197	0.8	199	0.8	1.0	4.3
Madhya Pradesh	260	11.0	302	12.9	16.2	17.9
Maharashtra	540	7.1	619	10.1	14.6	43.0
Odisha	111	3.3	179	5.7	61.3	75.4
Punjab	606	20.0	697	23.2	15.0	15.5
Rajasthan	154	4.8	180	6.1	16.9	27.5
Tamil Nadu	163	3.0	183	3.8	12.3	29.4
Tripura	13	0.4	14	0.5	7.7	18.3
Uttar Pradesh	2176	136.3	2406	147.1	10.6	7.9
Uttrakhand	28	0.8	55		96.4	126.3
West Bengal	502	59.0	514	59.5	2.4	0.8
Total	6863	**317.8**	8082	**369.7**	**17.8**	**16.3**

Source: Compiled from Horticultural Statistics at a Glance (2015) and Press release (23 Sep 2020 by PIB Delhi), Ministry of Agriculture and Farmers Welfare Department of Agriculture Cooperation and Farmers Welfare Directorate of Economics and Statistics, GOI

With this brief overview of the status storages facilities, the next sub-section deals with the status of various components of cold-chain in India as well as in different states.

5.2. Development of Cold-Chain and its Components: In this sub-section, we tried to put together the secondary information gathered from various government agencies to understand the status of cold-chain and its components. The detailed information with respect to various components of cold-chain supported by different agencies across states is given in Tables (8&9).

Table 9: Cold-chain projects supported by various government agencies (NHM, NHB, MOFPI, APEDA and NCDC) in India: 2006-07 to 2020-21 (Number)

State(s)	Cold storage	Integrated cold chain	Pack house	Pre-cooling unit	Refrigerated transport vehicle	Ripening Chamber	All components
Andhra Pradesh	145	11	3	0	2	32	193
Assam	10	2	2	0	0	0	14
Bihar	106	6	0	1	3	0	116
Chhattisgarh	23	3	0	1	0	2	29
Delhi	9	0	0	0	30	0	39
Gujarat	282	35	3	15	12	50	397
Haryana	73	14	0	0	8	11	106
Himachal Pradesh	12	237	13	0	3	1	266
J&K	10	48	0	0	29	1	88
Jharkhand	28	0	0	1	1	0	30
Karnataka	69	20	3	0	17	11	120
Kerala	5	7	3	0	1	0	16
Madhya Pradesh	85	4	2	0	0	11	102
Maharashtra	99	108	17	18	12	71	325
Odisha	27	4	1	6	17	2	57
Punjab	277	55	2	3	1	16	354
Rajasthan	54	27	4	1	9	26	121
Tamil Nadu	16	18	1	5	3	32	75
Telangana	69	8	4	0	6	16	103
Uttar Pradesh	1162	34	2	0	13	34	1245
Uttarakhand	3	37	0	4	7	1	52
West Bengal	93	29	2	0	0	1	125
Total	2657	707	62	55	174	318	3973

Source: http://nhb.gov.in/Iccap.aspx (Accessed on 12/01/21)
Note: Cold storage includes CA storage; Integrated cold chain includes cold room, conveyor belt & grading packing unit

Table 8 indicates that, sofar a total number of 3973 cold-chain projects have been assisted by different agencies in the country. Uttar Pradesh has highest cold chain projects in percentage terms (31.3%), which is followed by Gujarat (9.9 %). This percentage is less than 9.0 per cent for rest of the states. Out of total cold-chain projects, maximum projects (2/3rd) are related to cold storage in the country. Similar is true in almost all the states, except for Himachal Pradesh, Jammu & Kashmir, Uttarakhand, Maharashtra and Tamil Nadu.

Table 10: Subsidy sanctioned for cold-chain projects by various government agencies (NHM, NHB, MOFPI, APEDA and NCDC) in India: 2006-07 to 2020-21 (Rs. crore)

State(s)	Cold storage	Integrated cold chain	Pack house	Pre-cooling unit	Refrigerated transport vehicle	Ripening Chamber	All components
Andhra Pradesh	112	70	20	0	0	6	208
Assam	24	7	14	0	0	0	45
Bihar	45	17	0	1	1	0	63
Chhattisgarh	26	10	0	0	0	0	36
Delhi	3	0	0	0	12	0	15
Gujarat	224	172	12	11	11	13	443
Haryana	83	54	0	0	3	8	147
Himachal Pradesh	49	110	23	0	1	0	183
J&K	38	115	0	0	2	0	155
Jharkhand	14	0	0	0	0	0	14
Karnataka	54	76	11	0	1	3	145
Kerala	2	22	16	0	0	0	40
Madhya Pradesh	80	14	11	0	0	3	107
Maharashtra	50	334	59	4	2	23	473
Odisha	25	2	5	0	2	0	36
Punjab	185	97	8	0	0	6	297
Rajasthan	46	74	13	0	1	7	141
Tamil Nadu	22	76	0	0	0	8	106
Telangana	64	43	1	0	0	4	112
Uttar Pradesh	619	114	11	0	1	10	755
Uttarakhand	3	167	0	1	2	0	173
West Bengal	43	54	3	0	0	0	100
Total	1809	1628	206	18	40	92	3794

Source: http://nhb.gov.in/Iccap.aspx (Accessed on 12/01/21)
Note: Cold storage includes CA storage; Integrated cold chain includes cold room, conveyor belt & grading packing unit

Table 10 shows that, during 2006-07 to 2020-21, a subsidy of Rs 3794 crores has been sanctioned for cold-chain projects in India. In percentage terms, 90.59 per cent has been sanctioned for cold storage and integrated cold-chain projects against other components (9.38%). Maximum percentage of subsidy for cold-chain projects is sanctioned for Uttar Pradesh (19.9%), followed by Maharashtra (12.5%) and Gujarat (11.7%). Less than 6.0 % subsidy is sanctioned for rest of the states.

Table 11: State-wise financial progress of approved 162 cold-chain projects related with fruits and vegetables in India: 2008-09 to 2019-20 (as on 30.11.2020)

State	Project	Project Cost	Approved Amount of grant-in-aid	Amount Released	Physical Progress (No.)					
	(No.)	(Rs. Crore)	(Rs. Crore)	(Rs. Crore)	I	II	III	IV	V	VI
A.P	2	45.00	9.61	5.82	0	1	0	0	0	1
Assam	2	38.28	17.37	17.37	0	2	0	0	0	0
Bihar	3	70.84	27.33	12.23	1	0	1	0	0	1
Chhattisgarh	2	39.33	13.36	11.52	0	2	0	0	0	0
Gujarat	13	441.55	110.41	62.60	1	6	0	1	1	4
Haryana	7	199.95	50.39	40.39	0	6	0	0	0	1
H.P	15	349.25	129.53	94.50	2	8	0	1	2	2
J&K	5	93.68	47.76	32.87	1	3	0	0	0	1
Karnataka	4	77.19	33.92	20.91	0	2	0	1	0	1
Kerala	2	60.49	16.98	6.98	0	1	0	0	0	1
M.P	6	148.03	47.94	28.57	1	2	0	1	1	1
Maharashtra	31	813.69	221.26	187.62	5	20	0	5	1	0
Manipur	1	18.49	9.96	9.96	0	1	0	0	0	0
Punjab	12	271.48	97.23	75.45	1	9	0	1	0	1
Rajasthan	4	86.19	27.04	23.60	1	3	0	0	0	0
T.N	4	115.04	31.37	21.37	0	3	0	0	0	1
Telangana	4	116.12	32.16	22.44	0	2	0	1	1	0
U.P	15	362.47	131.41	97.85	3	8	1	1	1	1
Uttarakhand	23	407.53	216.29	164.97	2	13	0	5	0	3
W.B	7	154.81	39.15	39.15	0	7	0	0	0	0
Total	162	3909.41	1310.47	976.17	18	99	2	17	7	19

Source: Compiled from the information given by the Ministry of Food Processing Industries, Govt. of India (see https://mofpi.nic.in, information accessed on Dec 14, 2020).

Note: 1. I= Completed; II= Commercial Production Started; III= 75% Progress; IV= 65% Progress; V= 55% Progress; and VI= Under implementation

2. Arunachal Pradesh, Andaman and Nicobar Islands (U.T), Mizoram, Odisha and Nagaland have been excluded because no cold-chain projects related with fruits and vegetables are approved and implemented in these states/U.T.

The information released by MoFPI (as on 30.11.2020) with respect to the status of 328 approved cold-chain projects (since 2008-09) related with cold storage facilities in India shows that the total project cost these projects is Rs. 8987.09 crore with private investment of Rs. 6481.87 crore and grant-in-aid of Rs. 2505.22 crore. If we consider only cold-chain projects related to fruits and vegetables sector in India (projects excluded for: dairy, meat, marine, fishery, poultry, ready to eat, irradiation and mixed) the approved number of projects comes out to be 162 against the total of 328 cold chain-projects (see Table 11).

The total cost of these projects sanctioned so far is Rs. 3909.41 crore with private investment of Rs. 2598.94 crore and grant-in-aid of Rs. 1310.47 crore. In terms of physical progress, commercial production has started in maximum number of cold-chain projects (about 61% of total projects). Only 11 per cent of them are completed.

Foregoing discussion shows that the infrastructure created under cold-chain projects by various agencies biased towards the cold storage facilities in India as well as in states. Furthermore, the infrastructural support pertaining to other components of cold-chain, including the cold storages with controlled/modified atmosphere, remained very few in numbers. This discussion highlights that in view of strengthening the efficiency of cold-chain, it is imperative to support other components of cold-chain such as pack-houses, modern storage, refrigerated transportation, ripening chambers, grading pack units, etc- in terms of both capacity and finances. The gaps in the existing capacity of infrastructural components of cold-chain are discussed in next section.

6. Integrated cold-chain development: Status and issues

The efforts of the government and all related stakeholders in the past two decades has improved the understanding about the necessity of having a cold-chain rather than a stand alone cold storage. The establishment of the National Centre for Cold-chain Development (NCCD) in 2012 with the involvement of both the public and private sectors has enabled insights into the intricacies in terms of technical issues and financial feasibilities. The evolving consensus is that there has to be an integrated cold-chain, one that will protect the fruit and vegetables and other foods from the point of production until it reaches the consumers' plate, from degenerating by lowering the temperatures and thereby slowing down the microbial activities. Though there is some progress, there is a long way to go from educating the stakeholders and covering atleast a reasonable proportion of the produce in a country like India. However, it has to be underlined that these efforts have started very late relative to even other low-income developing countries like Sri Lanka, apart from the fact that this needs huge budgetary support to start with.

In the Indian context, several studies undertaken by different private agencies have estimated the installed versus required capacity of cold storages in the country and have highlighted that there exists severe shortage in the existing capacity and that the nature of installed capacity is inadequate in view of the kind of demand that exists for such refrigerated storage. The capacity gap as assessed in these studies lies in the range of 31 million tons to 37 million tons (Emerson Climate Technology, 2013; YES Bank, 2014; NCCD-NABCONS, 2015).

Table 12 presents the capacity requirement for each of the infrastructural component of cold-chain separately, using the demand-side projections along with the supply-side estimates of the baseline survey conducted by the NHB (NABCONS-NCCD, 2015). It estimates a gap of 3.2 million tons, amounting to 9.3 % in the installed capacity of cold storage-bulk and cold storage-hub taken together. This data are widely circulated in the media and other places to argue that there is a near saturation in the cold storage capacity in the country (For e.g.Nuthalapati et al., 2017). However, the reality is different. Much of the installed capacity is concentrated in few hubs in north-western states and western states in the country. Few states like UP, West Bengal, Punjab and Gujarat together have more than 70% of all the cold storage installed capacity, while several states have negligent levels of installed capacity. Therefore, the macro-scenario constructed at the all India level by NABCONS-NCCD does not reflect the ground level realities, where there is large unmet needs for both farmgate and market hub cold storages. The major limitation of the cold storage capacity at present is that the market hub cold storages do not constitute only 3% of the available cold storage capacity. As is now well documented by NCCD and several other experts in the sector, cold storages close to market are also required like at the farmgate. Traditionally, most cold storages in the country are at the production site and the market hub ones have been coming in the last decade only.

Table 12: Cold-chain infrastructure gap in India

Component	Requirement	Existing infrastructure	Gap (2-3)	% Share of gap to required (4/2)*100
Integrated pack houses (in numbers)	70080	249	69831	99.6
Reefer trucks (in numbers)	61826	9000	52826	85.4
Cold stores Bulk (Mn.tons) Hubs (Mn.tons) Total	 34.16 0.94 35.10	31.82	3.23	9.35
Ripening chambers (in numbers)	9131	812	8319	91.1

Source: MOFPI, Annual Report 2018-19, GoI

The gap in the case of other static infrastructural components such as pack houses and ripening chambers is assessed to be at alarming levels of 99.6 per cent and 91.1 per cent respectively. Similarly, in the case of mobile infrastructure i.e. reefer vehicles, the gap ascertained is about 85 per cent which in itself reflects the poor connectivity in the existing cold storages in India. An analysis by Chintada et al. (2017) has shown that the creation of new facilities to meet the deficit

of around 78 thousand integrated pack houses across the country can create one million jobs. It indicates that the cold chain sector has tremendous employment generation potential.

The study by National Centre for Cold-chain Development (NCCD, 2015) highlighted that cold chain plays a key role in modern post-harvest management of fresh produce. Lack of reefer transport deters useful application of cold-chain and is a missing link. Transport is of no avail without relevant source and receiving points. At source, there is a shortfall of modern pack-houses. Pack-houses function as decision making centres for the purpose of directing flow of produce to relevant consumption points. Perishable fruits and vegetables have a limited life span in normal conditions. However, unless the selling cycle will fall within this natural period, cold-chain intervention is required to mitigate food losses and to be future ready. Current movement of perishable produce can bypass cold-chain intervention but results in lowered access to markets and unnecessary food loss enroute. Current consumption of frozen and processed goods is met by using the existing cold-chain as it cannot bypass this intervention.

Current consumption demands greater focus on establishing end-to-end delivery systems to connect farm-gate value directly with consumption points. Cold-chain can have the greatest socio-economic impact when used as a logistics medium that empowers the farmers to directly connect with multiple markets, across geographies. Proper use of cold-chain allows farmers the opportunity to reach out to more buyers at greater distances, and will inevitably promote shrinking of the multi-layered value chain system (NCCD, 2015).

It is clear from the data presented in previous section and from above discussion that there is urgent need to focus on creation of pack houses, refrigerated transport, ripening chambers instead of large or small cold storage package projects.

The available cold strorages are mostly single commodity type and does not allow storing multiple commodities (Kohli, 2020). As the temperature control and other requiremens vary from crop to crop among the fruit and vegetables (Table 13), there is a need to create multi-commodity cold storages to cater to various crops. At present, that is one of the lacunae in the cold storage capacity creation, apart from having very low proportion of them near the market hubs for effective price realization for the farmer.

Challenges for the cold-chain are numerous. The major ones are power supply, overhead cost, availability of skilled manpower, inefficient handling of perishables, inadequate farmgate and mobile infrastructure, and availability of technology. These are briefly mentioned hereunder. Cold storages require steady power supply to maintain temperature. As large parts of India face regular power supply cuts, the operations of temperature controlled warehousing players get impacted. Power cost contributes to more than 50 per cent of total cost of operating cold storages. The cold chain industry is currently affected by limited availability of trained personnel in cold chain management such as warehouse supervisors/ managers, skilled labour etc. which affects the quality of the end product. This is mainly due to the lack of vocational or other training institutes focused on cold chain logistics in India (NCCD-NABCONS, 2015).

Table 13: Desired storage environment of fruits and vegetables in the cold storage

Commodity	Temperature (°C)	Relative Humidity (%)
Apple	-1-3	90-98
Apricots	-0.5-0	90-95
Avocado	7-13	85-90
Asparagus	0-2	95-97
Green beans	4-7	90-95
Beet root	0-2	95-97
Broccoli	0-2	90-95
Black berry	-0.5-0	95-97
Cabbage	0-2	90-95
Carrots	0-2	90-95
Cauliflower	0-2	90-95
Cherries	0.5-0	90-95
Cucumber	7-10	90-95
Brinjal	0-2	90-95
Grapes	-1-1	85-90
Lemons	4-15	86-88
Lettuce	0-1	95-98
Lime	3-10	85-90
Mango	11-18	85-90
Water melon	2-4	85-90
Orange	0-10	85-90
Peach	-1-1	88-92
Potato	1.5-4	90-94

Source: Rais and Sheoran (2015)

The quality of temperature-sensitive products deteriorates, if not handled well. Therefore greater awareness on this aspect is required. In addition appropriate skill building needs to be done on appropriate handling of perishables. Farmgate infrastructure including pack- houses, pre-coolers and value adding units, cold chain distribution hubs and mobile infrastructure (including transport units, infrastructure at point of sale etc. There is limited availability in development of

wide range of indigenous refrigeration and temperature control systems. Currently majority of the modern equipment's and technology are imported from foreign countries/suppliers. The role of government in strengthening the cold-chain industry in India is discussed in the next section (YES Bank, 2018). Further, controlled atmosphere cold storages that can control oxygen levels as well as carbon dioxide by sending in inert gases like natural nitrogen. These can reduce produce perspiration, slowing ethelene production, inhibiting pathogen reproduction, and killing insects. These are not becoming popular for fruits and vegetables in general except for apples because of the higher costs of these CA cold stores. However, the new generation technologies that can create CA cold stores can flatten the average cost curve and therefore efforts have to be made to harness them.

7. Cold-chain Industry: Investment Needs and Policy Measures

The rise of cold-chain as an industry is relatively new and only a decade old. This rise is facilitated by the recognition that cold-chain is an essential part of the food supply chain as opposed to the earlier view that the cool chain is for the rich sections of the population (Nuthalapati et al., 2017). Further, there has been realisation that reducing food loss and waste by efficient logistics and cold-chain can in fact enhance farmers' income by leveraging highly remunerative markets in India and abroad (Chand, 2017). Therefore, instead of just focusing on productivity rise, policymakers have been making efforts for effective storage and transportation methods. It is argued that, because of the rising facilities, the life of seasonal produce has been rising and thereby reducing wastage, though hard evidence in terms of numbers is yet to be demonstrated.

On the other hand, the demand for cold-chain enhances because of the changing consumer needs for quality and diversified food and requirements for last-mile delivery through e-commerce as well as organised organised food retail[4]. Supply of cold-chain compoents get a fillip with the emergence of hird party logistics (3PLS) providers as startups in good number and their mobilising large amount of funding and getting unicorn status. The demand for exotic fruits and vegetables also spurs the need for cold-chain. Moreover, the rising middle class and young age population are getting used to home deliveries and food storage using refrigerators. India can

[4] Entry of organized retail involves direct procurement from farmers and supply to consumers in an integrated cold-chain (Nuthalapati et al., 2020a)

leverage its fruit and vegetable production to supply globally only the cold-chain is updated to the global standards.

The cold-chain industry has been emerging as a sunrise sector because of several positive policies of the central government and active support of some of the fast-growing state governments. On its part, the central government enacted several promotional measures like- allowing FDI of upto 100%; providing viability gap funding of upto 40% of the project; infrastructure status to cold-chain industry; profit linked tax holiday; priority sector lender; lower GST. Also, it exempted service tax for cold chain services such as pre-conditioning, pre-cooling, ripening, waxing and retail packaging. Excise duty exemption was given for refrigeration machinery and parts used for the installation of cold storage or refrigerated vehicles

The cold-chain in India is currently a 62000 crore industry with high growth rates (Arora, 2018) and is expected to grow at 13-15% during 2017-2022, as per the Indian Cold Chain Industry Outlook 2022 (Rawat, 2019). Nearly two-thirds of the existing cold stores are used for potato in the country leaving a huge gap in meeting the cold preservation requirements of other fruit and vegetables. On the other hand, the cold-chain for frozen products captures most of the refrigerated transport and peri-urban storage capacities for market linkage (GoI, 2018).

It is relatively recession-free industry as the movement of food and its preservation faces largely inelastic demand. Even the pandemic-related lockdowns and economic crisis did not reduce the cold-chain and in fact boomed with the requirements of door delivery of food items. Consequently, big players, both from India and abroad are venturing into this. CRISIL Research estimated a prospective investment of Rs.21000 crores next 4-5 years. Available cold stores are small usually with less than one thousand tons of capacity, unorganised sector and single-commodity (Arora, 2018). India's 37 million ton cold storages are in the hands of 3500 entities, while 20 companies handle 125 mt capacity in the USA (Ramesh, 2020).

It has to ensure storage, temperature control, effective packaging, handling and transportation. Now apart from cold storage, new services like order processing, kitting, packaging, sorting, grading etc. Industry moving towards one-stop-shop for end to end solutions with greater efficiency (Srinivas, 2021). Outsourcing cold storage services is the new trend saving the need

for capital expenditure. Industry moving to smaller cities and bigger towns. Cold-chain infrastructure is estimated to be 50% less than the requirement (Arora, 2018). In the last three years, 4.5 to 5.0 million tons of cold chain capacity was added. Problems for the industry include acute shortage of skilled manpower to work in these novel cold-chains. Skilled workforce like drivers, forklift/reach truck operators, refrigeration technicians. Skill India may focus on these services. Operating costs are higher in India compared to developed countries as the technologies used are generally obsolete with high costs and larger carbon footprint.

Investment needs of cold-chain industry: Cold-chain industry is one of the fastest growing industries in India and has a huge potential. It also stands out with higher growth rate among all the countries in the world, as the base level of cold-chain infrastructure is very low in the country. As already mentioned, the available cold storage is mostly single commodity and production hubs, while the refrigerated transport is used for frozen foods especially meats and other such items. Much of the fruit and vegetable production is used in raw form without passing through cold-chain resulting in huge losses in quantity and quality. To add to this, the understanding of a cold-chain was until recently limited to creation of cold storages near production site. As the farm-to-fork cold chain understanding is emerging in the country, efforts have begun in the earnest for creating an integrated cold chain that starts with pre-cooling units at the harvest site to the supermarket racks including packaging. This is a humongous task to create a cold-chain to cover the huge production of fruit and vegetables and other items to feed 1.4 billion population and requires large investments. Creation of cold-chain infrastructure often requires high fixed capital. An effort is done to arrive at rough estimates of the required investments keeping in view the short-run cold-chain needs of fruit and vegetables (Table 14). It needs to be mentioned here that the same cold-chain can be used for other products also and cannot be segregated.

There is a need for investments of 18.51 billion US Dollars as per a conservative estimate prepared based on financial costs given by the National Centre for Cold Chain Development. The country has a cold storage capacity by the end of 2020 of 37 million tons and this needs to be upgraded technologically by involving thermal integrity, refrigeration installation, handling systems etc. Additional capacity of 40 million tons is needed in case of cold-storage of both

production site and marketing hubs. Both upgradation of the existing cold stores and creation of new capacity requires 11 billion USD as given in Table 12. Integrated packhouses and reefer transport will need an investment of 6.23 billion USD. Ripening chambers, and training the labour for working in cold-chain related jobs will require 600 million USD each of spending. These are the fixed capital costs of the cold-chain requirements in the coming years.

Table 14: Investment requirements for cold-chain creations in the short-run

Sl.no	Infrastructure component	Shortfall	Unit cost in USD	Investment in billion USD
1	New cold storages (Mn tons)	40	127/ton	5.08
2	Upgrading existing cold storages	37	27/ton	1.00
3	Integrated pack-houses (15 tons each)	70000	50000/unit	3.50
4	Reefer transport (Units)	62000	44000/unit	2.73
5	Ripening chambers (Units)	8000	75000	0.60
6	Training 2 million employees in cold	2000000	300	0.60
7	Land for new cold storages of 40 m.tons	40	-	5.00
				18.51 billion

Note: 1. Calculated using the unit costs provided by the National Centre for Cold Chain Development, Govt. of India, New Delhi.
2. The costs of front end investment at retail end and testing and laboratories as well as packaging are not accounted for in this estimation.

The investment needs of the cold-chain have been increasing in the last few years in view of the enhancing scope of cold-chain with the emergence of cutting edge technologies that increase efficiency, precision and speed of moving the fruit and vegetables from production site to the end consumer without losing the quality, texture and freshness. New technologies on the horizon are food tracking technologies, real-time data on refrigerated cargo movement, block chain for transparency in fresh produce movement, AI-based new generation cold chains etc. There is a need for new technologies for energy efficient practices like energy recovery systems, water reclamation systems, solar energy, refrigeration plug-ins, energy efficient designs of refrigeration equipment and automation (Srinivas, 2021). And in demand are cost-effective technologies like Radion Frequency identification (RFID), Track Management system (TMS), Order Management Systems (OMS) and Warehouse Management Systems (WMS). Further, the India Cooling Action Plan (ICAP) of the government brings in targets for energy efficiency, novel refrigerant gases, and innovative technology options to comply with the multi-lateral climate accords. Achieving energy efficiency to meet the carbon footprint targets of ICAP requires constant

upgrading of the old technologies and adoption of new technologies. This raises the investment requirements for cold-chain.

Rising role of startups: The country is witnessing virtually an explosion of startups with innovations to address several of the unaddressed problems in production and marketing as well as creation of the services for the aspirational people of the country. This is true in agriculture with several startups working in agricultural value chains in the last five years (Nuthalapati et al., 2020b). Concommitantly, cross-industry collaboration is becoming the norm in every economic activity including agriculture with specific initiatives bringing together IT leaders, technology startups, food retailers, NGOs, and systems integrators (Sachdeva, 2020).

The Pune-based Ecozen of small-sized solar powered has been making waves among the farmers for use in the field for pre-cooling before transport to the next level in the chain. They mobilized 10.6 million US Dollars of investment after being founded in 2009. Gurgaon-based *Godamwale* is harnessing AI computing techniques, like machine learning, deep learning, and natural language processing, to streamline and automate various processes. Micro-climate storage-cum-transportation device called *Sabjikothi* of *Saptakrishi* startup is useful in both pre-cooling and transporting to the next destination with wheels. *Stellaps* has solutions for cooling milk in the value chain and attracted 19 million USDollars Series funding. Declared as Technology Pioneers of 2020 by the World Economic Forum, it caters to two million farmers in 30000 villages and handles 10 million litres of milk by the end of 2020. It also provides other services like credit and insurance to marginal dairy farmers. Arya Collateral aggregates warehouses across the country under its *Atoz Godaam* and also provides other services. It is a digital platform for search, discovery and fulfilment of warehousing for farmers, FPOs, corporate and other stakeholders. It goes beyond storage by integrating with other services like financial and market linkages (Kashyap, 2020). Similar post-harvest services are provided by another startup called *Origo* with 3.5 million tonnes of storage capacity in 500 warehouses across 15 states.

Apart from these startups, there are several other startups that build state-of-the art cold-chains either on their own or through third party logistic providers like Delhivery and others. Some of the big startups that have been building cold-chains for fruits and vegetables in the country are

successful startups (Unicorns[5]) like BigBasket, Zomato, Swiggy, Udaan, Grofers. There are others like Ninjacart that supplies fruit and vegetables to Flipkart by directly procuring from farmers. They have build cold storage structures for preserving the fruit and vegetables starting from the point of procurement to the delivery to the retail end. In 2017, *BigBasket* got approval of 101 cold chain projects worth 3100 crores with 838 crores as grant to create a capacity of 2.76 lakh tons of capacity including 56 lakh litres per day of milk processing. They have been successful in mobilising money and attracted funding of 5.5 billion USD over the last few years. Some of this investment goes to improve the backend infrastructure including provision of temperature control systems for storing the agri-produce. The most successful among startups working livestock products viz., *Licious*, and *Fresh-to-home* follow a farm-to-fork model. They have been building a modern supply chain for this purpose and also leveraging third party logistic providers (3PLS). They have received funding worth 95 million US Dollars and 47 million US Dollars respectively.

Some innovations developed at the public sector research institutions can also be made available through the working of startups by way of commercialization. For example, we mention here the innovation of CIPHET here. To overcome post-harvest losses, by maintaining a moderate low temperature and sufficiently high relative humidity, low cost Evaporative Cooled Structure (ECS) is being developed by the Central Institute of Post-Harvest Engineering & Technology (CIPHET), Ludhiana (Punjab), for short-term storage of fruits and vegetables. This system requires minimum level of consumption of electricity, less initial investment and negligible maintenance cost. An ECS of about 5 -7 tonnes storage capacity may cost about Rs. 1.5 - 1.8 lakhs. This kind of low cost storage may be beneficial for small and marginal farmers. However, field studies show that due lack of awareness among farmers; adoption of ECS is very low in India. This needs to be popularized and made available to them (Jha et al, 2015).

Innovations solar-powered micro-cold storages of Ecozen, Sabjikothi of Saptakrishi and warehouse aggregators like Arya Collateral can be promoted to encourage debt financing, equity investment, distribution network and policy support. Startups have the solution to strengthen the

[5] The startups whose valuation is above one billion US Dollars is referred to as a unicorn.

supply chain by bringing in necessary innovations as well as diffuse them to remote corners of the country with vigor.

Government support to cold-chain industry: The government, especially the central government, has been pro-active in supporting the rise of this sunrise industry, though the evolution of the cold-chain ecosystem has been propelled basically by demand side factors. The government support until recently was to start cold storages in production site and things started changing with the explicit recognition for an integrated cold-chain in the last few years. Our analysis shows that the central government released a subsidy of Rs.3794 crores during 2006-07 to 2020-21 by various agencies like Ministry of Food Processing Industries (MoFPI), National Horticultural Mission (NHM) and National Horticultural Board (NHB), Agricultural and Processed Food Products Exports Development Authority (APEDA), and National Cooperative Development Corporation (NCDC). This level of support, at Rs.252 crores per annum over the last 15 years, is too small in relation to the cold-chain building requirements of the country. Nevertheless, these grants have played catalytic role in the emergence of the cold-chain industry. Moreoever, the value of the tax incentives and tariff deductions have been helping the industry, apart from the articulation of enabling environment and promotional campaigns. As a result, there has been an active trickling down of FDI proposals into the cold-chain too. Among the several other initiatives, establishment of the National Centre for Cold Chain Development (NCCD) under public-private partnership in 2013 was the major milestone in the evolution of this industry. As a result, the central government support in recent times focuses more on creation of integrated cold chains.

The Ministry of Food Processing Industries brought *Pradhan Mantri Kisan Sampada Yojana* (PMKSY) as a comprehensive package which will result in creation of modern infrastructure with efficient supply chain management from farm gate to retail outlet and is implemented by the ministry of food processing industries. Under PMKSY, there are cold-chain scheme (CCS) and mega food park scheme (MFPS). However, the scheme could not take off evenly in the entire country, as PMKSY funds allotment was found to be skewed towards southern and western states. For example, Maharashtra sanctioned an amount of Rs. 1164 crores as of May 2019 compared to Rs.41 crores by Bihar (Hussain, 2020). Several parastatal organisations of the

central and state governments have been upgrading their storage systems to control temperature and other gases. For example, National Agricultural Cooperative Marketing Federation of India (NAFED) is also setting up a 10000 ton capacity temperature controlled warehouse for long-term storage on 'build, operate and transfer' (BOT) basis by leveraging back-end subsidy from NHB.

The recently introduced 'Operations Greens Scheme' incentivizes reefer transport by providing 50% transport subsidy and allows farmers to send small packages of 50-100 kgs through this mobile cold chain infrastructure of special trains. By December end of 2020, 100 trains transported F&V to distant markets of roughly 4.0 lakh tons. Growers associations of banana articulated the need for creation of APEDA-certified pack houses to ease export of banana, apart from better farming infrastructure including cable way conveyor system (Kulkarni, 2020).

The central government trying to make the COVID-19 driven crisis as an opportunity brought a new scheme to modernize backend infrastructure in the food system through announcing one – lakh crore Agricultural Infrastructure Fund (AIF). Under the scheme, one lakh crores of loans with 3% interest subvention will be provided by banks and financial institutions as loans to Primary Agricultural Credit Societies (PACS), Marketing Cooperative Societies (MCS), Farmer Producer Organisations (FPOs), Self-Help Groups (SHGs), Farmers Joint Liability Groups (JLG), agri-entrepreneurs, startups, central/state agencies and local bodies sponsored PPP projects. The detailed guidelines are yet to be released for the scheme, for which the central government will give a grant of Rs.5000 crores. Further, it is flawed as it does not give detailed guidelines on the allocation of loans to be sanctioned to states.

The question is how to make banks give loans to FPOs, PACs and SHGs under the ambit of AIF (Hussain, 2020). It is argued that creating robust post-harvest infrastructure with cold-chain by agri-infrastructure fund (AIF) is a sufficient condition, where the necessary legal framework is put in place through marketing reforms. However, the FPOs should be able to advance loans to farmers through negotiable warehousing receipt by creating cold storages. NABARD should step into provide working capital loans to FPOs. However, the grant from the central government will be Rs.5000 crores only for this supposedly one lakh crore investment (Gulati, 2020).

The negotiable warehouse receipt (NWR) sytem was introduced for items stored in cold storages by the Warehouseing Development and Regulatory Authority (WDRA) in consultation with the National Horticultural Board. The WDRA has notified 26 horticultural commodities for issuing (NWR) by cold storages. NABARD was entrusted with the task of maping and geo-tagging them in the 2020-21 budget. However, the scheme has not become very popular for post-harvest finance due to some reasons (Shalendra et al., 2016). The foremost is that the cold storages have to take insurance for 100% capacity of the cold storage to register under the scheme. Many owners are not willing as the capacity utilization rarely reaches full level. Usually, farmers in unorganized cold storages approach collateral management companies, APMCs and Agricultural Marketing Boards for loans against the warehouse receipt (WR) with higher interest rates. The electronic NWR system can be a game changer if the government makes it mandatory for all the cold storages to register under WDRA (Hussain, 2018). The study by Shalendra et al., (2016) in Rajasthan found that the reasons dragging down the adoption of NWR are the poor availability of registered warehouses, complicated procedures and poor awareness among farmers. They concluded that the scheme has the potential to improve institutional post-harvest credit to farmers storing produce in cold-storages, if these are rectified.

Despite several incentives given in taxation and tariff deduction, there are still several tax and import issues that drag down the growth of the cold-chain industry. Most of the incentives meant for the cold storages apply only to the single-commodity cold storages and do not extend to the new age cold-storages with multi-commodity service as well as other support services rendered as the scope of the industry expands (Kohli, 2020). In the same way, several related components used for related operations energy optimization and automation systems, data recorders and other sensorts, still attract basic customs duty.

To conclude, the promotional policies of the government have succeeded in creating critical mass for the cold-chain industry and some level of understanding among the stakeholders. It is now time to have long-term policies, strategies and action plans from the private and public sectors, commercial financing at low interest rates and subsidies to encourage local and international cold chain investment, greater education about food handling, cold chain technology and post-harvest activities to increase the efficiency of logistics processes throughout

the food supply chains. Crucial point is that short and medium-term investment by manufacturers should be coupled with government grants, subsidies or investment to allow the supply chains to grow and benefit manufacturers, consumers and governments (Sachdeva, 2020).

Adoption of cold-chain technology needs interventions in both the demand and supply side. The India Cooling Action Plan of the Government of India takes a technological view without addressing these issues (Gorthi and Waray, 2019). Enabling equitable access of cold-chain facilities to resource poor farmers in contrary to the exclusive use of these facilities by export-oriented and resource rich farmers. There is a need to provide incenstives to enable SHGs, farmer producer organizations and resource poor farmers to get cold storage services at affordable rates through government support. Also, the government needs to mandate an integrated clean cold chain from production to consumption as in Europe for harmonised food system. That can create demand for the cold-chain. Council on Energy, Environment and Water (CEEW) calls for large-scale, strategic pilots across the country are needed for enhancing demand and flowing in of investments.

8. Conclusions and Policy Implications

Though horticulture production outpaced food-grains production since 2012-13 and made India the second largest producer of fruits and vegetables worldwide, its distribution suffers significant post-harvest losses in the supply chain primarily due to the perishable nature of fresh produce and its sensitivity to handling damages. This study examines the pathways for food security by reducing the losses by cold-chain network; examines the losses and works out potential welfare gains from loss reduction; analyses the build-up of cold-chain over the last two decades; works out the investment needs of the industry; and analyses the policy support measures to give some policy suggestions.

Improving the cold-chain has a crucial bearing in driving down food loss and waste in developing countries, where supply-side factors are important in reducing the consumable food. There are direct and indirect causes of food loss and waste. Direct causes associated with actions (or lack thereof) of individual actors in the food supply chain that directly cause food loss and waste; whereas indirect causes refer to the economic, cultural and political environment of the

food system under which actors operate. The socio-economic and demographic characteristics of a household also influence the level of food waste it produces. Small households and high-income households generally waste more food, because the amount of food they buy and prepare is usually larger than the amount they can consume. Culturally, food may also be used as a symbol of prosperity. Reductions in food losses or waste may improve the food security and nutrition status of food-insecure groups, depending on where these groups are located and where the reductions are made. The food loss is a supply side problem and most often happens in developing countries like India where the post-harvest technology and cold chains are primitive. Therefore, we look at the likely impacts of reducing food loss in the country from a supply-side perspective.

Literature points out that at global level, 35 % of fruits and vegetables production is wasted every year: 40% for developing countries as compared to 15 % for developed counties (Kitinoja and Alhassan, 2012; Kitinoja, 2013). Recent studies conducted in different countries, also reported losses in fruits and vegetables. For example, in China about 20-30 % of fruits and vegetables lost at the storage and transportation stages (Zhao et al, 2018). India is no exception in this regard. Around 30% of fresh fruits and vegetables production is wasted every year; more disaggregated analysis suggests that these losses were in the range of 6.7-15.9% for fruits and 4.6-12.4% for vegetables, respectively (Mittal, 2007; Jha et al., 2015; MPEnsystems et al., 2019). The important determinants in leading to the high quantities of these losses were lack of cold-chain, poor post-harvest care, highly complex and inefficient supply chains, lack of storage and processing infrastructure.

The investment in cold-chain infrastructure benefits all stakeholders along the supply chain-growers, aggregators, transporters, distributors, and retailers, in terms of economic gain by reducing the post-harvest losses (Mercier et al., 2017; Minten et al., 2020). For instance, it is evident that investment (especially in pre-cooling and transport refrigeration equipment) has reduced food loss from 32% (sell in open truck) to 9 % (sell in refeer truck) and CO_2 equivalent emissions by 16% in Kinnow cold-chain in India (Sodhi et al., 2016).

Efficient cold-chain also ensures greater prospects of reasonable returns to farmers, allows farmers to move up the value chain and encourages crop diversification to high-value crops (Minten et al., 2014; Singhal and Saksena, 2018). Farm households which are likely to have access to storage facility are more likely to take part in market transaction, sell more number of crops, and are more likely to have higher number of market transactions in the country (Kumar and Das, 2020). Apart from reducing post-harvest losses and economic gains, infrastructure development in cold-chain offers employment opportunities as well. Estimate shows that the creation of new facilities to meet the deficit of around 78 thousand integrated pack houses[6] in India has created one million jobs (Chintada et al., 2017).

Nevertheless, case studies in Indian context show that where the government has developed pack-houses, there is often poor use of these facilities due to: lack of refrigerated transport, limited financial capacity of marginal and small farmers to store the produce at the farm-gate, higher cost of electricity coupled with lower operational efficiencies, poor operation and maintenance of facilities, lack of understanding of business, specifically farm to fork business models and a failure to take full advantage of the potential of new technologies (MPEnsystems et al., 2019; Negi and Anand, 2019).

In a nutshell, efficient cold-chain not only provides possible solution for reducing post-harvest losses but can also help in increasing the value of the produce by enabling sales out of season and in far-away markets. Eventually, it offers many employment opportunities and ensures reasonable returns to all the stakeholders in the chain and improving their economic status.

With above back-ground, this report gives an overview of the cold-chain sector in India (including present storage capacity and corresponding gaps in terms of cold-chain infrastructure). This report made use of various secondary sources to assess the current status viz. published studies, reports and data taken from various stakeholders (Ministries, Agencies and Departments), which are supporting cold-chain infrastructure creation in the country. This report also highlights government initiatives, some research concerns and major challenges with respect to the promotion of cold-chain industry in the country. In what follows the summary of main findings.

[6] Integrated packhouses contain packhouses along with ripening chambers

Salient findings: Positive rate of growth (2010-11 to 2017-18) has been registered in the production of fruits (1.4%), vegetables (1.1%) and their total (1.2%) for all India. Majority of the states followed similar pattern of growth. This is pointing to its immense contribution to the economy and suggesting the need of priority investments. Our estimates of economic value of losses among fruit and vegetables using the ICAR-CIPHET (2015) projected loss percentages indicate that there was a loss of Rs.1.14 lakh crores in 2017-18 at 2018 prices in all crops including food crops. They form 3.5% of the gross value added agriculture in that year for all crops and 1.52% from fruit and vegetables. Before going any further, it needs to be pointed out that these losses are not necessarily due to lack of cold-chain alone and that the cold-chain forms the crucial cog. Therefore, we assume a reduction of 50% through various means including cold-chain.

If these estimates are correct, what justifies this low estimates of food loss in India? The prevalence of widespread poverty and lack of productive employment might explain the the low level of food loss in India is low as compared to developed countries. Where there is more poverty there will be less wastage because the poor cannot afford to expect to eat too high level of hygienic and safe food. As incomes increase, their expectation level of their food hygiene and safety increases and therefore higher food losses might be reported. This is akin to the established research studies that the poor withdraw from labour market partially when the wages increase. On the whole, food loss is also a dynamic concept. Leave that as it may, the low food losse estimates given by the government agency are not accepted by several scholars including some government committees.

However, the loss proportions among all crops including fruit and vegetabls in CIPHET-ICAR (2015) study are too low and questioned by many scholars including the High Level Committee on Doubling Farmers Income (GoI, 2017). The Committee endorsed the estimates of SFAC (2017) as representative of losses in the country as a whole which range from 9-32%. Therefore, we have generated an alternative scenario with the relatively modest FAO (2019) loss estimates and our calculcation using this indicate a net loss in the supply chain of Rs.1.01 lakh crores that constitutes 3.2% of gross value added in agriculture. The same for all crops amounts to 11% of

gross value added in agriculture. Both the estimates show that there is a significant chance to increase the agricultural growth by reducing food losses to an extent of more than 5% by reducing the losses even by half.

A natural corollary to this prospective growth opportunities will be to examine the welfare gains by reducing the losses, as the focus now is on farmer (human) welfare than rather than growth prospects. As mentioned above, we tried to calculate the likely additional people that can be fed with loss reduction by half. The percapita consumption of fruits and vegetables from the NSSO consumption data was leveraged to arrive at the crop-wise welfare gains. Maximum welfare gains can be obtained where the losses have been huge. We show that large numbers of additional people can be fed reducing losses by half in the case of mango, papaya, guava, green peas, citrus, grapes, tomato, cabbage, onion, cauliflower and potato. A noteworthy finding from this exercise is that the additional welfare gains from reducing losses in fruits and vegetables are relatively high and far outweigh from those in food crops. Even among food crops, more gains can be obtained from loss reduction in minor millets and pulses indicating the relatively less focus on preserving these crops through better storage.

Across the crop groups, large quantities are wasted in vegetables followed by fruits and then the food crops. Potato, onion, tomato, cabbage, green peas and cauliflower from UP, MP, West Bengal, Maharashtra, Bihar and AP need particular attention in view of the seriousness of the problem. Among fruits, the major losses are in mango, grapes, apples, guava, and papaya from AP, UP, MP, Bihar, Maharashtra and J&K.

The analysis in terms of percentage changes in the number and storage capacity of FCI, CWC, SWCs and godowns has shown improvement for India and in most of the states during 2015-2019. Zone-wise and state-wise analysis suggests that barring North-East Zone and South Zone, other zones have shown increase in storage capacity with FCI, CWC, and SWCs. However, within zones, states have shown mixed pattern of change in storage capacity. With respect to godowns, reverse pattern is observed for number in Haryana (-8.23%) and Kerala (-2.37%). Whereas, for storage capacity, Haryana and Uttarakhand have shown negative change. Cold storages have also shown improvement (both in its number and capacity) across all the states of

India, barring Andhra Pradesh for storage capacity (-0.64%). At present (up to 23-09-2020), there are 8186 number of cold storages with capacity of 374.25 lakh tons is available in the country for storing fruits and vegetables (an excess capacity of 6.62%) against the required capacity of 351.00 lakh tons (as assessed by NCCD- NABCONS study on All India Cold-Chain Infrastructure Capacity, 2015).

The top five states in terms of total installed cold storage capacity are Uttar Pradesh (14.71 million tons), West Bengal (5.95 million tons), Gujarat (3.82 million tons), Punjab (2.32 million tons) and Andhra Pradesh and Telangana (1.57 million tons) and these 5 states together contribute to an overall 76.73 per cent of the total storage capacity. Apart from cold storages, the status of existing infrastructure pertaining to other components of cold-chain in India indicates that there are only 249 fully equipped functional integrated pack houses as against the required number of 70,080 (as assessed by NCCD- NABCONS study on All India Cold-Chain Infrastructure Capacity, 2015). Reefer transportation is under severe shortage; with about 9,000 reefer vehicles in place of the required number of approximately 61,826. Similar is true with ripening chambers, i.e, 812 against the requirement of 9,131 chambers.

To narrow down the existing gap in infrastructure, the government's emphasis on mega food parks and integrated cold-chain development has increased in the recent past, by providing financial assistance in the form of subsidies. Till now, a total of 1,248 cold-chain projects with respect to various components (such as cold storages, pre-cooling units, reefer vehicles, and ripening chambers) have been supported by NHM during 2006-07 to 2015-16 (having a capacity of 4.57 million tons); 2,347 projects by NHB during 1999-00 to 2019-20 (having a capacity of 8.44 million tons) and 789 projects by MoFPI during 2013-14 to 2018-19 in India. Most of these projects were related to cold storages as compared to other components of cold-chain infrastructure: 72% (under NHM) and 71% (under NHB) and 30% (MoFPI), respectively. Note that, out of total capacity generated under NHM and NHB, about 95.9 per cent and 97.3 per cent belongs to cold storage, respectively.

Under MoFPI, 30 per cent of the projects supported were related to cold storages followed by 28 per cent projects pertaining to reefer transport. Further (out of 81 projects), 68 per cent of

projects supported by APEDA were related to pack-houses. For fruits and vegetables, MoFPI has sanctioned 162 cold-chain projects (out of 328 projects) so-far (up to 30.11.2020). It is evident that the total cost of these projects is Rs. 3,909.41 crore with private investment of Rs. 2,598.94 crore and grant-in-aid of Rs. 1,310.47 crore.

In terms of physical progress, analysis suggests that commercial production has started in maximum number of the projects related with fruits and vegetables (about 61%). However, only 11% of them are completed (out of 162 projects). It indicates that market is gradually getting better organized and focus has shifted towards multi-purpose cold storage is rising. In principle, everybody stands to gain if we can reduce the loss of food quantity. It would make food systems more efficient and making the cost of food goes down. That will be a gain for consumers, but it may also be a gain for producers because they can sell more and produce at lower cost.

The cold-chain industry in India is still at a nascent stage and despite large production of perishable produce, the cold-chain potential remains untapped due to high share of single commodity cold storage. For instance, about 60 % of the cold storage capacity is concentrated in the states of West Bengal, Uttar Pradesh and Bihar, wherein storage of potatoes accounts for 85-90% of the capacity. The other reasons noted, from the literature are: high initial investment (for refrigerator units), lack of basic infrastructure (roads, water supply, power supply, drainage, etc), lack of awareness for handling perishable produce and lapse of service either by the storage provider or the transporter leading to poor quality produce.

Cold-chain is a highly fragmented industry and the unorganized sector accounts for an estimated 80-85% share of the total capacity. Wholesalers and organized retailers are the key user segments of cold-chain services with a share of 70-75% and 10-15%, respectively. The cold-chain sector in India has not progressed at par with the global developments in the monitoring and control technologies. Even though new entrants in the sector are employing some of these modern technologies, most of the earlier generation cold storages are still dependent on the manual modes of monitoring assisted with conventional measuring systems.

Lack of proper and adequate refrigerated food storage, processing and cold-chain logistics remains a serious challenge. Moreover, maintaining cold-chain services during fruits and

vegetables distribution has its own set of challenges. Most workers are not properly trained in handling the perishable products resulting in deterioration of product quality before reaching to the consumers.

The cold-chain industry has been emerging as a sunrise industry because of several positive and promotional policies of the central government and active support of some of the fast-growing state governments. The cold-chain in India is currently a 62000 crore industry with high growth rates (Arora, 2018) and is expected to grow at 13-15% during 2017-2022, as per the Indian Cold Chain Industry Outlook 2022 (Rawat, 2019). Nearly two-thirds of the existing cold stores are used for potato in the country leaving a huge gap in meeting the cold preservation requirements of other fruit and vegetables. On the other hand, the cold-chain for frozen products captures most of the refrigerated transport and peri-urban storage capacities for market linkage (GoI, 2018). India's 37 million ton cold storages are in the hands of 3500 entities, while 125 million ton capacity of the USA is in the hands of 20 companies. Therefore, consolidation is round the corner for this industry, while some startups have already started aggregating the services by means of digital platforms. The scope of modern cold storage is increasing to provide related services. Given the recession free nature of this industry, new entrants from both India and abroad are coming forward to invest. The industry needs huge investments and our calculations show that there is a need of 18.51 billion USDollars worth of investment in the short-run to make integrated cold chain operational for the fruits and vegetables along with others. While this will make available more fruits and vegetable to additional people and enable welfare gains through food security, this can also create an employment of 2.5-3.0 million in the coming years, provided the right impetus is given.

Several innovative startups have been coming up with novel solutions for improving the cold-chain and several others have been building cold-chain on their own or creating market for third party logistic services (3 PLS). Solar-powered cold storages at field level by Ecozen, storage-cum-transporter named Sabjikothi by Saptakrishi, cold storage build up by Godaamwale, cold storage aggregator model of Arya Collateral and Oregon are some of the exciting innovations worth policy support to scale up. There are also some innovative solutions from the public sector institutions that deserve support for commercialization. The unicorn status received startups like

BigBasket, Zomato, Swiggy, Grofers and Udaan have been building their own cold chain by using the large funds mobilized to the tune of 5.5 billion US Dollars in the last few years.

The government, especially the central government, has been pro-active in supporting the rise of this sunrise industry, though the evolution of the cold-chain ecosystem has been propelled basically by demand side factors. The government support until recently was to start cold storages in production site and things started changing with the explicit recognition for an integrated cold-chain in the last few years. Our analysis shows that the central government released a subsidy of Rs.3794 crores during 2006-07 to 2020-21 by various agencies. This level of support, at Rs.252 crores per annum over the last 15 years, is too small in relation to the cold-chain building requirements of the country. Nevertheless, these grants have played catalytic role in the emergence of the cold-chain industry. Moreoever, the value of the tax incentives and tariff deductions have been helping the industry, apart from the articulation of enabling environment and promotional campaigns. Establishment of the National Centre for Cold Chain Development (NCCD) in 2013 as a PPP model was a major milestone in developing integrated cold chain.

Several of the ongoing schemes course corrections to make them more helpful in upgrading the existing cold-chain and build up large capacities. The Pradhan Mantri Kisan Sampada Yojana grants were found to be skewed in favour of the fast-growing western and southern states. Schemes like Operation Greens, one-lakh crore Agricultural Infrastructure Fund (AIF) have to be made more concrete with detailed guidelines for operationalization. Though it is a good initiative to provide support to farmers, FPOs, PACS and MCS through AIF with interest subvention, the actual operationalization is fraught with procedural difficulties in view of their lack financial muscle. The electronic Negotiable Warehousing Receipt system could not take off much because of lack of registration to the cold storages, lack of awareness and complicated procedures. The government may take steps to make registration of warehouses mandatory so that post-harvest loans with lowe interest rates become accessible to resource poor farmers.

To conclude, the promotional policies of the government have succeeded in creating critical mass for the cold-chain industry and some level of understanding among the stakeholders. It is now time to have long-term policies, strategies and action plans from the private and public

sectors, commercial financing at low interest rates and subsidies to encourage local and international cold chain investment, greater education about food handling, cold chain technology and post-harvest activities to increase the efficiency of logistics processes throughout the food supply chains. Crucial point is that short and medium-term investment by manufacturers should be coupled with government grants, subsidies or investment to allow the supply chains to grow and benefit manufacturers, consumers and governments (Sachdeva, 2020).

Adoption of cold-chain technology needs interventions in both the demand and supply side. The India Cooling Action Plan of the Government of India takes a technological view without addressing these issues (Gorthi and Waray, 2019). Enabling equitable access of cold-chain facilities to resource poor farmers in contrary to the exclusive use of these facilities by export-oriented and resource rich farmers. There is a need to provide incenstives to enable SHGs, farmer producer organizations and resource poor farmers to get cold storage services at affordable rates through government support. Also, the government needs to mandate an integrated clean cold chain from production to consumption as in Europe for harmonised food system. That can create demand for the cold-chain. Council on Energy, Environment and Water (CEEW) calls for large-scale, strategic pilots across the country are needed for enhancing demand and flowing in of investments.

Policy Implications: Infrastructure created under cold-chain projects by various agencies biased towards the cold storage facilities in India as well as in states. Developing of cold storages alone cannot mitigate the losses incurred by domestic perishable produce, unless other infrastructure like pack-houses, modified cold storages, integrated cold-chain, ripening chambers and transport are also associated to avail connectivity with consumption areas. It may ensure round-the-year delivery of fresh produce to vast majority of consumers and economic gains to all the stakeholders in the chain.

Indian government is one of the driving forces in developing the cold-chain industry and supports private participation through various subsidy schemes. Eventually, this support makes cold-chain more efficient and provides a huge opportunity for multi-commodity & multi-value chain based interventions, especially for the development of post-harvest logistics, storage,

handling and marketing infrastructure. As findings indicate that market is gradually shifting towards organised players, which serves well for not just storage but overall inventory management, and it is expected to gain momentum in the cold-chain industry in India in the near future.

The cold-chain sector in India has not progressed at par with the global developments in the monitoring and control technologies. Focus needs to be given in supporting development and implementation of upcoming technologies and improvement of cold-chain from farm to fork in order to cater the rising demand for quality and quantity, predominantly from urban markets. Innovative approaches across the cold-chain focusing on new age storage systems, real time monitoring of storage and quality parameters, data recording applications, leveraging ICT tools as well as use of renewable sources of energy are some of the innovations shaping up this space.

Future research agenda: There are many areas in cold-chain for fruits and vegetables that are not adequately addressed by academia despite an urgent need for practicing at grass-root level. For instance, how farmers (especially horticultural growers) are coping with different risks associated with the raising of fruits & vegetables? What are the characteristics of farmers that have access to cold storage as compared to those who do not have access? Identify and analyse the determinants that play a vital role in promoting the awareness of advanced technologies for assuring the quality of perishable products during transportation across rural areas, especially among small and marginal farmers? What is the impact of efficient cold-chain on different categories of the farmers associated with the chain in terms of their well-being and sustainable livelihoods? These issues need to be verified by carrying out detailed assessment of few cold-chain projects across different locations in the country which will help us to understand how the government still plays a major role in the cold-chain industry.

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Appendix

Table A1: Additional number of people that can be fed by reducing food loss by half in green peas

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/ annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Madhya Pradesh	96.16	3.61	1.80	1.27	1417.38
Uttar Pradesh	251.14	9.42	4.71	4.04	1164.40
Odisha	5.02	0.19	0.09	0.20	461.58
West Bengal	14.43	0.54	0.27	0.59	459.98
Chhattisgarh	13.72	0.51	0.26	0.68	375.99
Jharkhand	34.71	1.30	0.65	1.81	359.21
Karnataka	2.34	0.09	0.04	0.13	332.95
Punjab	39.40	1.48	0.74	5.57	132.68
Assam	2.89	0.11	0.05	0.47	115.67
Himachal Pradesh	29.50	1.11	0.55	6.66	83.04
Uttarakhand	9.34	0.35	0.18	2.53	69.16
Bihar	5.78	0.22	0.11	1.67	64.94
Maharashtra	3.06	0.11	0.06	1.03	55.60
Haryana	13.52	0.51	0.25	4.69	54.01
Rajasthan	3.34	0.13	0.06	1.61	38.90
Jammu & Kashmir	3.08	0.12	0.06	2.33	24.82
Tamil Nadu	0.20	0.01	0.00	0.17	21.88
Kerala	2.19	0.08	0.04	1.92	21.39
Andhra Pradesh	0.01	0.00	0.00	0.19	0.78
Total	**529.80**	**19.87**	**9.93**		**5254.35**

A2: Additional number of people that can be fed by reducing food loss by half in tomato

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
West Bengal	126.53	7.84	3.92	6.01	652.41
Madhya Pradesh	241.93	15.00	7.50	16.87	444.51
Bihar	94.16	5.84	2.92	7.30	400.06
Karnataka	208.16	12.91	6.45	18.22	354.25
Andhra Pradesh	274.43	17.01	8.51	24.58	346.17
Odisha	131.21	8.13	4.07	16.50	246.51
Maharashtra	108.66	6.74	3.37	14.66	229.70
Gujarat	135.75	8.42	4.21	19.28	218.23
Uttar Pradesh	84.16	5.22	2.61	12.79	203.95
Assam	39.62	2.46	1.23	7.12	172.62
Tamil Nadu	88.71	5.50	2.75	20.89	131.63
Haryana	75.37	4.67	2.34	20.60	113.40
Chhattisgarh	108.73	6.74	3.37	32.18	104.73
Himachal Pradesh	48.19	2.99	1.49	18.37	81.32
Jharkhand	26.53	1.64	0.82	14.12	58.22
Punjab	22.43	1.39	0.70	13.51	51.45
Uttarakhand	10.39	0.64	0.32	14.44	22.30
Rajasthan	8.87	0.55	0.28	16.97	16.21
Jammu &	5.30	0.33	0.16	14.94	10.99
Kerala	1.26	0.08	0.04	12.77	3.06
Total	**1840.37**	**114.10**	**57.05**		**3861.72**

Table A3: Additional number of people that can be fed by reducing food loss by half in cabbage

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/ annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
West Bengal	228.85	10.76	5.38	11.05	486.61
Madhya Pradesh	68.69	3.23	1.61	5.58	289.29
Odisha	105.88	4.98	2.49	10.96	227.10
Haryana	34.25	1.61	0.80	4.57	176.02
Uttar Pradesh	30.30	1.42	0.71	4.69	151.74
Bihar	67.34	3.17	1.58	10.50	150.72
Assam	64.01	3.01	1.50	11.58	129.91
Karnataka	23.34	1.10	0.55	4.27	128.39
Punjab	11.53	0.54	0.27	2.15	126.09
Gujarat	62.95	2.96	1.48	12.97	114.04
Chhattisgarh	41.42	1.95	0.97	9.86	98.68
Jharkhand	32.62	1.53	0.77	9.61	79.76
Tamil Nadu	20.04	0.94	0.47	6.70	70.32
Maharashtra	20.48	0.96	0.48	8.22	58.54
Himachal Pradesh	16.83	0.79	0.40	8.89	44.47
Jammu & Kashmir	11.47	0.54	0.27	7.72	34.93
Uttarakhand	6.79	0.32	0.16	6.38	24.99
Andhra Pradesh	5.86	0.28	0.14	6.55	21.01
Rajasthan	1.17	0.05	0.03	5.10	5.39
Kerala	1.26	0.06	0.03	6.22	4.77
Total	**855.06**	**40.19**	**20.09**		**2422.75**

Table A4: Additional number of people that can be fed by reducing food loss by half in onion

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/ annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Maharashtra	885.41	36.30	18.15	20.40	889.75
Madhya Pradesh	370.10	15.17	7.59	18.76	404.51
Karnataka	298.66	12.25	6.12	20.44	299.59
Bihar	124.06	5.09	2.54	20.42	124.52
Rajasthan	99.67	4.09	2.04	18.76	108.94
Andhra Pradesh	91.57	3.75	1.88	23.78	78.93
West Bengal	63.36	2.60	1.30	16.55	78.49
Haryana	70.15	2.88	1.44	23.72	60.62
Gujarat	54.62	2.24	1.12	19.84	56.45
Uttar Pradesh	43.96	1.80	0.90	16.34	55.14
Odisha	37.93	1.56	0.78	15.35	50.67
Chhattisgarh	42.12	1.73	0.86	17.96	48.07
Tamil Nadu	30.11	1.23	0.62	19.61	31.48
Jharkhand	28.90	1.19	0.59	20.20	29.34
Assam	8.04	0.33	0.16	10.14	16.25
Punjab	21.46	0.88	0.44	28.91	15.21
Jammu & Kashmir	5.80	0.24	0.12	20.75	5.73
Uttarakhand	4.41	0.18	0.09	16.91	5.35
Himachal Pradesh	5.22	0.21	0.11	23.51	4.55
Kerala	0.03	0.00	0.00	18.46	0.03
Total	**2285.59**	**93.71**	**46.85**		**2363.63**

Table A5: Additional number of people that can be fed by reducing food loss by half in cauliflower

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
West Bengal	193.95	9.31	4.65	9.66	481.86
Madhya Pradesh	100.85	4.84	2.42	8.90	271.82
Karnataka	9.36	0.45	0.22	1.30	173.37
Odisha	61.73	2.96	1.48	9.02	164.18
Bihar	93.56	4.49	2.25	13.85	162.14
Assam	41.87	2.01	1.00	7.25	138.64
Gujarat	55.36	2.66	1.33	10.04	132.28
Haryana	69.90	3.36	1.68	13.60	123.39
Chhattisgarh	48.18	2.31	1.16	9.78	118.24
Uttar Pradesh	40.08	1.92	0.96	9.30	103.43
Jharkhand	29.96	1.44	0.72	9.52	75.57
Tamil Nadu	5.04	0.24	0.12	1.80	67.17
Maharashtra	23.05	1.11	0.55	8.30	66.63
Punjab	33.85	1.62	0.81	13.04	62.28
Andhra Pradesh	5.32	0.26	0.13	3.58	35.70
Jammu & Kashmir	10.54	0.51	0.25	10.98	23.04
Himachal Pradesh	13.10	0.63	0.31	17.63	17.84
Rajasthan	5.17	0.25	0.12	7.57	16.39
Uttarakhand	4.20	0.20	0.10	9.80	10.27
Kerala	0.18	0.01	0.00	0.78	5.54
Total	**845.25**	**40.57**	**20.29**		**2249.80**

A6: Additional number of people that can be fed by reducing food loss by half in potato

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Uttar Pradesh	1555.55	56.78	28.39	64.69	438.83
West Bengal	1278.25	46.66	23.33	70.24	332.14
Gujarat	380.70	13.90	6.95	32.11	216.36
Madhya Pradesh	314.46	11.48	5.74	27.89	205.79
Bihar	774.08	28.25	14.13	70.81	199.50
Punjab	257.10	9.38	4.69	36.00	130.34
Karnataka	50.95	1.86	0.93	8.93	104.14
Chhattisgarh	69.46	2.54	1.27	29.74	42.63
Haryana	89.76	3.28	1.64	39.64	41.33
Assam	72.10	2.63	1.32	34.88	37.72
Maharashtra	25.92	0.95	0.47	17.50	27.04
Jharkhand	69.02	2.52	1.26	54.94	22.93
Rajasthan	27.85	1.02	0.51	22.32	22.77
Uttarakhand	36.22	1.32	0.66	36.55	18.08
Tamil Nadu	6.77	0.25	0.12	10.61	11.64
Odisha	29.81	1.09	0.54	48.07	11.32
Andhra Pradesh	6.83	0.25	0.12	11.47	10.86
Himachal Pradesh	19.87	0.73	0.36	34.74	10.44
Jammu & Kashmir	11.02	0.40	0.20	26.68	7.54
Kerala	0.75	0.03	0.01	8.84	1.55
Total	**5076.46**	**185.29**	**92.65**		**1892.94**

Table A7: Additional number of people that can be fed by reducing food loss by half in mango

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Uttar Pradesh	455.2	20.94	10.47	2.30	4543.93
Andhra Pradesh	437.4	20.12	10.06	3.28	3070.61
Tamil Nadu	123.4	5.68	2.84	1.21	2341.75
Karnataka	176.1	8.10	4.05	1.90	2135.75
Bihar	244.3	11.24	5.62	3.19	1760.65
Kerala	43.9	2.02	1.01	1.40	719.49
Maharashtra	79.1	3.64	1.82	3.07	592.49
Madhya Pradesh	65.5	3.01	1.51	2.54	591.99
Gujarat	120.8	5.56	2.78	6.49	427.89
West Bengal	91.8	4.22	2.11	4.97	425.16
Chhattisgarh	46.2	2.12	1.06	2.71	391.59
Uttarakhand	15.3	0.70	0.35	1.00	352.64
Odisha	80.6	3.71	1.85	7.30	254.01
Jharkhand	43.6	2.00	1.00	4.13	242.85
Punjab	11.7	0.54	0.27	3.19	83.96
Assam	4.8	0.22	0.11	1.43	78.02
Haryana	9.9	0.45	0.23	3.89	58.33
Rajasthan	8.7	0.40	0.20	3.90	51.53
Jammu & Kashmir	3.0	0.14	0.07	2.45	28.52
Himachal Pradesh	3.1	0.14	0.07	3.68	19.57
Total	**2064.4**	**94.96**	**47.48**		**18170.71**

Table A8: Additional number of people that can be fed by reducing food loss by half in papaya

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Andhra Pradesh	168.78	5.65	2.83	0.43	6544.21
Gujarat	125.65	4.21	2.10	1.32	1594.44
Chhattisgarh	38.14	1.28	0.64	0.44	1438.92
Karnataka	59.37	1.99	0.99	0.76	1315.38
West Bengal	36.60	1.23	0.61	0.48	1277.01
Tamil Nadu	14.16	0.47	0.24	0.28	859.23
Odisha	7.03	0.24	0.12	0.20	577.14
Maharashtra	40.83	1.37	0.68	1.28	532.63
Jharkhand	11.64	0.39	0.19	0.40	492.39
Madhya Pradesh	42.16	1.41	0.71	3.50	201.51
Kerala	9.50	0.32	0.16	0.80	197.98
Uttar Pradesh	9.68	0.32	0.16	1.20	135.16
Bihar	4.27	0.14	0.07	0.58	124.23
Assam	14.74	0.49	0.25	2.42	101.85
Rajasthan	0.44	0.01	0.01	2.50	2.93
Himachal Pradesh	0.12	0.00	0.00	0.78	2.60
Total	**583.11**	**19.53**	**9.77**		**15397.61**

Table A9: Additional no.of people that can be fed by reducing food loss by half in guava

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/ annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Chhattisgarh	19.7	1.57	0.78	0.36	2177.20
Odisha	10.5	0.84	0.42	0.216	1933.03
Karnataka	14.0	1.11	0.56	0.348	1601.77
Uttar Pradesh	92.8	7.38	3.69	3.528	1046.07
Madhya Pradesh	68.7	5.46	2.73	2.664	1024.64
Bihar	42.8	3.40	1.70	1.692	1004.58
Gujarat	17.0	1.35	0.67	1.212	556.14
Tamil Nadu	15.5	1.23	0.62	1.152	535.04
Andhra Pradesh	23.0	1.83	0.91	1.932	472.76
Punjab	19.6	1.56	0.78	2.04	381.13
Maharashtra	12.3	0.98	0.49	1.32	369.89
West Bengal	21.5	1.71	0.86	2.352	363.70
Assam	9.7	0.77	0.38	1.116	344.39
Jharkhand	8.9	0.71	0.36	1.104	321.56
Haryana	13.7	1.09	0.54	2.988	182.28
Rajasthan	5.5	0.44	0.22	1.884	116.32
Jammu &	0.8	0.06	0.03	0.516	59.86
Uttarakhand	2.0	0.16	0.08	3.42	23.68
Kerala	0.1	0.01	0.01	0.36	15.68
Himachal Pradesh	0.3	0.02	0.01	1.476	7.03
Total	**398.4**	**31.67**	**15.83**		**12536.73**

Table A10: Additional number of people that can be fed by reducing food loss by half in grapes

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Maharashtra	228.644	9.832	4.916	1.860	2642.93
Karnataka	52.420	2.254	1.127	0.984	1145.36
Tamil Nadu	5.893	0.253	0.127	1.740	72.82
Punjab	0.823	0.035	0.018	0.996	17.77
Andhra Pradesh	1.592	0.068	0.034	2.016	16.98
Madhya Pradesh	0.128	0.006	0.003	1.020	2.70
Jammu & Kashmir	0.089	0.004	0.002	0.756	2.53
Himachal Pradesh	0.013	0.001	0.000	1.500	0.19
Kerala	0.018	0.001	0.000	3.000	0.13
Haryana	0.009	0.000	0.000	1.776	0.11
Total	**289.629**	**12.454**	**6.227**		**3901.50**

Table A11: Additional number of people that can be fed by reducing food loss by half in apple

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
J&K	180.83	9.31	4.66	9.66	482.03
Himachal Pradesh	44.66	2.30	1.15	8.51	135.16
Uttarakhand	5.87	0.30	0.15	3.94	38.38
Arunachal Pradesh	0.74	0.04	0.02	2.87	6.60
Kerala	0.40	0.02	0.01	2.20	4.69
Nagaland	0.20	0.01	0.01	1.43	3.59
Total	**232.69**	**11.98**	**5.99**		**670.45**

Table A12: Additional number of people that can be fed by reducing food loss by half in citrus (lemon, mousambi and orange)

States	**Production 2017-18 (LT)**	**Total Loss (LT)**	**Saving with 50% loss reduction (LT)**	**Per capita consumption/ annum 2009-10 (Kg)**	**Additional no of people to be fed (Lakhs)**
Madhya Pradesh	252.21	12.23	6.12	3.53	1732.28
Andhra Pradesh	256.51	12.44	6.22	5.84	1065.32
Maharashtra	173.34	8.41	4.20	6.04	695.59
Punjab	124.11	6.02	3.01	6.89	436.56
Gujarat	60.56	2.94	1.47	6.36	231.12
Rajasthan	33.48	1.62	0.81	5.66	143.22
Karnataka	41.11	1.99	1.00	7.07	141.53
Odisha	25.98	1.26	0.63	5.02	125.39
Tamil Nadu	16.97	0.82	0.41	3.55	115.43
Assam	31.81	1.54	0.77	7.02	109.74
Bihar	11.76	0.57	0.29	4.16	69.76
Jharkhand	5.46	0.26	0.13	2.56	50.86
West Bengal	4.02	0.19	0.10	6.40	15.62
Jammu & Kashmir	2.39	0.12	0.06	4.55	13.20
Chhattisgarh	11.07	0.54	0.27	29.88	9.04
Himachal Pradesh	2.36	0.11	0.06	6.86	8.75
Kerala	0.14	0.01	0.00	4.91	0.00
Total	**1053.28**	**51.08**	**25.54**		**4963.41**

Table A13: Additional number of people that can be fed by reducing food loss by half in banana

States	**Production 2017-18 (LT)**	**Total Loss (LT)**	**Saving with 50% loss reduction (LT)**	**Per capita consumption/ annum 2009-10 (Kg)**	**Additional no of people to be fed (Lakhs)**
Gujarat	44.72	1.74	0.87	8.92	97.53
Andhra Pradesh	50.03	1.95	0.98	16.53	59.27
Uttar Pradesh	31.72	1.24	0.62	10.69	58.00
Maharashtra	42.09	1.64	0.82	16.56	49.52
Tamil Nadu	32.05	1.25	0.62	15.10	41.05
Madhya Pradesh	18.34	0.72	0.36	10.34	34.80
Bihar	13.96	0.54	0.27	9.83	27.46
Karnataka	23.29	0.91	0.45	17.71	25.41
West Bengal	12.00	0.47	0.23	10.33	22.26
Chhatisgarh	7.46	0.29	0.15	6.53	22.98
Assam	9.13	0.36	0.18	14.90	12.08
Kerala	11.19	0.44	0.22	23.12	9.51
Odisha	4.50	0.18	0.09	9.55	9.42
Jharkhand	0.32	0.01	0.01	5.92	1.69
Punjab	0.05	0.00	0.00	10.18	0.00
Rajasthan	0.01	0.00	0.00	9.24	0.00
Himachal Pradesh	0.00	0.00	0.00	11.76	0.00
Total	**300.88**	**11.73**	**5.87**		**470.98**

Table A14: Additional number of people that can be fed by reducing food loss by half in rice

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Punjab	118.70	3.26	1.63	23.14	70.54
Haryana	40.10	1.10	0.55	21.17	26.05
Uttar Pradesh	132.70	3.65	1.82	84.65	21.56
Madhya Pradesh	41.20	1.13	0.57	48.64	11.65
West Bengal	149.70	4.12	2.06	209.80	9.81
Bihar	71.80	1.97	0.99	148.69	6.64
Andhra Pradesh	81.70	2.25	1.12	234.77	4.79
Tamil Nadu	66.40	1.83	0.91	209.70	4.35
Odisha	58.10	1.60	0.80	282.30	2.83
Chattisgarh	43.70	1.20	0.60	227.80	2.64
Assam	46.90	1.29	0.64	274.14	2.35
Total	**851.00**	**23.40**	**11.70**		**163.21**

Table A15: Additional number of people that can be fed by reducing food loss by half in wheat

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Uttar Pradesh	318.80	7.81	3.91	173.80	22.47
Punjab	178.50	4.37	2.19	187.06	11.69
Madhya Pradesh	159.10	3.90	1.95	184.07	10.59
Haryana	107.80	2.64	1.32	197.84	6.67
Bihar	61.10	1.50	0.75	134.46	5.57
Rajasthan	93.80	2.30	1.15	209.02	5.50
Gujarat	30.70	0.75	0.38	112.39	3.35
Maharashtra	17.00	0.42	0.21	99.32	2.10
Uttarakhand	9.20	0.23	0.11	129.94	0.87
Himachal Pradesh	5.70	0.14	0.07	139.39	0.50
Total	**981.70**	**24.05**	**12.03**		**69.30**

Table A16: Additional number of people that can be fed by reducing food loss by half in pearl millet

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Karnataka	31.1	0.81	0.40	0.48	842.29
Haryana	78.3	2.04	1.02	2.36	430.58
Rajasthan	407.6	10.60	5.30	27.41	193.33
Uttar Pradesh	17.9	0.47	0.23	1.46	158.95
Madhya Pradesh	7.6	0.20	0.10	0.80	122.89
Maharashtra	72.8	1.89	0.95	7.92	119.49
Gujarat	104.8	2.72	1.36	28.14	48.42
Total	**720.1**	**18.72**	**9.36**		**1915.95**

Table A17: Additional number of people that can be fed by reducing food loss by half in sorghum

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Rajasthan	62.6	1.88	0.94	0.35	2698.28
Tamil Nadu	4.3	0.13	0.06	0.02	2687.50
Uttar Pradesh	2.1	0.06	0.03	0.04	875.00
Maharashtra	334.5	10.04	5.02	34.26	146.45
Karnataka	237.4	7.12	3.56	32.51	109.54
Gujarat	26.0	0.78	0.39	5.15	75.76
Madhya Pradesh	5.7	0.17	0.09	3.86	22.13
Andhra Pradesh	3.0	0.09	0.05	5.17	8.70
Total	**675.6**	**20.27**	**10.13**		**6623.36**

Table A18: Additional number of people that can be fed by reducing food loss by half in pigeon pea

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Madhya Pradesh	145.8	4.67	2.33	7.19	324.54
Uttar Pradesh	63.5	2.03	1.02	5.20	195.54
Andhra Pradesh	62.9	2.01	1.01	9.42	106.84
Maharashtra	11.3	0.36	0.18	8.11	22.29
Tamil Nadu	11.1	0.36	0.18	8.87	20.03
Karnataka	7.6	0.24	0.12	7.60	16.01
Jharkhand	2.2	0.07	0.04	3.76	9.37
Gujarat	3.4	0.11	0.05	7.76	7.01
Odisha	1.2	0.04	0.02	4.67	4.11
Total	**309.0**	**9.89**	**4.94**		**705.73**

Table A19: Additional no.of people that can be fed by reducing food loss by half Chickpea

States	Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/annum 2009-10 (Kg)	Additional no of people to be fed (Lakhs)
Rajasthan	148.4	5.27	2.63	2.82	934.08
Maharashtra	161.2	5.72	2.86	3.65	784.35
Karnataka	68.8	2.44	1.22	3.07	397.53
Chattisgarh	28.2	1.00	0.50	1.46	341.91
Madhya Pradesh	46.0	1.63	0.82	2.87	284.69
Gujarat	33.1	1.18	0.59	2.32	253.68
Jharkhand	25.1	0.89	0.45	4.18	106.69
Andhra Pradesh	5.9	0.21	0.10	1.22	85.56
Uttar Pradesh	5.8	0.21	0.10	2.29	44.92
Total	**522.5**	**18.55**	**9.27**		**3233.40**

Table A20: Additional n.. of people that can be fed by reducing food loss by half in sugar

States	Sugarcane Production 2017-18 (LT	Sugar Production 2017-18 (LT)	Total Loss (LT)	Saving with 50% loss reduction (LT)	Per capita consumption/ annum 2009-10 (Kg)	Additional no of people to be fed (Crores)
Uttar Pradesh	1770.3	132.77	5.24	2.62	18.1	1.45
Tamil Nadu	171.5	12.86	0.51	0.25	15.5	0.16
Maharashtra	218.4	16.38	0.65	0.32	23.3	0.14
Andhra Pradesh	77.9	5.84	0.23	0.12	12.7	0.09
Karnataka	82.0	6.15	0.24	0.12	17.7	0.07
Bihar	36.4	2.73	0.11	0.05	9.6	0.06
Madhya Pradesh	54.3	4.07	0.16	0.08	20.8	0.04
Gujarat	31.8	2.39	0.09	0.05	24.6	0.02
Haryana	25.4	1.91	0.08	0.04	31.1	0.01
Uttarakhand	16.5	1.24	0.05	0.02	23.8	0.01
Punjab	21.1	1.58	0.06	0.03	37.0	0.01
Total	2505.6	187.92	7.42	3.71		2.05