ENERGY EFFICIENCY SERVICES LIMITED
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CHILDREN'S INVESTMENT FUND FOUNDATION

SHEETAL
Alliance for Sustainable Habitat, Energy Efficiency and Thermal Comfort for All

Alliance for an™ Energy Efficient Economy

ANALYSIS OF POTATO VALUE CHAIN IN WEST BENGAL

ROADMAP FOR MODERNIZATION OF COLD STORAGES

OCTOBER, 2021

Project: Alliance for Sustainable Habitat, Energy Efficiency and Thermal Comfort (SHEETAL)

The Alliance for Sustainable Habitat, Energy Efficiency and Thermal Comfort (SHEETAL) is a consortium of Civil organizations led by The Energy and Resource Institute (TERI) with the Alliance for an Energy Efficient Economy (AEEE), and the Council on Energy, Environment and Water (CEEW) as partners. Supported by CIFF, SHEETAL facilitates the roll out of India's sustainable cooling agenda enshrined in the India Cooling Action Plan. Engaging with national and international stakeholders, the consortium partners discuss, identify and test integrated approaches best suited to improve the development, access and use of energy efficient cooling practices and technologies for R&D, space cooling, cold-chain, transport air-conditioning, and the servicing sector. SHEETAL convene different line ministries and international and domestic cooling policy experts to collaborate and synergise actions to accelerate sustainable cooling in India.

Funded by: Children's Investment Fund Foundation (CIFF)

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Prepared by:

Alliance for an Energy-Efficient Economy (AEEE) is a policy advocacy and energy efficiency market enabler with a not- or-profit motive. AEEE advocates energy efficiency as a resource and collaborates with industry and government to transform the market for energy-efficient products and services, thereby contributing towards meeting India's goals on energy security, clean energy, and climate change. AEEE collaborates with diverse stakeholders such as policymakers, government officials, business and industry, consumers, researchers, and civil society organizations. We believe that our work speaks for itself and we hold Respect, Integrity, and Synergy as central to our efforts.

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ABBREVIATIONS

AEEE	Alliance for an Energy Efficient Economy
ACU	Air Cooling Units
CIFF	Children's Investment Fund Foundation
CS	Cold Storage
DG	Diesel Generator
EEMs	Energy Efficiency Measures
EESL	Energy Efficiency Services Limited
EPS	Expanded Polystyrene
HSD	High Speed Diesel
ICAP	India Cooling Action Plan
kg	Kilogram
MIDH	Mission on Integrated Development of Horticulture
MMT	Million Metric Tonnes
MT	Metric Tonnes
M&V	Measurement and Verification
PUF	Polyurethane Foam
PV	Photovoltaic
SHEETAL	Sustainable Habitat, Energy Efficiency and Thermal Comfort for All
TDS	Total Dissolved Solids
TE	Triennium Ending
T/RH	Temperature/Relative Humidity

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Around 13.4 Million Metric Tonnes of potatoes were produced on 4.5 lakh hectares of land in West Bengal during TE 2018-19. Hooghly, Burdwan, Bankura and Medinipur are the major potato growing districts in West Bengal.

EXECUTIVE SUMMARY

West Bengal is an agricultural economy with 44% of its total workforce dependent upon agriculture. It ranks as the second-largest horticultural crop-producing State in India, after Uttar Pradesh.

Potato (primary horticultural produce of West Bengal) plays a vital part in the agricultural economy of West Bengal. Potatoes in the State are grown during the Rabi season. The sowing period is from mid-September to November, and the crops are harvested from December to March.

The potato supply chain involves several intermediaries ranging from village traders, cold storage owners, commission agents to wholesalers and retailers. The harvested crop is generally sold to village traders, as Mandis and wholesalers are not accessible to a majority of potato farmers in West Bengal. As a result, a farmer earns an average of INR 5 per kilo of the table variety of potato in West Bengal. In contrast, the average farmgate prices of potato in Gujrat comes around to about INR 9.65 per kilo.

Post-2015 food processing industries have witnessed an exodus from West Bengal to Gujarat due to factors like the quality of potatoes and the starch ratio in the potatoes produced.

Potatoes are usually stocked in cold storages to improve their shelf life. The cold storages are used from the end of February when the produce starts coming in. The stored potato stock begins depleting from May until the end of the storage season, usually November. Peak season utilization sees 100% of the storage capacity being utilized, which gradually decline, starting from May to the end of the season, ie. November as the stocks are unloaded. Currently, the storage rate in West Bengal is INR 157/quintal/season.

An average of 27% to 30% of the total potato produce is written off/lost annually in West Bengal due to supply chain irregularities. Improper temperature, humidity, and air movement within the cold storage contribute to the said losses as well. Roughly 5% losses are accounted for at the farmers' level, 9.5-10% at the storage level, 4-5% at the wholesale level and 8-10% at the retail level.

Legacy cold storages account for a much higher rate of produce loss while in storage than state-of-the-art modern cold storages. It is estimated that retrofitting-cum-modernization of all the existing legacy cold storages in West Bengal can lead to a 75% reduction in overall losses. West Bengal faces annual monetary losses of more than INR 200 crore due to these legacy cold storages. These annual losses escalated to over INR 599 crore in 2020 due to a notable increase in potatoes' wholesale prices.

Detailed energy audits of three different types of cold storage facilities located in the Hooghly district of West Bengal were carried out to understand the potato handling, storage practices and energy utilization. It was observed that with traditional bunker coil systems and single chamber designs, the desired air circulation, temperature and humidity conditions are challenging to maintain. Infiltration losses are commonplace due to leaky building envelopes. The average unit rate of electricity purchased from the Grid varies from INR 7 to 8 per kWh among the audited facilities. More than 90% of the energy expenditure was attributed to the electricity grid.

Standardized Energy Efficiency Measures (EEMs) have been assessed and proposed to improve the cold storages' overall energy performance while retaining the product quality. In addition, a cost-benefit assessment of the EEMs was carried out with audit data in consultation with leading industry players. Finally, the report analyzed the state-level energy-saving potential, investment potential, and the monetary benefits from potato loss reduction through the modernization of potato cold storages in West Bengal. It is estimated that around 3.6 lakh metric tons of potato losses can be avoided by modernizing cold storages, leading to monetary benefits of over INR 566 crore/year.

To sum up, the State has vast growth potential in the horticulture sector. This will require shifting from traditional cold storages to integrated cold chains, which will unlock the full potential of the potato supply chain. Modernization of the existing conventional cold storages into multi-purpose cold storages will be an appropriate first step. This will incentivize diversification of the cropping pattern and bring new avenues of growth for the farmers. The modernization will also help to maintain the potatoes' quality and minimize the post-harvest losses. It will help the farmers realize a more significant economic value for their produce and boost their income.

There were 514 cold storages in West Bengal in August 2020, out of which 90% (463 cold storages) were being used for storing potatoes. The average capacity of a cold storage dedicated to potatoes in West Bengal is around 11,000 MT.

1
BACKGROUND

Alliance for an Energy Efficient Economy (AEEE) has collaborated with Energy Efficiency Services Limited (EESL) to assess the cold storage infrastructure in West Bengal. The Government of West Bengal requested EESL's assistance to conduct detailed energy audits at select cold storage facilities and prepare state-level policy documents to bring energy efficiency and sustainability to the State's cold storage infrastructure.

As part of the Alliance for a Sustainable Habitat, Energy Efficiency and Thermal Comfort for All (SHEETAL) project facilitating the implementation of the India Cooling Action Plan (ICAP) funded by the Children's Investment Fund Foundation (CIFF), AEEE is leading the sectoral actions on cold chain and space cooling work themes. AEEE supports EESL through diagnostic studies on energy efficiency and resource conservation to identify investment avenues in energy efficiency in different sectors.

The study aims to understand West Bengal's cold storage scenario and identify the energy performance baseline and state-level energy-saving projection. Standardization of Energy Efficiency Measures (EEMs) for implementation in the ESCO model is also studied. Consultations with diverse stakeholders, including cold storage owners & operators, cold storage industry associations, state government officials in the agricultural marketing, food processing and horticulture departments, academia, and national and global cold chain industry experts, were an integral part of the research.

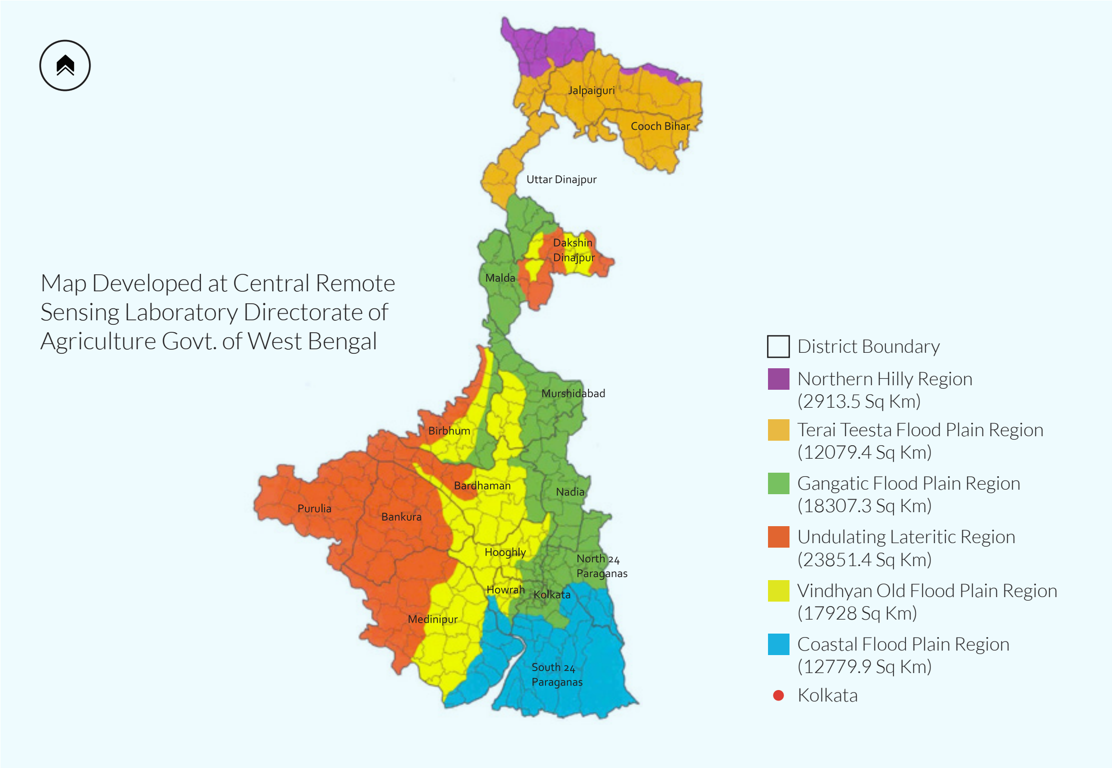
This research work on "Analysis of Cold Storage Infrastructure in West Bengal: Retrofitting Opportunities in the ESCO model" stems from the SHEETAL project and AEEE's collaboration with the Government of India's EESL.

2

INTRODUCTION

West Bengal is located in eastern India and shares state boundaries with Sikkim in the north, Assam in the northeast, Odisha in the south-west and Bihar and Jharkhand in the west. The State also shares international borders with Bangladesh, Nepal and Bhutan. West Bengal occupies a geographical area of 88,752 square kilometres, sharing 2.7% of India's land and is home to 7.6% of the country's population. Based on its diverse topography, terrain and climate, the State comes under three agro-climatic regions. These include Eastern Himalayan Region (Zone II), Lower Gangetic Plain Region (Zone III) and Eastern Plateau and Hilly Region (Zone VIII) (Figure 1).

Figure 1: **Agro-climatic subregions of West Bengal**



Source: State Agriculture Plan for West Bengal, NABARD Consultancy Services Pvt Ltd (NABCONS)

Around 72.03 % of the state population lived in rural areas in 2011, which is higher than the national average of 68.8%. In 2011-12, the State's poverty ratio was 19.98 %, marginally lower than the national average of 21.92%[1].

1. The poverty levels for the year 2011-12 are based on the Tendulkar Methodology

2.1 AGRICULTURAL LANDSCAPE IN WEST BENGAL

Agriculture and allied activities employ over 44% of the state workforce. West Bengal redistributed 1.04 million acres of land to 2.54 million poor households per the Urban Land (Ceiling and Regulation) Act, 1976 (Hanstad, Nielsen & Brown, 2004). Over 60% of the total land area in West Bengal is used in agriculture (NABCONS), and around 96% of the operational holdings are either marginal (less than 1 ha) or small (1-2 ha). Marginal operational holdings in West Bengal (less than 1 ha) account for 88.8% of the total operational holding as against 69.8% at a national level. (NABCONS 2009).

The State has varied agro-climatic conditions and is bestowed with diverse natural resources, making the land suitable for cultivating various crops. West Bengal ranks first in paddy production and second in potato production in India. Although West Bengal produces many agro commodities, the average agrarian households' income remains one of India's lowest due to low average land endowment (Mandal et al., 2017). Although a steady drop in the share of agriculture in the State's domestic product and total workforce employed in agriculture has been observed over the years, a corresponding increase in the average farmers' income has been absent.

In TE 2018-19, around 17% of the total cropped area was utilized for horticulture crops (fruits and vegetables) in West Bengal.

According to the NSS data (January-December 2013), the all India annual income of an agricultural household was INR 36,972, which was in stark contrast to the average yearly income of a farming household in West Bengal at INR 11,748. Large scale farm mechanization in West Bengal has been impeded mainly due to high population density and lower labour costs as compared to other agrarian states such as Punjab and Haryana(Ghosh).

The net cropped area is 52.05 lakh hectare which is 92% of its arable land.

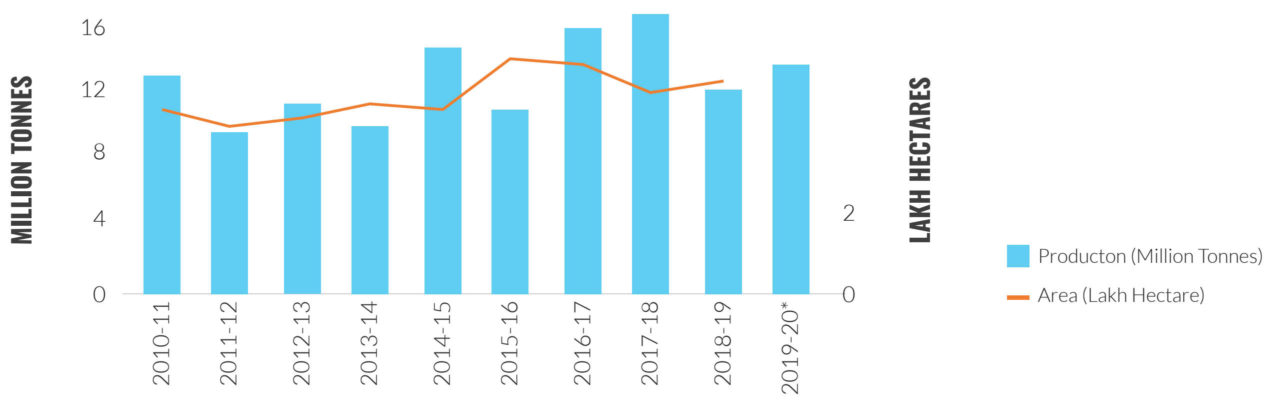
In 2018-19, rice was cultivated on 5.52 million hectares (production of 1.6 MMT), followed by jute on 0.53 million hectares (7.69 million bales) and potatoes on 0.43 million hectares (13.78 million tonnes) in West Bengal. Among the horticulture crops, potato plays a vital role in the agricultural economy of West Bengal. The major strains of potatoes grown in West Bengal include Kufri Jyoti, Kufri Pukhraj and Kufri Chandramukhi(Pradel, Gatto, Hareau, Pandey & Bhardway, 2019).

West Bengal produced 13.5 Million Metric Tonnes (MMT) of potatoes on 4.5 lakh hectares of land and contributed about 27% of India's total potato production in TE 2018-19. The share of potato production in West Bengal has increased from 23.4% in 2011-12 to 29% in 2017-18. The area under potato cultivation has increased from 3.8 lakh hectare in 2011-12 to 5 lakh hectare in 2016-17 **(Figure 2)**.

According to the NSS data (January-December 2013), the all India annual income of an agricultural household was INR 36,972, which was in stark contrast to the average yearly income of a farming household in West Bengal at INR 11,748.

Figure 2: **Potato production and area in West Bengal**

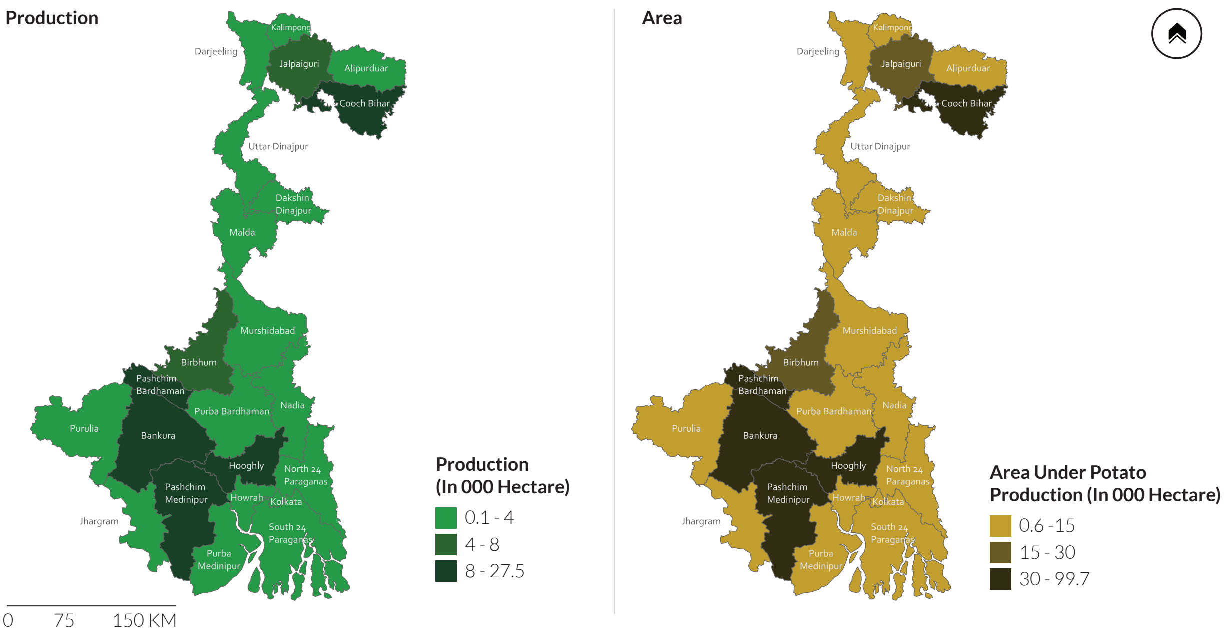
Source: Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare and National Horticulture Board (Monthly report on Potatoes, various years)



Due to the favourable agro-climatic zones, Hooghly, Burdwan, and West Midnapore districts are the leading producers of potatoes in West Bengal. In TE 2018-19, around 2.7 MMT of potatoes were produced on 0.99 lakh hectares of land in the Hooghly district, followed by West Midnapore, where 21.8 MMT of potatoes were produced on 0.68 lakh hectares of land. In the Burdwan district, 2.07 MMT of potatoes were produced on 0.63 lakh hectares of land (Figure 3).

Figure 3: **District wise production and area under potatoes in West Bengal**

Source: Directorate of Economics and Statistics, Ministry of Agriculture and Farmers



2.2 ORGANIZATION OF THE STUDY

The study is organized into six sections. Section 1 introduced the scope and aim of the study, while Section 2 highlighted the agricultural landscape (with particular emphasis paid to potato cultivation) in West Bengal. Section 3 discusses the stake-holders involved in the supply chain of potatoes in West Bengal along with potatoes' prices and arrivals in some of India's major potato producing districts. Section 4 discusses the growth of the cold storage industry in West Bengal and the losses incurred (quantitative and monetary) at each level in the supply chain. Additionally, this section sheds further light on the statistics involved pertaining to the losses incurred in the potato supply chain due to legacy cold storage technologies. Section 5 highlights the key findings of the detailed energy audits of three cold storage facilities in West Bengal, carried out as per the mandated objectives. Section 6 concludes the study based on the reports and analysis furnished thus far.

In 2019-20, of the 13.16 million metric tons of potatoes produced in the State

4.37 million metric tons were consumed by the domestic consumers, 6.79 million metric tons were exported to the other states, and the remaining 2 million metric tonnes was lost during the intermediation process.

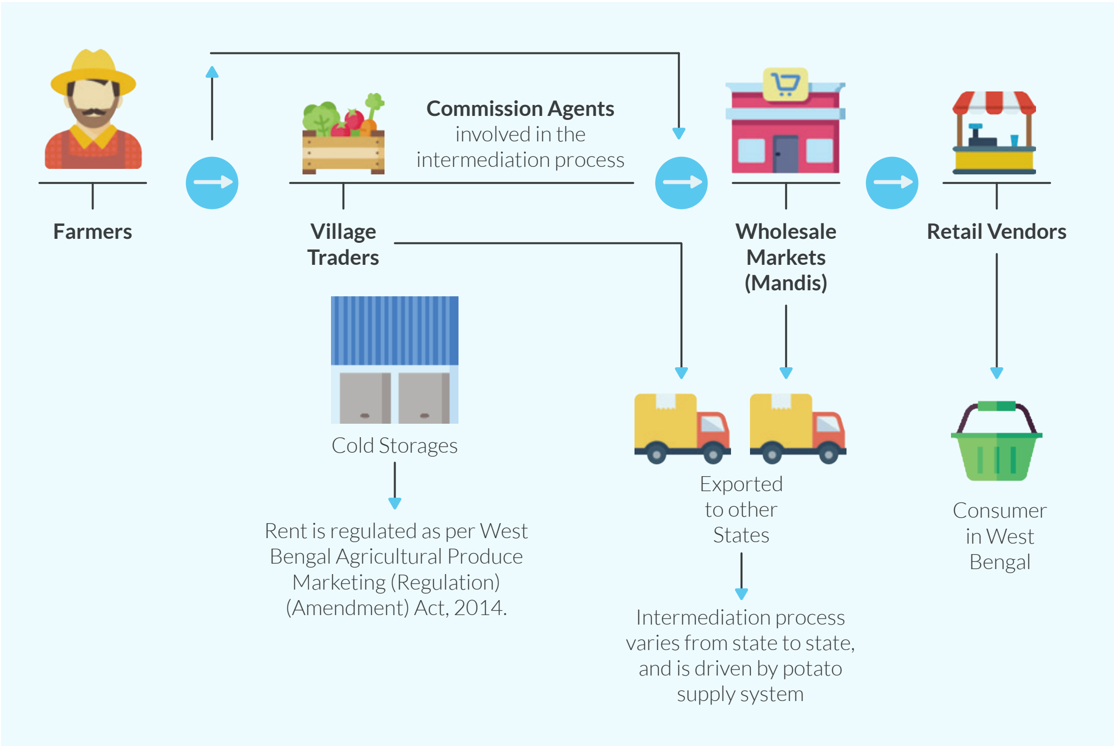
3

SUPPLY CHAIN OF POTATOES IN WEST BENGAL

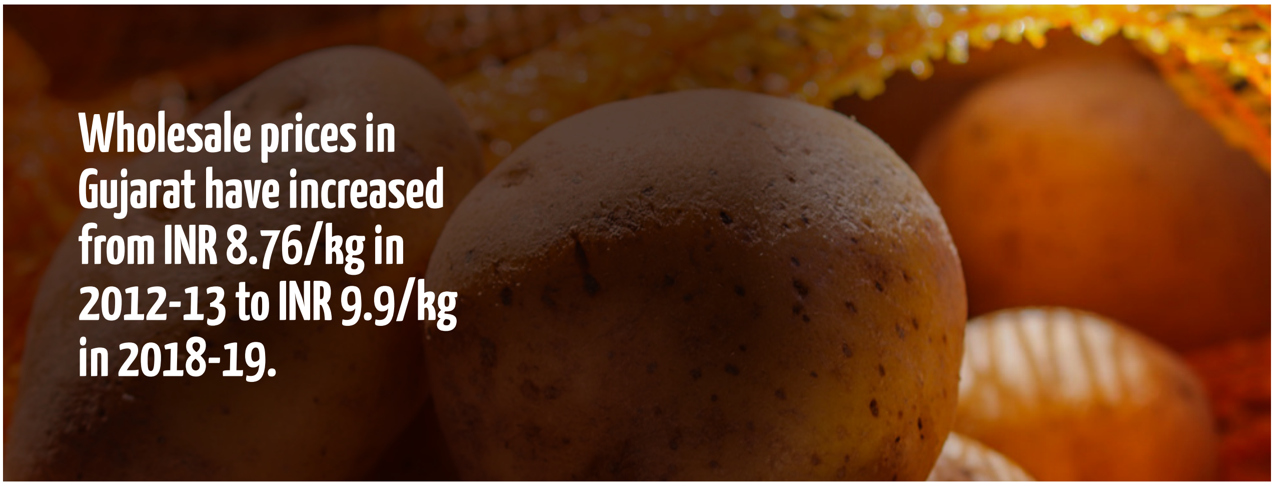
According to a study by Mitra, Mookherjee, Torero, Visaria, 2017, over 90% of potato farmers in West Bengal sell their crop to village traders instead of Mandis or wholesalers, which can be attributed to various reasons, including but not limited to inaccessibility, logistical issues et cetera. Further down the supply chain, the village traders sell part of the produce to the block/district mandis, and the remainder is stored at cold storages, at which point wholesalers purchase the same as per demand in their respective markets. The produce is then sold to vendors from city markets, wholesalers from other states, and other direct-to-consumer retailers.

The cold storage business is a necessary value add to the potato farming business in West Bengal. Farmers, traders and wholesalers hire the storage capacity at their local cold storage to increase the shelf life of their produce.

Figure 4: Supply chain of potatoes in West Bengal



Source: Authors' assessment



Paddy and potatoes remain the primary crops in West Bengal due to easy access to irrigated land and the comparatively high selling prices. Critical challenges that inhibit potatoes in the cropping cycle include small landholdings (Roy, Saha, Kadian, Quiroz & Ilangantileke 2007) and a lack of quality seed tuber. An ancillary drawback attributed to the lack of quality seed tuber in West Bengal is the importation of seed tubers from Punjab, which increases the total cost of cultivation and adds a substantial financial burden for the farmers(Chakraborty, Mukhopadhyay, Konar and Banerjee, 2015). Potato seeds are procured from Punjab, account for almost 60% of the total production cost. All the above issues have discouraged farmers from producing potatoes in West Bengal, thereby causing an increase in the retail price of potatoes, which in turn leaves a tiny amount of tuber crop for seeding purposes. Over the years, this has become a vicious catch 22 situation and contributed to the low profitability of potato crops in West Bengal compared to other states (Roychowdhury 2020).

Figure 5 shows the arrivals of potatoes in the Burdwan district of West Bengal compared to the other select districts in India and the wholesale prices of potatoes prevailing in these districts.

The graph also illustrates that the wholesale prices of potato in Uttar Pradesh and West Bengal remained at INR 4 per Kilogram (kg), while in Madhya Pradesh, it was INR 8 per kg. Uttar Pradesh is the largest potato producing State in India, where the supply has consistently outstripped local demand, which has ensured that the State has one the lowest wholesale prices of potato in the entire country.

The average price of potato declined from 6.5 per Kilogram (kg) in 2012-13 to INR 5.5 per Kilogram (kg) in 2018-19 in the Burdwan district of West Bengal, whereas in Indore (Madhya Pradesh), the prices increased from INR 8.7 per kg in 2012-13 to INR 10 per kg in 2018-19. Various environmental factors such as droughts, floods, pest attacks led to a fluctuation in the arrivals of potatoes in the wholesale mandis of the Burdwan district, resulting in a fluctuation in the wholesale prices over the years. The change in demand for potatoes could be another reason for the variation in potatoes' wholesale prices in the district.

The higher wholesale price of potatoes in Madhya Pradesh can be attributed to the premium strains of table potato cultivated in the State, compared to the table variety of potatoes produced in West Bengal. Wholesale prices in Gujarat have increased from INR 8.76/kg in 2012-13 to INR 9.9/kg in 2018-19. Production of potatoes in Gujarat is demand-driven, and food processing companies collaborate with the potato farmers, supplying them with quality potato seeds. The maturity index and harvesting period of potatoes are crucial factors contributing to a better price for processed potatoes in Gujarat.

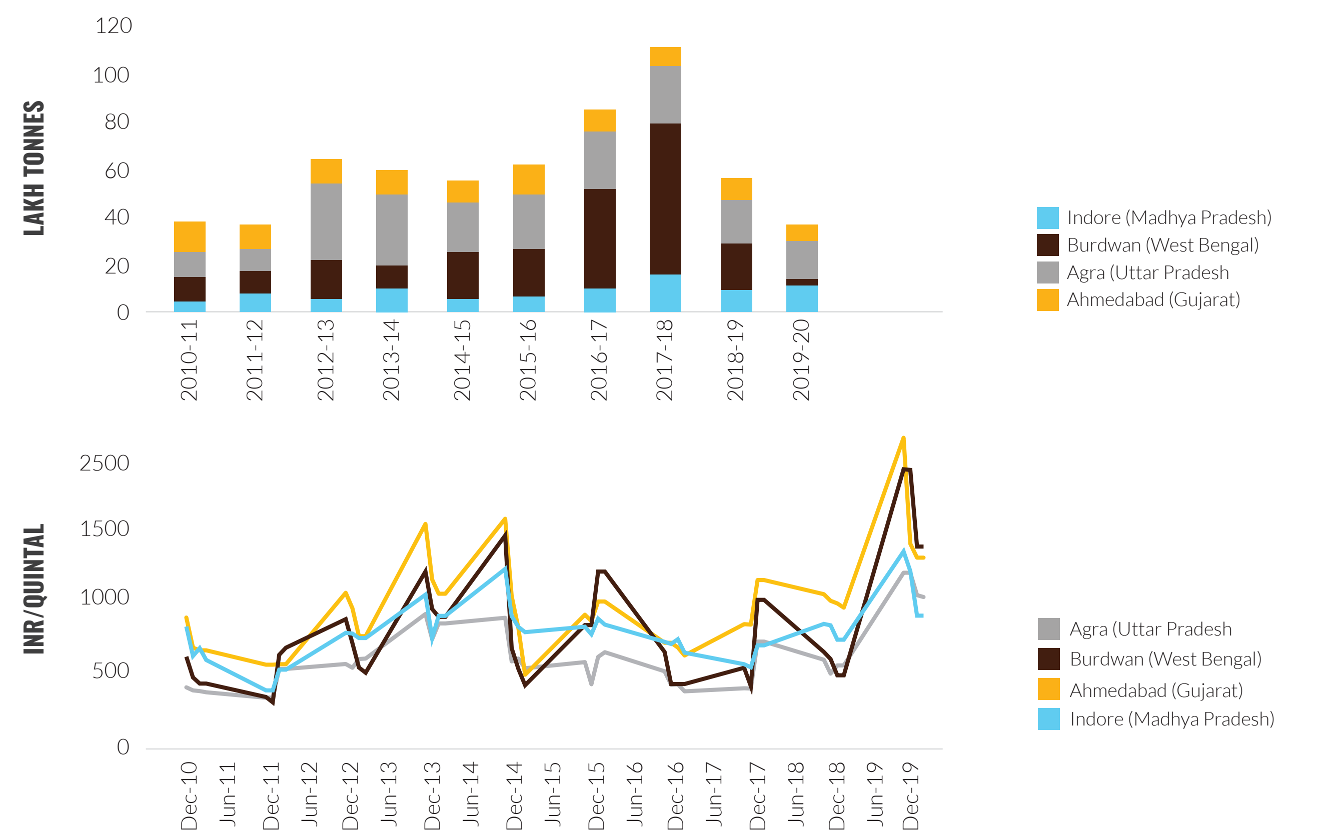
Good quality potatoes stored in the cold storages, modernization of cold storages, and proper farming equipment can help inflate the wholesale prices of potatoes and thereby increase the profitability of cultivating potatoes in West Bengal. Inhibiting factors include lack of modern technology and government intervention, viz. lowering the slabs on electricity and rental rates.

The input cost of producing potatoes in West Bengal is around INR 4/kg (which includes production cost amounting to INR 3-3.5/kg and handling cost of INR 0.5/kg). As mentioned earlier, the farmgate prices of potato in Bengal hovers around INR 4 to 5 per Kilogram, making it hard for the farmers in West Bengal to cover the cost of production, let alone turn up a decent profit on the produce.

Hooghly, Burdwan, Bankura and Medinipur are some of the major potato growing districts in West Bengal.

Figure 5: Arrival and wholesale prices of potatoes in select districts of India

Source: Agmarknet (https://agmarknet.gov.in/)



A majority of food processing giants like McCain and Hyfun foods have shifted their manufacturing facilities from West Bengal to Gujarat post-2015. This shift has been attributed to factors such as the quality of potatoes produced (table variety of potatoes account for 98% of the total production, which is suboptimal for the food processing industries). Moreover, according to the input cost vis-à-vis the farmgate price, the potato production trend in West Bengal and Gujarat shows that a farmer in Gujarat earns higher profits than a farmer in West Bengal.

In TE 2019-20[2], around 13.05 million tonnes of table variety of potatoes were produced in West Bengal, of which about 4.4 million tonnes[3] were used for domestic consumption. Around 80-85% of the potatoes produced during the Rabi season are stored in cold storage facilities of other states (Datta K, 2020). Due to technical constraints and regulations, the potatoes cannot be carried over to the next year and sold by November until the cold storage is emptied. (Mitra, Mookherjee, Torero, Visaria, 2017).

2. The potato production data for 2019-20 is 2nd Advanced Estimates
3. According to NSSO 2011-12, per capita consumption of potato in West Bengal stands at 3.8 kg/per capita/per month. Multiplying this with the projected population of West Bengal in 2019 gives the total consumption of potatoes in West Bengal.

Cold storages in India have grown at 19% YoY, increasing from 6891 in 2014 to 8186 in 2020, of which 75% of the total storage capacity is used for potatoes (Rajya Sabha Unstarred Question 2241, 2017).

4

COLD STORAGE LANDSCAPE IN WEST BENGAL VIS-A-VIS POTATO STORAGE

The first cold storage unit was set up in Kolkata in 1892(NCCD 2015). Post-independence, the cold chain industry was regularised and promoted under the aegis of Cold Storage Order enacted by the Central Government in 1964 and later amended in 1980.

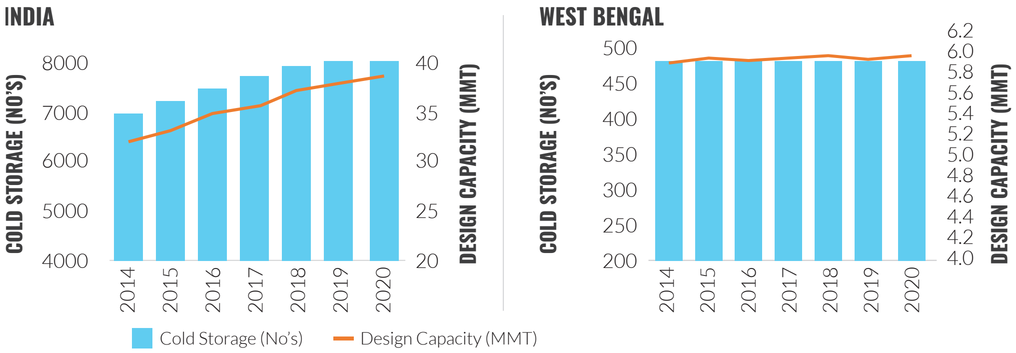
States like West Bengal, Uttar Pradesh, Punjab, and Haryana have enacted individual legislations concerning cold storage regulations and management.

The cold storage facilities in West Bengal are plagued with poor capacity utilization due to its single commodity (potato, apple, orange, grapes, et cetera) based designs and availability schedules. (Rais & Sheoran, 2015).

The average capacity of a cold storage unit in India is around 6000 Metric Tonnes (MT).

In West Bengal, over 90% of cold storage units cater to potatoes, with an average capacity utilization of 100% during the peak season. The average capacity of a potato cold storage unit in West Bengal is around 11,000 MT. With 514 active cold storage units, West Bengal ranks fifth in terms of the number of active cold storage units and second in terms of average storage capacity, which remained at about 5.9 MMT since 2014. (Figure 6).

Figure 6: Number of Cold Storages and Storage Capacity in India and West Bengal



Source: Agriculture Statistics at a glance (various years), NCCD (2014)

The loading of potatoes in cold storages begins towards the end of February and closes by the end of March. The unloading, driven by the market demand, typically starts from May/June onwards and continues till the end of the storage season in November. Annual maintenance at most cold storages units is carried out in December. Capacity utilization at peak seasons is 100% of the total storage capacity, which gradually decreases starting from May and June as unloading of the stock starts.

The storage rental rates in West Bengal fluctuate weekly, monthly, and annually based on various factors and are currently pegged at INR 157 per quintal per season[4] (i.e. nine months, March-November). The monthly rental for storing potatoes is currently INR 0.17/kg. Cold Storage entrepreneurs have requested a revision of the cold storage rents to about INR 180/quintal owing to increased input and capital costs. (Munshi, S 2021).

4.1 FOOD LOSSES (POTATO) REPORTED IN COLD STORAGES IN WEST BENGAL

Food loss is the total quantity of food[5] lost in the supply chain (Kashyap & Agarwal, 2019). Potato is a perishable commodity, and its preservation requires storing the produce in cold storages. Incorrect temperature, humidity, and air movement in cold storages can adversely affect the quality of the stored produce. Potatoes not appropriately stored are prone to tuber losses due to fungal and bacterial infection.

An average of 7.32% of harvest and post-harvest losses of potatoes were reported in India compared to 8.99% in 2005-07 (ICAR 2015). A reduction in storage losses from 2.26% to 0.78% during this period is attributed to the better availability of cold stores and other infrastructure. However, this study has not been able to quantify the produce loss due to inadequacy in the storage conditions. Inputs received from cold storage owners and operators in West Bengal and Uttar Pradesh indicates that potato losses are significant but have not been quantified adequately due to an absence of weighing and monitoring systems. Potato losses while in storage mainly occur due to poor handling practices and inadequate storage conditions with respect to the required temperature, humidity, and air circulation parameters.

Total reported losses within the supply chain of potatoes in West Bengal amount to 27-30% of the harvest.

Improper handling during the loading and unloading processes at the cold storage contribute to losses at the wholesale and retail levels. Total reported losses within the supply chain of potatoes in West Bengal amount to 27-30% of the harvest. Around 5% of these losses occur at the farm level, 9.5-10% of losses occur during the storage processes, and 12-15% of losses together at the wholesale and retail levels (Figure 7). Post-harvest losses of fresh vegetables at farm levels can be attributed to inadequate harvesting methods (Verma & Singh, 2004).

Several storage inefficiencies and poor handling processes are the operational cause of waste in the supply chain (Negi & Anand, 2016).

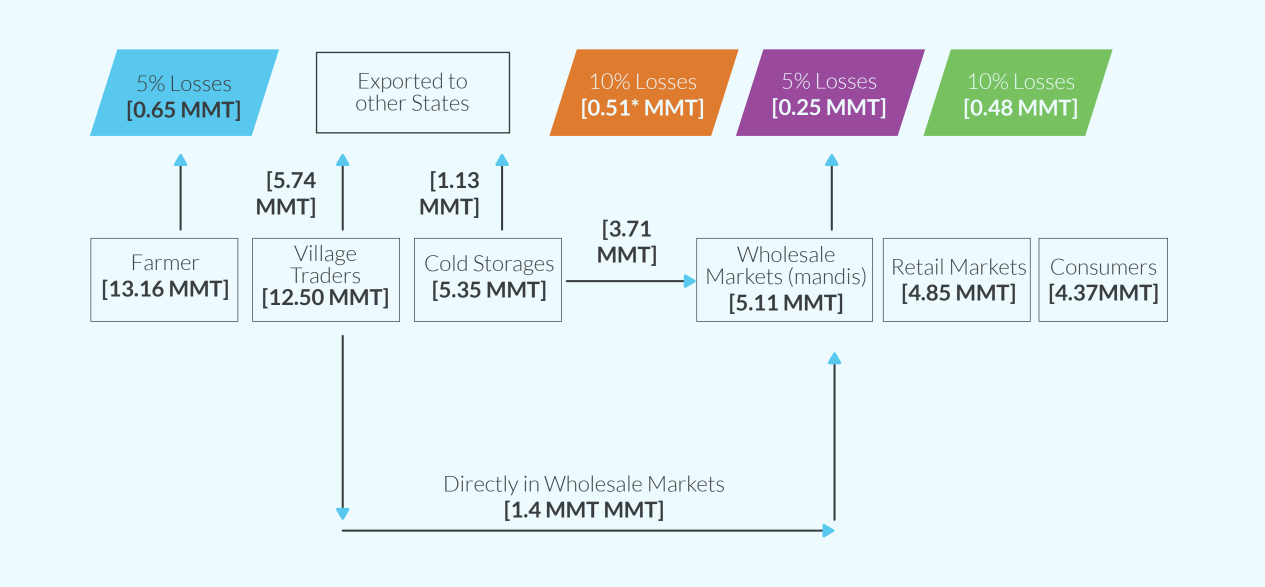
Figure 7: Traditional post-harvest (value) losses in West Bengal

Source: Authors' estimation

4. As per the inputs from the West Bengal Cold Storage Association
5. It only includes the products which are meant for human consumption and excludes the food that is used for Seed, Feed and Wastage (SFW)

A significant portion of total wastages of fruits and vegetables occurs between the farms and mandis, can be attributed to the poor packaging of the produce and the lack of cold storage units (Sivaraman 2016). Figure 8 shows the movement of potatoes produced in 2019-20 from the farmers to the ultimate consumers in a typical post-harvest chain in West Bengal. The losses at each step vary depending upon the technologies used in the supply chain.

Figure 8: Traditional post harvest supply chain of potatoes in West Bengal (2019-20)



Source: Authors' estimation

Note: The value of potato produce at each stage is calculated after considering the losses that occur in the post-harvest chain

**calculated considering that 95% of the total Cold Storages in West Bengal are susceptible to higher losses*

Around 13.16 Million Metric Tonnes (MMT) of potatoes were produced in West Bengal in 2019-20. According to the NSS 2011-12, the monthly per capita consumption of potatoes in West Bengal is 3.8 kg[6]. In 2019-20, the total consumption of potatoes in West Bengal amounted to 4.37 MMT[7]. Of this 4.37 MMT, 1.4 MMT[8] potatoes bypassed the cold storages and were directly sold to consumers via retailers buying from wholesale markets and village traders.

During the peak season, 100% of cold storage capacity is utilized for storing potatoes. Considering the above, a maximum amount of 5.35 MMT of potatoes can be stored in the cold storages, and the remaining 5.74 MMT are exported to other states. During this process, 5% of losses are reported.

From the cold storage, 3.71 MMT of potatoes are sold at various wholesale mandis in different districts of West Bengal and the remaining 1.13 MMT is exported to the other states. Around 0.51 MMT of potato losses are reported in the process of storing these potatoes in the traditional cold storages. Over 5.11 MMT of potato produce reaches the wholesale mandis in West Bengal (directly and from cold storages), of which 4.85 MMT reach the retail vendors, and the remaining 5% is lost/ written off in wholesale markets.

The retailers sell the remainder, i.e. 4.37 MMT of potato produce, after reporting 10% losses in the intermediation process. From the farm gate to a final consumer, a horticulture product passes through various intermediaries, which add up to the waste and increases the commodity's per unit consumption price (Negi & Anand, 2016). The wholesale level losses depend on the number of participants in the marketing channel (Verma & Singh, 2004).

Potato losses in cold storages can be broadly classified into two categories- evaporative losses (reduction in weight due to loss of moisture; (freshly harvested potato contains 80% water and 20% dry matter) (FAO 2008)) and spoilage losses (physical deterioration of potato quality). Factors such as ambient condition, temperature and air circulation affect the shelf life of potatoes leading to spoilage. Both types of losses increase with longer storage periods. Table 1 shows the percentage of traditional cold storage losses compared to a modern facility, assuming linear unloading.

6. The per capita consumption is calculated by taking the weighted average of per capita potato consumption in rural and urban areas
7. Total potato consumption is calculated by multiplying the per capita consumption of potatoes in West Bengal with the projected population of 2019-20
8. Per month consumption of potatoes in West Bengal multiplied by 4 months (in which potatoes goes directly in the wholesale mandis)

Table 1: **Percentage of losses that occurs in the traditional and modern cold storages in West Bengal**

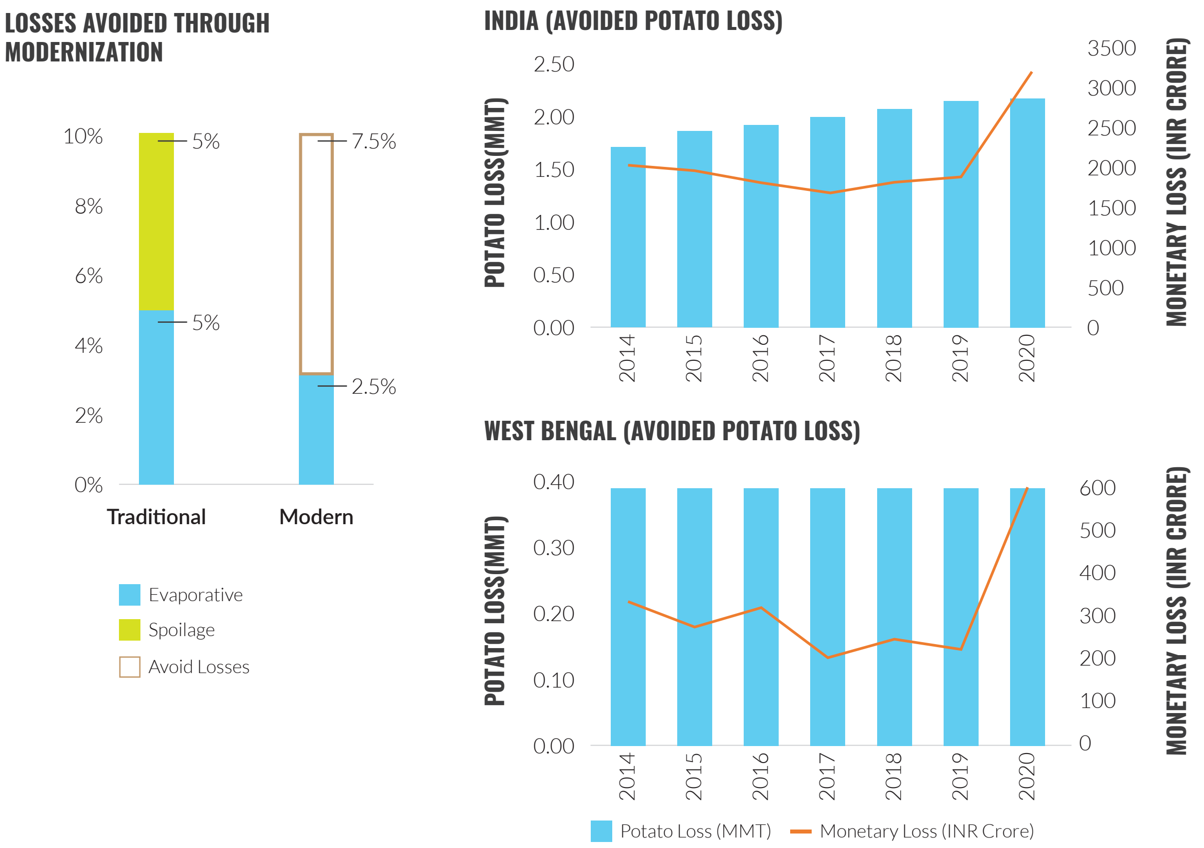
Seasons/Cold Storages	Evaporative (Weight Loss)		Spoilage		Total	
	Traditional	Modern	Traditional	Modern	Traditional	Modern
Mid-season (Jun-Aug)	4%	2%	4%	0%	8%	2%
End-season (Sep-Nov)	6%	3%	6%	0%	12%	3%
Seasonal average	5%	2.5%	5%	0%	10%	2.5%

Source: Authors' estimation based on extensive stakeholder consultation

Potato losses due to spoilage alone could be as high as 6% in the traditional bunker coil type cold storages by the end of the storage season. The seasonal average (assuming linear unloading) potato losses could be 10% in traditional cold storages, which is quite significant as losses in modern cold storages following correct handling practices and maintaining prescribed storage conditions amount to only 2.5%. It is estimated that a seasonal average evaporative loss of up to 5% is widespread in traditional cold storages. The evaporative losses could be reduced to up to 2.5% in modern cold storages. No spoilage losses occur in modern cold storages with state-of-the-art refrigeration systems and handling best practices as compared to over 6% in traditional cold storage units. It is estimated that there would be a 75% reduction in losses if traditional cold storage units are retrofitted to modern cold storages. A detailed description of the difference between a traditional and a modern cold storage facility is presented in section 5.

Around 32% of West Bengal's cold storages are more than 30 years old (Hansa Research Group 2014). Of the 514 cold storages existing in West Bengal in 2020, 95%[9] of cold storages are traditional bunker coil type, while the remaining 5% have modern refrigeration systems handling multiple commodities. The lack of modern cold storage technology is working against the potato farmers, leading to substantial quantitative[10] and monetary losses[11] while storing potatoes.

Figure 9: **Potato loss (volume and value) in cold storages, which could be avoided through modernization.**



9. As per the inputs from the West Bengal Cold Storage Association
10. The quantitative losses are estimated by "Number of potato cold storage x Average capacity of cold storage x 6.8 % (Potato loss which could be avoided through modernization)"
11. Monetary losses are estimated by "Potato loss (quantity) x Average wholesale prices of potatoes (December-March: Harvesting season of major potato growing states)"

The lack of modern cold storage units is working against the potato farmers in West Bengal, leading to financial losses amounting to the north of INR 200 crore every year. At a national level, financial losses of more than INR 2000 crores are reported every year since 2014 except in 2020, where losses increased to INR 3174 crore owing to an upswing in wholesale prices.

The Government of India has taken several measures to boost the number of cold storage units in India. The Government subsidizes and incentivizes the cold storage industry via the Mission on Integrated Development of Horticulture (MIDH) of the Ministry of Agriculture and Farmers Welfare. Financial Assistance of up to 35-50% of the allowable costs is provided to the stakeholders and promoters to construct, expand and modernize the cold storages. Details of the grant-in-aid assistance provided by the different Ministries/Government of India agencies can be found in Annexure I.

It is estimated that there would be a 75% reduction in losses if traditional cold storage units are retrofitted to modern cold storages.

5
KEY FINDINGS FROM THE FIELD ASSESSMENT

Detailed energy audits of three cold storage facilities in West Bengal were carried out with the following specific objectives:

- Understanding the cold storage utilization profile in MT: product-wise, season-wise
- Assessing the temperature, relative humidity and air circulation
- Evaluation of the refrigeration plant's energy consumption patterns and environmental performance
- Assessing the installation of controls and automation system in the refrigeration plant and evaluating the potential of such control systems as an energy efficiency measure
- Measuring and evaluating the thermal integrity of the building envelope by taking into account heat transfers and air leakages
- Energy performance baselining of the facility assisted with historical electricity bills/consumption statistics and measuring of the equipment performance levels
- Evaluation of refrigeration plant operations and maintenance practices
- Evaluation of electricity distribution system (power supply, sanctioned load, transformers, and diesel generator (DG) set requirements)
- Identification of the scope for renewable energy integration with solar rooftop

The details of the three cold storages in the Hooghly district of West Bengal, where the energy audits were conducted, are presented in Table 2 below:

Table 2: Details of three cold storages in West Bengal

	Facility #1	Facility #2	Facility #3
Year of establishment (age in 2020)	1987 (33 years)	1986 (34 years)	2010 (10 years)
Location (Climatic Zone)	Hooghly district of West Bengal (Warm and Humid)		
Cold Storage Capacity	9,500 MT	15,673 MT	16,200 MT
Commodity stored	Single commodity: Table Potatoes (Jyoti and Chandramukhi)	Multi-commodity: Table Potatoes (Jyoti and Chandramukhi), Processing Potatoes (for chips manufacturing), Maize, Chilli and Ground-nut	Multi-commodity: Table Potatoes (Jyoti and Chandramukhi), Processing Potatoes (for chips manufacturing), Chilli and Dhania
No. of chambers	2	14	14
Refrigeration plant	Reciprocating Ammonia compressors with gravity flooded system	Reciprocating Ammonia compressors with gravity flooded system	Reciprocating Ammonia compressors with gravity flooded system
No. of compressors (capacity)	7 (110TR X 2,100TR X 2, 80TR X 2, 65 TR)	7 (110TR X 2,100TR, 80TR X 2, 65 TR, NA)	5 (110TR X 2, 80TR X 2, 60 TR)
Evaporator	Traditional bunker coil	Hybrid of traditional bunker coil and modern ACUs	Modern ACUs
Ammonia flow control	Manual	Manual	Manual
Condenser	Atmospheric	Atmospheric	Atmospheric
DG Sets	2 Nos. (70 kVA and 110 kVA)	3 Nos. (63 kVA, 110 kVA and 250 kVA)	3 Nos. (15 kVA, 110 kVA and 250 kVA)
On-site PV	None	Rooftop PV of capacity 300 kWp with net metering	None
Automated material handling system	None	None	None
Strip Curtain	None	None	None
Air Curtain	None	None	None
Wall Insulation	Chamber 1: Fibre Glass; Chamber 2: Thermocol (EPS)	Varies from chamber to chamber: Thermocol (EPS) or PUF	Varies from chamber to chamber: Thermocol (EPS) or Fibreglass or PUF
Roof Insulation	Thermocol (EPS)	Fibre Glass	Fibre Glass
Door Insulation	PUF	Thermocol (EPS)	Thermocol (EPS)

Source: Energy Audit reports of the cold storages in West Bengal

5.1 BUILDING DESIGN

The majority of the State's cold storages catering to a single commodity, i.e., table potatoes, representing 95% of the total 514 nos., have legacy designs with mezzanine floors like Facility #1. However, the audited Facilities #2 and #3 are designed with multiple chambers for storing more than one commodity. As per NHB guidelines, a 5000 MT cold storage should have four chambers with a capacity of 1250 MT each, irrespective of whether it caters to one or more than one commodity.

As per NHB guidelines, a 5000 MT cold storage should have four chambers with a capacity of 1250 MT each, irrespective of whether it caters to one or more than one commodity.

5.2 BUILDING ENVELOPE

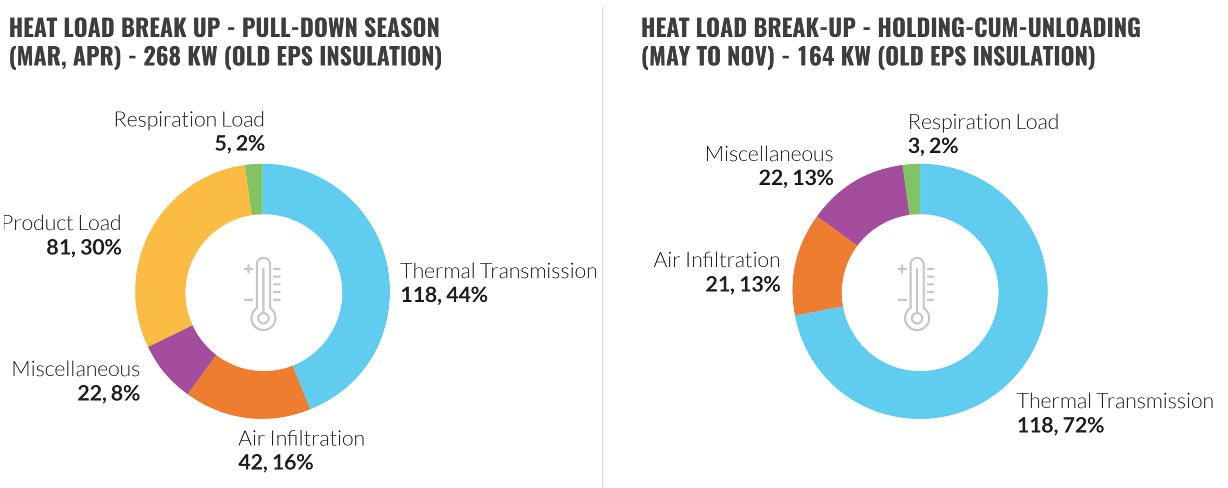
The thermal integrity of the building envelope was not appropriately maintained in any of the three audited facilities. The thermal performance of the walling and roofing material was inadequate, and air leakages were commonplace as a result of un-tended cracks in walls and on roofs. The air leakages led to condensation issues within the cold storages. Leakages from the cold room doors were also noted as the doors were kept open for long durations during loading and unloading. There was no provision for strip curtains or air curtains with the doors whose insulating properties were also inadequate.

Thermocol, i.e., Expanded Polystyrene (EPS), is the most common insulation material used for wall insulations. Roof insulation is created either with Fibre Glass or EPS. In the absence of a proper vapour barrier and natural contraction of EPS over time, most of these cold storages lose their insulation properties significantly due to moisture ingress and other wear and tear. EPS is also susceptible to damage by rodents and require continuous maintenance and patchwork.

Heat Load Calculations

A heat load break-up for a 5700 MT capacity chamber of Facility 1, showing a comparison of the pull-down season (Mar-Apr) with holding-cum-unloading season (May-Nov), is presented in Figure 10 below:

Figure 10: A heat load break-up for one of the chambers of Facility 1 for the pull-down season and holding-cum-unloading season



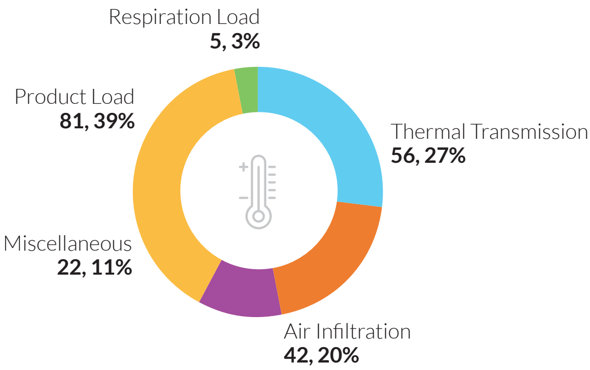
Source: Authors' estimation

NHB recommended values have been considered for the different heat load blocks in the absence of real-time site data. Thermal degradation in the insulating properties of EPS has been factored in when calculating the transmission heat gains from walls and roofs. The design thermal conductivity of EPS (0.036 W/m.K) may increase to 0.072 W/m.K over a period of 10 years. A 100 mm thickness of this degraded EPS will have a low R-value of 1.4 m2.K/W, providing very little resistance to conductive heat gains. During the pull-down season in March and April, the product load (30%) due to potato field temperature is the most significant load component after the thermal transmission (44%). During the holding-cum-unloading season from May to November, the product load decreases to zero. The thermal transmission load (which is the same in absolute terms) becomes the most significant contributor to the heat load at 72%. The air infiltration load also reduces to half in absolute terms during the holding-cum-unloading season as there is less frequent opening/closing of doors, unlike the pull-down season. The respiration load due to potatoes' breathing reduces slightly during the holding-cum-unloading season compared to the pull-down season. The miscellaneous loads due to lighting, equipment and people also remain the same in absolute terms.

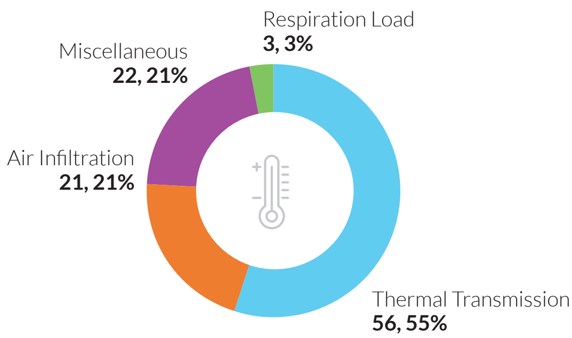
Figure 11 shows the same chamber's heat load with Polyurethane Foam (PUF) insulation for walling and roofing with a comparatively lower (improved thermal resistivity) thermal conductivity of 0.021 W/m.K. A 100 mm thick PUF panel provides an excellent thermal resistance with an R-value of 4.3 m2.K/W, as against 1.4 m2.K/W for the same thickness of a degraded EPS. With PUF insulation, the share of thermal transmittance load during the pull-down season reduces to 27% compared to 44% in the case of EPS insulation. During the holding-cum-unloading season, the share of thermal transmittance load reduces to 55% compared to 72% in the case of EPS insulation.

Figure 11: **Heat load for the same chamber with Polyurethane Foam (PUF) insulation walling and roofing with thermal conductivity of 0.021 W/mK**

HEAT LOAD BREAK UP - PULL-DOWN SEASON (MAR, APR) - 206 KW (PUF INSULATION)



HEAT LOAD BREAK UP - HOLDING-CUM-UNLOADING (MAY TO NOV) - 102 KW (PUF INSULATION)



5.3 PRODUCE HANDLING PRACTICES AND STORAGE CONDITIONS

Potato handling while sorting/grading, loading and unloading are done manually, which leads to an increase in spoilage. During the holding-com-unloading season, the potato bags are manually shifted/flipped in a sequential manner. Each potato bag changes its position at least twice during the season. This inefficient practice carried out to minimize the possible potato spoilage due to compression of bottom bags as well as inadequate air circulation, ends up damaging the potatoes due to physical shocks by improper manual handling of bags, as well as adds up additional heat load due to working staff and lighting operation. Modern cold storage, which can maintain the desired temperature, relative humidity and air circulation levels, obviates the need for flipping bags, thus minimizing handling and the associated damages.

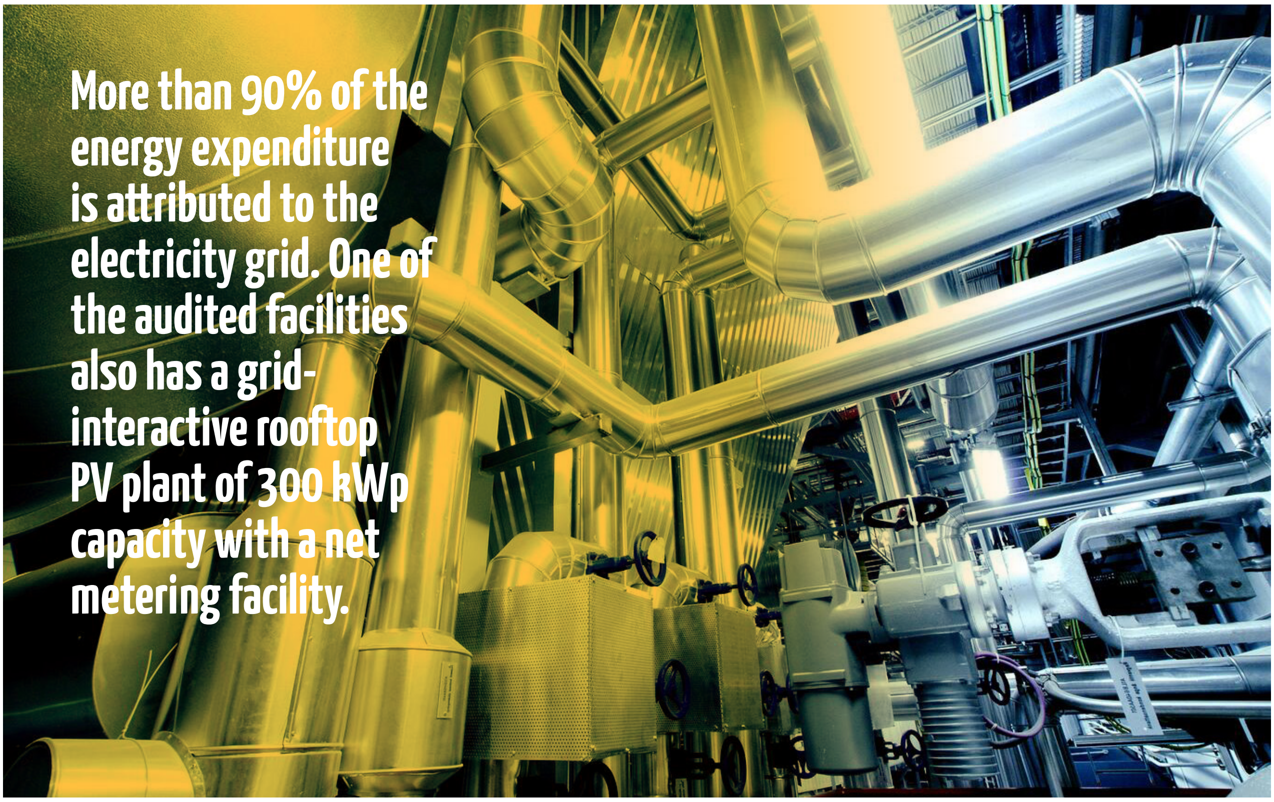
With traditional bunker coil systems and single chamber designs (mezzanine floors), the desired air circulation, temperature and humidity conditions are difficult to maintain. The storage and stacking pattern should accommodate space for adequate air circulation. Hot pockets are created due to potato respiration, adversely impacting the potato quality. A comparison of the monitored/observed storage conditions concerning NHB recommended levels are presented in Table 3 below. The mezzanine floor design hampers even distribution of cooling, which results in asymmetrical temperatures recorded across different floors. The lower floors are often susceptible to inadequate air circulation leading to heat built up, thus damaging the potatoes.

For most traditional cold storages catering to Table potato, ventilation requirements are met by opening a window on the roof and doors on the ground floor for 1-2 hours at 3-4 am early morning. This leads to massive heat gains due to infiltration, thus adversely impacting the refrigeration system's performance. CO2 extractors/scrubbers are only installed in cold storages catering to processed potatoes.

Table 3: **Comparison of the monitored/observed storage conditions with respect to the recommended levels**

	Facility 1- Table Potato	
	Monitored/Observed	Recommended (NHB guidelines)
Temperature (deg C)	1.7	1.5 to 2
Relative Humidity (%)	89	95%
CO2 level (ppm)	-	Loading: <4000; Holding: <2000
Air Circulation	-	Minimum 50 CFM/MT of potato
Light	Dark	Dark

Source: Authors' estimation based on energy audit data



5.4 REFRIGERATION SYSTEM AND CONTROLS

Ammonia-based gravity flooded refrigeration systems are the most common refrigeration plant configurations observed in West Bengal, mainly due to their cost-effectiveness, low maintenance expenditure, and easy availability of maintenance technicians. The refrigeration plant is typically run (operated manually) for only 4-6 hours per day, leading to suffocation of stored produce and deterioration of its quality.

Redundant compressor capacity is observed in many of the cold storages audited. The overall refrigeration system is generally designed based on non-standard engineering practices. Traditional bunker coil system with manual ammonia flow control is the most common evaporator configuration. A thick layer of ice gets accumulated over the tubes, thus hindering heat transfer. Many cold storages have started to replace bunker tubes with finned coil tubes, which is an improvement as it increases heat transfer area. However, the overall system remains non-standard, with no inbuilt functionalities for performance assessments. With a traditional bunker coil type of evaporator, it is impossible to precisely maintain desired temperature, relative humidity and air circulation levels. However, Facility #2 (partially) and Facility #3, which are multi-commodity cold storages, have standard fin-coiled evaporators called Air Cooling Units (ACUs). Automatic temperature-based ammonia flow regulation and isolation valves are not present in any of the facilities audited. Moreover, ammonia safety control valves are absent.

Analogue temperature and RH meters are generally installed in a few areas in cold storage. The operators manually regulate the ammonia flow based upon the temperature conditions maintained. None of the audited facilities has any CO_2 meters to check for any unwanted accumulation of CO_2 levels. It is recommended to have one sensor per 100 MT of storage (Univ. of Idaho study).

All three facilities have atmospheric condensers. The TDS level of condenser water is high, and there are algae deposits in the condenser water tank. Blowdown is conducted only once or twice a season, leading to both high TDS and algae formations.

5.5 ENERGY CONSUMPTION

Following Table 4 shows the three facilities' annual energy consumption and expenditure for 2018-19 and 2019-20. The average unit rate of electricity purchased from the Grid varies from INR 7 to 8 per kWh among the audited facilities, compared to the average unit rate for DG generation, ranging from INR 18 to 33 per kWh depending upon the specific energy generation of the DG sets. More than 90% of the energy expenditure is attributed to the electricity grid. One of the audited facilities also has a grid-interactive rooftop PV plant of 300 kWp capacity with a net metering facility. Around 10 Nos. of cold storages in the states have rooftop solar with net metering.

Table 4: **Annual energy consumption and expenditure for the three facilities for 2018-19**

S. No	Particulars	Unit	Facility #1		Facility #2		Facility #3	
			2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Energy Consumption								
1	Annual Energy Purchased & Consumed from Grid	kWh	5,85,712	4,41,249	8,15,685	7,62,920	4,74,255	6,46,150
2	Annual Energy Generated (by DG Sets) & Consumed	kWh	16,933	12,687	16,236	5,904	4,360	12,644
3	Annual Energy Consumed from Solar PV System	kWh	NA	NA	1,13,575	1,81,441	NA	NA
4	Total Annual Energy Consumption	kWh	6,02,645	4,53,937	9,45,496	9,50,265	4,78,615	6,58,794
Energy Expenditure								
5	Cost of Electricity Purchased from Grid	INR Lakh	40.6	32.1	62.2	55.0	34.7	48.3
6	Unit Rate of Electricity Purchased from Grid	INR/ kWh	6.9	7.3	7.6	7.2	7.3	7.5
7	HSD Purchased & Consumed	Litre	5,799	4,345	4,400	1,600	2,000	5,800
8	Cost of HSD purchased & Consumed	INR Lakh	4.0	2.9	3.0	1.2	1.4	4.2
9	Unit Rate of HSD Purchased & Consumed	INR/ Litre	68.1	67.8	68.0	73.0	68.0	73.0
		INR/ kWh	23	23	18	20	31	33
10	Total Annual Energy Expenditure	INR Lakh	44.6	35.0	65.2	56.2	36.1	52.6
Energy Use Intensity								
12	Design Capacity	MT	9,500	9,500	15,673	15,673	16,200	16,200
13	Energy Use Intensity	kWh/ MT	63	48	60	61	30	41

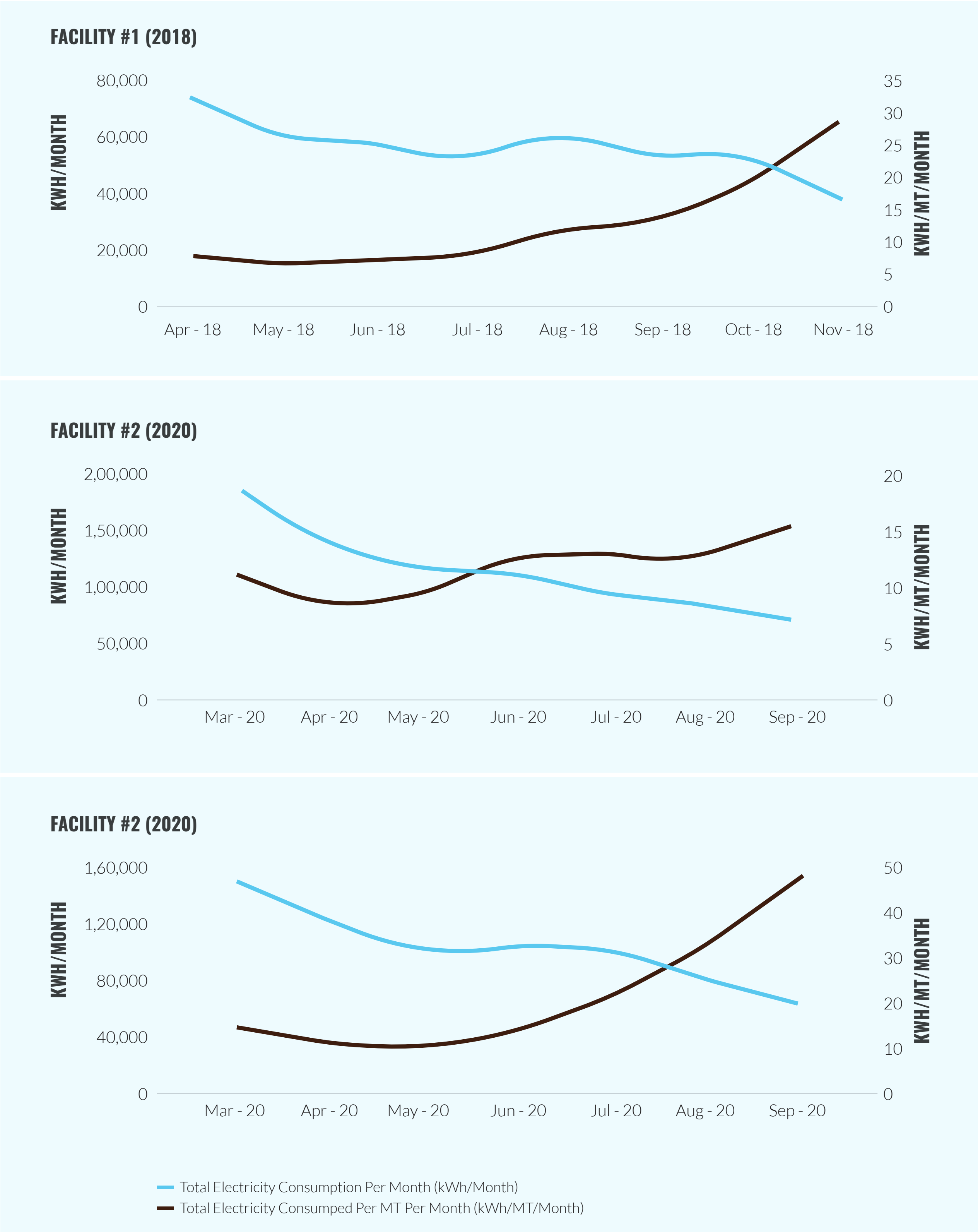
Source: Authors' estimation based on energy audit data

5.6 CORRELATION OF ENERGY CONSUMPTION WITH COLD STORAGE UTILIZATION

The monthly average potato load at cold storages varies seasonally. As noted earlier, the loading of the produce happens during March, and the unloading starts from May/June. The monthly energy consumption is based upon the current stock levels at the cold storage and is generally expected to reduce from May due to the part-loading or off-loading of the refrigeration system to match the reduced potato load demand.

However, it has been noted that the energy consumption per MT of potato (or other produce) per month has been increasing during the unloading-cum-holding season for all the three audited facilities. The design heat load for a potato cold storage in the Warm and Humid climate of West Bengal reduces by up to ~40% (Figure 12) in the holding-cum-unloading season, as compared to the pull-down season. This mismatch in the energy consumption per MT with the design heat load profile shows the huge infiltration losses occurring due to improper insulation leading to leakages in the walls, roof, and frequent opening of doors. The miscellaneous load can be attributed to cold storage staff manually unloading and shifting/flipping of potato bags, contributing to the additional heat loads during the holding-cum-unloading season.

Figure 12: **Energy consumption per MT of potato (or other produce) per month**



Source: Authors' calculation based on energy audit data

Note: The break up of total electricity consumed from Grid and DG is given in Annexure-II; The break up of total electricity consumed from Grid, solar and DG is given in Annexure III and IV

6

STANDARDIZED ENERGY EFFICIENCY MEASURES (EEM)

The EEMs have been worked out for a standard 5000 MT cold storage with four chambers of 1250 MT each. The EEMs are worked out in two broad heads:

1. Improving the thermal performance of the building envelope;
2. Optimizing the overall refrigeration system performance to match product load and seasonal variations.

As defined above, the broad EEM categories work seamlessly to improve overall energy performance while retaining the product quality at cold storages. The energy efficiency impact and the applicability of MIDH subsidy support also have been mapped for individual EEMs. The capital required to implement the aforementioned energy efficiency measures at individual cold storages is calculated to be around INR 233 Lakh (based on technical data and financial information received by various industry experts), which is partly paid for the MIDH subsidy. The energy-saving potential of the above measures is calculated to about 20-25% annually.

Table 5: Cost-Benefit Analysis of the Standardized Energy Efficiency Measures (EEM)

S. No.	Identified Intervention Areas	Proposed EEM	EE Impact	MIDH Subsidy	Investment	Energy Saving Potential			Simple Payback
					(lakh INR)	(%)	(kWh)	(Lakh INR)*	W (years)
1	Improving the thermal performance of the building envelope								
1.1	Wall and roof insulation	Replacement of existing EPS insulation with 100 mm PUF insulation panels with GI cladding on one side and Al foil on the other side	Reduction in thermal transmittance load from the building envelope; PUF manufacturing in environment-friendly as compared to EPS	Yes	110	overall 31% reduction in heat load with corresponding energy savings	1,54,060	12.3	10.2
1.2	Reducing infiltration load	Replacement of existing hinged doors with airtight horizontal insulated doors with air-curtains (20 Doors)	Reduction in heat transfer and air leakage through doors	Yes	16				

S. No.	Identified Intervention Areas	Proposed EEM	EE Impact	MIDH Subsidy	Investment	Energy Saving Potential			Simple Payback
					(lakh INR)	(%)	(kWh)	(Lakh INR)*	W (years)
2	Optimizing the overall refrigeration system performance to match product load and seasonal variations								
2.1	Compressor	Installation of VFD drive for reciprocating compressor	More efficient part load energy performance	No	8	7%	24,179	1.9	4.1
2.2	Atmospheric condenser	Replacement of atmospheric condenser with an evaporative condenser with SS coils including condenser pressure control valves	Condenser water pump motor capacity will be reduced from 12.5 kW to 8.2 kW (2.2 kW Pump + 6 kW Fan (2X3 kW each)) with a reduction in water consumption, i.e. lower drift losses	Yes	12	34%	19,393	1.6	7.7
2.3	Bunker coil	Replacement of existing bunker coils with SS fin coil evaporator including EE VFD fan and evaporator pressure control valves	Better air circulation, better product quality and lower ammonia leakages	Yes	42	-**	-	-	-
2.4	Gravity flooded system	Replacement of gravity flooded system with pump recirculation (over feed) system with ammonia pumps and flow regulating valves and controls	Increase the overall system efficiency through flow regulation to the evaporator and reducing the compressor running time	No	24	9%	44,431	3.6	6.8
2.5	PLC controller	Installation of PLC controller for T/RH management and optimizing the refrigeration plant performance for varying load conditions	Improve the overall system efficiency	Yes	10	4.5%	22,215	1.8	5.6
2.6	Subcooling with PHE	Installation of economizer for subcooling	Improve the evaporation efficiency through subcooling	No	2.5	5.5%	27,152	2.2	1.2
2.7	Suction line insulation	Improving the suction line insulation through Armaflex / PUF	To reduce the superheat, thus improving the overall system efficiency	No	8	3%	14,810	1.2	6.8
	Overall system efficiency				233	20 to 25%	3,06,240		

* @ ₹8/kWh
** Energy savings from the replacement of existing bunker coils with modern Air Cooling Units (ACU) has not been estimated

Source: Authors' estimation based on energy audit data and inputs from industry experts

Table 6 shows a prioritized list of EEMs based upon ascending payback periods after factoring in the MIDH subsidy support (up to 50% of the allowable cost) wherever applicable.

Table 6: Prioritized Energy Efficiency Measures (EEMs) factoring MIDH subsidy support

S.No.	Identified Intervention Areas	Proposed EEM	MIDH Subsidy Available	Investment	Investment after factoring MIDH subsidy*	Simple Payback with MIDH Subsidy
				(lakh INR)	(lakh INR)	(years)
1	**Subcooling with PHE**	Installation of economizer for subcooling for improve the evaporation efficiency	No	2.5	2.5	1.2
2	**PLC controller**	Installation of PLC controller for T/RH management and optimizing the refrigeration plant performance for varying load conditions	Yes	10	5	2.8
3	**Atmospheric condenser**	Replacement of atmospheric condenser with an evaporative condenser with SS coils including condenser pressure control valves for a reduction in energy and water consumption, i.e. lower drift losses	Yes	12	6	3.9
4	**Compressor**	Installation of VFD drive on reciprocating compressor for more efficient part-load energy performance	No	8	8	4.1
5	**Wall and roof insulation**	Replacement of existing EPS insulation with 100 mm PUF insulation panels with GI cladding on one side and Al foil another side for a reduction in thermal transmittance load from the building envelope	Yes	110	55	5.1
6	**Reducing infiltration load**	Replacement of existing hinged doors with airtight horizontal insulated doors with air curtains (20 Doors) for a reduction in heat transfer and air leakage through doors	Yes	16	8	
7	**Gravity flooded system**	Replacement of the gravity flooded the system with pump recirculation (overfeed) system with ammonia pumps and flow regulating valves and controls for better flow regulation, thus lower compressor run time	No	24	24	6.8
8	**Suction line insulation**	Improving the suction line insulation through Armaflex / PUF to reduce the superheat, thus improving the overall system efficiency	No	8	8	6.8
9	**Bunker coil**	Replacement of existing bunker coils with SS fin coil evaporator including EE VFD fan and evaporator pressure control valves for better air circulation, better product quality and lower ammonia leakages	Yes	42	21	-
	Total			**233**	**138**	

* Up to 50% of the admissible cost for select EEMs

Table 7 shows the state-level energy-saving potential, investment potential, and the monetary benefits from potato loss reduction through the modernization of potato cold storages in the State of West Bengal.

Table 7: Overall scenario for modernizing potato cold storages in West Bengal

S. No.	Parameter	Unit	Value
1	No. of Potato CS in the state (90% of total 514 Nos.)	Nos.	463
2	Avg. capacity per CS	MT	11,000
3	Avg. energy consumption per CS per year	kWh/year	7,50,000
4	Avg. Energy Expenditure per CS (@INR 8/kWh)	INR/year	60,00,000
5	Statewide energy consumption for potato cold storages per year	GWh/year	347
6	Statewide energy expenditure for potato cold storages per year	Crore INR/year	278
7	Investment potential for modernization per CS (of 11000 MT)	Crore INR	3.72
8	Avg. energy cost-saving potential per CS through modernization (@20-25%)	INR/year	13,50,000
9	Statewide investment potential for modernizing potato cold storages	Crore INR	1722
10	Statewide energy cost-saving potential through modernization	Crore INR/year	63
11	Statewide potato losses avoided through modernization	Lakh MT/year	3.8
12	Statewide monetary benefit from avoided potato losses (@wholesale price of INR 15,711/MT for 2020)	Crore INR/year	599

Source: Authors' estimation based on energy audit data

Note: CS- Cold Storage

Ad-hoc equipment replacement may not be of much value when attempting to improve the energy performance of legacy cold storage units. The correct way forward would involve formulating a cohesive modernization strategy for the entire cold storage regarding the refrigeration design and operational guidelines. The benefits of modernization will significantly outweigh the energy savings considered in isolation. Modernization will reduce food losses (weight losses and spoilage) and open up new revenue streams for the cold storage owners.

A modern multi-chamber cold storage can store various commodities, including fruits, vegetables and spices. Quantifying the benefits accrued to cold storage owners through diversification of products and improved net-capacity utilization is beyond the scope of this study; however, they are estimated to be significant in fiscal terms.

By implementing the above measures, cold storages in West Bengal can ideally save INR 599 Crore per season by avoiding waste and spoilage. The estimated energy savings (INR 63 Crore), coupled with the financial benefits of avoided food losses, can return the total investment of INR 1722 Crore in a short period of 2.6 years. The simple payback period will further reduce to 1.6 years, considering MIDH subsidy support of approximately 40% over the total investment requirement.

Table 8 below maps possible options for the recovery of EESL's investment

Table 8: Possible options for recovery of EESL's investment

Recovery of Investment	
Energy Savings	Very well established. Though energy efficiency gains are much smaller than non-energy benefits
Monetizing Avoided Food Losses	Measurement and Verification (M&V) framework to be established by EESL in coordination with West Bengal State Government
MIDH Subsidy	Can be directly transferred to EESL; facilitated through a tripartite agreement between MIDH, Cold Storage (owners) Associations and EESL
Better Space Utilization	The net capacity of modern cold storage can be increased by upto 20% through replacing the traditional bunker coil system. The capacity expansion will lead to additional revenue for the cold storages
Business Expansion	Modern multi-commodity cold storages will open up new revenue streams through the ability to store other high value horticulture produce. Assured market linkages, will in turn incentivize farmers to diversify their cropping patters

7

CONCLUSION AND WAY FORWARD

Fruits and vegetables are highly nutritious agricultural produce but have a short shelf life due to their delicate nature. They require care and proper post-harvest handling practices to minimize the quality deterioration while extending their shelf life. Cold chains can preserve the quality loss of perishables (and reduce loss) and increase the distance to which the produce can be economically transported. Gaps in cold chain infrastructure (including pack-houses and refrigerated transport) coupled with traditional refrigeration design and outdated operational methodologies employed at cold storages are the most significant contributor to food loss in India (Emerson, nd). Reduced food loss can lead to increased food security, reduction in hunger and malnutrition (Chauhan, 2020). Controlling food loss is a broader problem and is beyond the scope of individual farmers and consumers. Reduction of post-harvest food loss requires focused government intervention and pronounced action by all stakeholders in the cold chain sector.

In 2017-18, West Bengal was the second-largest horticulture producing State in India, growing approximately 15% of the country's total vegetables. Worryingly enough, an agrarian household's average annual farm income is the least in West Bengal compared to other states. There has also been a notable rise in the State's malnutrition index as the percentage of underweight children (under five years) have increased from 31.6% in 2015-16 to 32.2% in 2019-20, which is ironic given West Bengal's status as a food surplus state.

Considering all of the above, it is therefore imperative to invest in the cold chain infrastructure facilities. Cold storages play a vital role in post-harvest management functions, including the storage and distribution of perishable commodities and food products. Food loss at the storage level has several implications in West Bengal, where more than 95% of the farmers are either marginal or small. Food losses lead to an increase in food prices for the consumers and means lost income for the small farmers. Poor cold storage infrastructure affects the freshness and quality of the produce, leading to food losses and below par price realization.

The cold storage ecosystem in West Bengal is working in a controlled environment and has not been able to take off due to restrictive policies and regulations by West Bengal's Government.

Nationally, West Bengal ranks second in terms of cold storage capacity (5.9 MMT), 90% of which is utilized for storing potatoes. The majority of the cold storages in West Bengal are designed with a traditional single chamber with multiple mezzanine floors that do not provide the flexibility to store multiple products that are already grown or grown/sold in West Bengal. Different produce requires different storage conditions in terms of temperature and humidity levels, which the traditional single chamber cold storages are unable to cater to. As a result, storage for other fruits and vegetables are grossly inadequate. The lack of multi-commodity cold storages disincentivizes farmers from diversifying their cropping patterns.

Multi-commodity cold storage facilities can cater to various perishables such as fruits, vegetables, spices, et cetera. Modern multi-commodity cold storages will help the farmers diversify their horticulture crops and make seasonal adjustments without having to worry about suitable storage options. With separate chambers operating at different temperatures, these cold storages save cost, space and deliver high profitability with greater net capacity utilization. However, investing in a modern cold storage unit of about 5000 MT from scratch can cost up to INR 5 Crore (Mohite & Patil, 2020). Therefore, retrofitting-cum-modernization of the existing cold storages comes across as the next best cost-effective solution that offers better net-capacity utilization at lower capital and operational expenses.

It is assumed that modern cold storages will bring new marketing avenues by attracting the food processing industries back to West Bengal. A case in point worth mentioning is Gujarat, where a potato farmer nets INR 9.5 to 12.5 per kg by producing 1 kg of processed variety for the food processing industry. In contrast, by producing the table variety of potatoes in West Bengal, a farmer barely breaks even. Multi-purpose cold storages in West Bengal will encourage the farmers to diversify their crop production and focus on better quality production, thus yielding higher revenues.

The latest produce handling, energy management, automation and control technologies in the modern multi-purpose cold storages can help maintain the product's quality and minimize the losses attributed to human error. The freshness and shelf life of perishable commodities such as fruits and vegetables can be significantly increased by storing them in a controlled atmosphere by regulating the temperature, humidity and diluting the built-up of carbon dioxide levels. This process can delay the softening, evaporation, and quality changes of potatoes and other horticulture commodities.

Retrofitting-cum-modernization of the existing cold storages into multi-purpose one's will stretch the marketable time of potatoes for a longer duration and diversify the farmer's crop production.

To conclude, retrofitting-cum-modernization of the existing cold storages into multi-purpose one's will stretch the marketable time of potatoes for a longer duration and diversify the farmer's crop production. Modern cold storages can verily transform the lives and livelihoods of small and marginal farmers of West Bengal. It will help realize a more significant economic value for their produce. The modernization of cold storages will boost farmers' income in West Bengal and incentivize them to use modern equipment for agricultural production- a win-win situation for the farmers and the consumers.

West Bengal, a prominent horticulture producing state in the country, should set the pace for other states to follow. West Bengal Department of Food Processing Industries and Horticulture should develop a cold chain action plan outlining the approach and benefits of a modern, environment-friendly cold storage value chain in the State. The policy document should introduce state-level subsidy support to supplement the central MIDH as Viability Gap Finance to make the retrofitting-cum-modernization scheme financially viable.

7.1 PROPOSED NEXT STEPS

THE PROPOSAL FOR IMMEDIATE NEXT STEPS IS AS FOLLOWS:

1. Acceptance of the AEEE-EESL report by the West Bengal Department of Food Processing Industries and Horticulture
2. Submission of a project and financial proposal by EESL to the West Bengal Department of Food Processing Industries and Horticulture
3. Tripartite Memorandum of Understanding (MoU) between 1) EESL, 2) West Bengal Cold Storage (owners) Association and 3) West Bengal State Food Processing and Horticulture Development Corporation Limited
4. Expression of Interest (EoI) by Cold Storage owners/association followed by identification of individual cold storages and interventions
5. Signing of agreements followed by project execution
6. Recoveries and project closure

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ANNEXURES

Annexure I

A. Cost Norms & pattern Of Assistance for integrated post harvest management

S.No	Item	Cost Norms	Pattern of Assistance
Cold Storage (Construction, Expansion and Modernization)			
1	Cold storage units Type 1 - basic mezzanine structure with large chamber (of >250 MT) type with single temperature zone	INR 8000/MT (max 5000 MT capacity)	Credit linked back-ended subsidy @35% of the cost of project in general areas and 50% of cost in case Hilly and scheduled areas, per beneficiary.
	Cold Storage Unit Type 2 – PEB structure for multiple temperature and product use, more than 6 chambers (of < 250 MT) and basic material handling equipment.	INR 10,000/MT (max 5000 MT capacity)	Credit linked back-ended subsidy @35% of the cost of project in general areas and 50% of cost in case Hilly and scheduled areas, per beneficiary.
	Cold Storage Units Type 2 with add on technology for Controlled Atmosphere	Additional INR 10,000/ MT for add on components of controlled atmosphere technology. Details are as per Annexure I (b)	Credit linked back-ended subsidy @35% of the cost of project in general areas and 50% of cost in case Hilly and scheduled areas, per beneficiary.
2	Technology induction and modernization of cold-chain	Max INR 250.00 lakh for modernization of PLC equipment, packaging lines, dock levelers, advanced graders, alternate technologies, stacking systems, modernization of insulation and refrigeration, etc. Details are in Annexure I (b)	Credit linked back-ended subsidy @ 35% of the cost of project in general areas and 50% of cost in case Hilly & Scheduled areas, per beneficiary.

Source: Mission for integrated development of horticulture (Operational guidelines)

B. Admissible cost on the technology induction in cold chain and modernization of existing cold storage

S.No.	Item	Description	Admissible Cost
1	Programmed Logic Controller (PLC) equipment#@	Electronic and electrical logic controls for machinery and equipment for existing or new cold stores	50% of cost as per original invoice, maximum 10 lakh
2	Modernization of refrigeration@	For upgrading of evaporator system, compressor system	50% of cost as per original invoice, maximum INR 100 lakh @ INR 2500/ MT
3	Modernization of insulation@	For repair or modernizing of cold chamber insulation	50% of cost as per original invoice, maximum INR 100 lakh @ INR 1500/ MT

Note: # Other add-ons and @ Modernization

Annexure II

Total electricity consumed from Grid and DG in Facility #1

2018-19

Months	Total energy purchased and consumed from Grid (kWh)	Energy generated by DG sets and consumed (kWh)	Total energy consumed (kWh)
Apr-18	77,018	2,330	79,348
May-18	60,866	1,183	62,049
Jun-18	58,421		58,421
Jul-18	53,710	1,770	55,480
Aug-18	63,661		63,661
ep-18	54,051		54,051
Oct-18	56,287	1,989	58,276
Nov-18	38,053		38,053
Dec-18	25,650	2,581	28,231
Jan-19	5,133	2,380	7,513
Feb-19	4,509	2,354	6,863
Mar-19	1,02,895	2,351	1,05,246
Total	**5,85,712**	**16,936**	**6,17,191**

2019-20

Months	Total energy purchased and consumed from Grid (kWh)	Energy generated by DG sets and consumed (kWh)	Total energy consumed (kWh)
Apr-19	53,426	2,354	55,780
May-19	55,425		55,425
Jun-19	53,967	1,171	55,138
Jul-19	20,020	1,171	21,191
Aug-19	49,791		49,791
Sep-19	47,554		47,554
Oct-19	44,314	1,165	45,479
Nov-19	30,767	-	30,767
Dec-19	8,259		8,259
Jan-20	1,881		1,881
Feb-20	2,760	2,286	5,046
Mar-20	73,086	4,541	77,627
Total	**4,41,249**	**12,687**	**4,53,937**

2020-21

Months	Total energy purchased and consumed from Grid (kWh)	Energy generated by DG sets and consumed (kWh)	Total energy consumed (kWh)
May-20	50,847		50,847
Jun-20	52,519		52,519
Jul-20	52,650		52,650
Aug-20	49,388		49,388
Sep-20	37,418		37,418
Total	**2,42,821**	**-**	**2,42,822**

Annexure III

Total electricity consumed from Grid, DG, and roof top PV in Facility #2

2018-19

Months	Total energy consumed from Solar PV system (kWh)	Total energy purchased and consumed from Grid (kWh)	Energy generated by DG sets and consumed (kWh)	Total energy consumed (kWh)
Apr-18	13,630	1,07,260	5,166	1,26,056
May-18	12,931	93,480	-	1,06,411
Jun-18	10,266	81,040	-	91,306
Jul-18	9,825	95,410	3,690	1,08,925
Aug-18	9,959	83,400	-	93,359
Sep-18	11,211	95,950	3,690	1,10,851
Oct-18	11,738	63,115		74,853
Nov-18	9,142	33,485		42,627
Dec-18	6,830	9,485		16,315
Jan-19	4,200	4,710		8,910
Feb-19	2,251	2,495		4,746
Mar-19	11,592	1,45,855	3,690	1,61,137
Total	**1,13,575**	**8,15,685**	**16,236**	**9,45,496**

2019-20

Months	Total energy consumed from Solar PV system (kWh)	Total energy purchased and consumed from Grid (kWh)	Energy generated by DG sets and consumed (kWh)	Total energy consumed (kWh)
Apr-19	13,208	1,26,335	-	1,39,543
May-19	13,057	95,690	-	1,08,747
Jun-19	10,217	79,450	-	89,667
Jul-19	18,656	82,195	-	1,00,851
Aug-19	17,956	71,630	-	89,586
Sep-19	17,855	69,045	2,214	89,114
Oct-19	18,275	51,790	-	70,065
Nov-19	25,738	33,505	-	59,243
Dec-19	-	8,660	-	8,660
Jan-20	2,030	1,845	-	3,875
Feb-20	2,708	1,460	-	4,168
Mar-20	41,741	1,41,315	3,690	1,86,746
Total	**1,81,441**	**7,62,920**	**5,904**	**9,50,265**

Annexure IV

Total electricity consumed from Grid and DG in Facility #3

2018-19

Months	Total energy consumption from DG system (kWh)	Total energy purchased and consumed from Grid (kWh)	Total energy consumed (kWh)
Apr-18	1,744	70,470	72,214
May-18	0	50,300	50,300
Jun-18	0	57,945	57,945
Jul-18	1,308	53,595	54,903
Aug-18	0	47,250	47,250
Sep-18	1,308	41,660	42,968
Oct-18	0	29,630	29,630
Nov-18	0	16,355	16,355
Dec-18	0	7,085	7,085
Jan-19	0	2,585	2,585
Feb-19	0	8,445	8,445
Mar-19	0	88,935	88,935
Total	**4,360**	**4,74,255**	**4,78,615**

2019-20

Months	Total energy consumption from DG system (kWh)	Total energy purchased and consumed from Grid (kWh)	Total energy consumed (kWh)
Apr-19	0	93,485	93,485
May-19	3,488	87,770	91,258
Jun-19	0	71,165	71,165
Jul-19	0	61,905	61,905
Aug-19	0	56,025	56,025
Sep-19	2,180	49,280	51,460
Oct-19	0	40,345	40,345
Nov-19	0	22,835	22,835
Dec-19	0	7,400	7,400
Jan-20	0	4,360	4,360
Feb-20	0	7,175	7,175
Mar-20	6,976	1,44,405	1,51,381
Total	**12,644**	**6,46,150**	**6,58,794**

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