COLD CHAIN ENERGY EFFICIENCY IN INDIA

Analysis of Energy Efficiency Opportunities in Packhouses

Bureau of Energy Efficiency, Ministry of Power, Govt. of India

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ESMAP
Energy Sector Management Assistance Program

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The report was commissioned by the World Bank, as part of a collaboration with the Bureau of Energy Efficiency (BEE) and was funded by the Energy Sector Management Assistance Program (ESMAP). Primary research and analysis presented in the report was undertaken by the Alliance for an Energy Efficient Economy (AEEE), who were engaged as consultants for this assignment, with oversight and contributions from the staff and consultants of the World Bank and BEE.

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This report was prepared by a team of World Bank staff and consultants, as part of a collaboration with the Bureau of Energy Efficiency, represented by Abhay Bakre, Director General, Arijit Sengupta, Director, and Sumit Mudgal, Project Engineer. The World Bank task team that worked on this activity comprised Defne Gencer, Sandhya Srinivasan, Ashok Sarkar, Martina Bosi, and Arvind Jhamb. AEEE project team was led by Satish Kumar, and its members included Tarun Garg, Sneha Sachar, Sandeep Kachhawa, Gerry George, Anukriti Pathak, and Rajagopal Sivakumar. Professor Pawanexh Kohli served as a senior advisor to the study team, and provided continued technical guidance and advice from the inception stage to its conclusion.

The activity was initiated at the request of the BEE in early 2019. The study team greatly appreciates the cooperation from various institutions and entities in India, including the Ministry of Power, BEE, Ministry of Agriculture and Farmers' Welfare, Ministry of Food Processing Industry, Ministry of Environment, Forest and Climate Change, NITI Aayog, Agricultural and Processed Food Products Export Development Authority, State Horticulture Boards, State Agriculture Marketing Boards, State Designated Agencies, Small Farmers Agri-Business Consortiums, ICAR-CIPHET, NIFTEM, ISHRAE, industry representatives, and packhouse owners and operators. Representatives from these key stakeholders generously shared their experience and offered insights starting from the initial stages of this study, and continued through the preparation of early drafts, and during consultation workshops held in New Delhi in October and November 2019. These consultations were further complemented by virtual stakeholder consultations carried out with key Government of India agencies from November 2020 to February 2021. The diverse set of inputs and comments collected through the stakeholder engagement process informed the study, and main insights were incorporated into the final report. In addition, the study benefitted from discussions with and technical advice received from other World Bank colleagues, including Adarsh Kumar, Mary-Ellen Foley, and Viraj Vithoontien. The team is thankful to Shaukat Javed and Ritika Rodrigues for the administrative and client service support provided throughout the activity. Finally, the team wishes to acknowledge support from World Bank management for their continuing support to this study, including Mr. Junaid Kamal Ahmad, World Bank India Country Director; Demetrios Papathanasiou, Global Director for Energy; Simon Stolp, South Asia Energy Practice Manager; and Rohit Khanna, Program Manager for ESMAP, which provided valuable technical and financial resources for this activity.

ESMAP is a partnership between the World Bank and 18 partners to help low and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing

and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets.

FOREWORD FROM BUREAU OF ENERGY EFFICIENCY

A good distribution system is required to address the missing links in the cold chain infrastructure at farm levels like packhouses and transportation through reefer vehicles, to integrate the cold chain, and thereby minimise the loss to perishable produce. Creating an energy-efficient integrated system supported with innovative business models will benefit different stakeholders, especially farmers in India. There is an excellent opportunity to integrate energy efficiency in packhouses as more than 90% of the stock is yet to be built. It is important to have application-based and consumer-centric solutions to promote energy efficiency in the cold chain sector.

The Bureau of Energy Efficiency (BEE) under the aegis of Ministry of Power is already supporting the development of several policies to promote energy efficiency in India like Standards and Labelling (S&L) for appliances, Perform, Achieve and Trade (PAT) Scheme for industries, Energy Conservation Building Code (ECBC) and carrying out capacity building programs for Government institutions. Given the importance of cold chain sector in India, BEE and the World Bank's Energy and Extractives Global Practice with support from Energy Sector Management Assistance Program (ESMAP), collaborated for this study on the assessment of energy efficiency potential and development of regulatory tools for promoting energy efficiency in packhouses.

A three-way approach covering appliance, building and the overall plant is needed for any energy efficiency policy development. For packhouses, BEE will use the recommendations of this study to start with the appliance approach where specific equipment is addressed in terms of technology, benchmarking and monitoring. The findings shall also work as a basis for further policy analysis.

I congratulate the World Bank, ESMAP, and AEEE team for preparing this first of its kind report that will fill a very important gap in the cold chain segment. I am sure this document will be extremely valuable and relevant publication, that will go a long way in achieving the objective of farmers welfare in India while reducing food loss and improving food quality and security.

Abhay Bakre
Director General
Bureau of Energy Efficiency

FOREWORD FROM THE WORLD BANK

Given the significance of agriculture in India's economy, the development of an integrated cold chain is critical for improving farmers' livelihoods, reducing avoidable post-harvest food loss and waste, and ensuring the sustainability of the entire agricultural value chain from the farmer to the consumer. The development of a robust infrastructure can provide important market linkages and ensure food security but will also be a major driver in supporting the objectives of Government of India's Doubling Farmers' Income initiative (DFI). While some key elements of cold chain infrastructure in India have been mostly built up, such as cold storages and refrigerated warehouses, other parts of an uninterrupted cold chain – pack houses, reefer transport and ripening chambers – are yet to be built.

India's rapidly growing cooling demand is expected to grow significantly over the next decades, driven by space cooling, cold chain, refrigeration and transport air conditioning. Meeting the country's increasing cooling needs will require more energy, with a corresponding impact on power generation capacity, system peak load and greenhouse gas (GHG) emissions. The 2019 India Cooling Action Plan (ICAP) is recognized as many in the international community as an exemplary initiative that seeks to provide an integrated vision for managing, reducing and meeting India's cooling needs.

In view of the strategic significance of the cold chain sector, and the anticipated capacity additions in the coming years, which in turn can lead to substantial additional energy needs, the World Bank has partnered with the Bureau of Energy Efficiency (BEE) to explore policy and regulatory options for promoting energy efficiency in the cold chain. As a quasi-regulatory authority under the Ministry of Power, BEE has an important role to play in supporting the advancement of energy efficiency in India.

This study, funded by the Energy Sector Management Assistance Program (ESMAP), focuses on packhouses as the entry point into the cold chain, and the least developed segment where the biggest capacity addition is anticipated in the next two decades. According to estimates by the Ministry of Agriculture and Farmers' Welfare and its National Centre for Cold Chain Development, the number of packhouses in India is expected to grow from about 500 at present to 55,000 in the next decade and to 125,000 by 2038, with an associated growth in energy consumption from 2.4 TWh and 5.2 TWh, over the same period. The study provides an overview of the current institutional, policy and development landscape in packhouses in India, draws insights from site visits to a sample of packhouses in different agro-climatic zones across the country, and identifies options for energy efficiency improvements. The study concludes with policy and regulatory options that the BEE could consider for incentivizing energy efficiency in this sector.

Given the complexity of the topic, and the diversity of actors involved, it is clear that any solution to building an efficient and sustainable integrated cold chain in India will also involve a multi-sector solution, involving collaboration among various sector stakeholders. In this context, coordination and forward thinking are key.

We thank the Ministry of Power and BEE for their collaboration on this activity, and appreciate the contributions from important stakeholders, especially the Ministry of Agriculture and Farmers' Welfare and the Ministry of Environment, Forests and Climate Change. The World Bank is committed to supporting India on this important topic and looks forward to future collaboration.

Junaid Kamal Ahmad
Country Director
World Bank in India

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ABD	Agribusiness Development
ACA	Additional Central Assistance
AEEE	Alliance for an Energy Efficient Economy
AMC	Annual Maintenance Contract
APEDA	Agriculture and Processed Foods Export Development Authority
APMC	Agricultural Produce Market Committee
BEE	Bureau of Energy Efficiency
CA	Controlled Atmosphere
CII	Confederation of Indian Industry
DAC&FW	Department of Agriculture, Cooperation & Farmer's Welfare
DFI	Doubling of Farmers' Income
DG	Diesel Generator
EA	Energy Auditors
ECBC	Energy Conservation Building Code
EEMs	Energy efficiency measures
EEV	Electronic expansion valves
EM	Energy Managers
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agriculture Organization
FAR	Floor Area Ratio
FPO	Farmer Producers' Organizations
GCCA	Global Cold Chain Alliance
GDP	Gross Domestic Product
GHG	Greenhouse Gas

GoI	Government of India
GST	Goods and Services Tax
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HMNEH	Horticulture Mission for North East and Himalayan States
HVAC	Heating, ventilating, and air conditioning
ICAP	The India Cooling Action Plan
ICAR	Indian Council of Agricultural Research
ICT	Information Communication Technology
INR	Indian Rupee
ISA	International Solar Alliance
ISAM	Integrated Scheme for Agricultural Marketing
ISHRAE	Indian Society of Heating, Refrigerating and Air Conditioning Engineers
kW/MT	KiloWatt/Metric Tonne
kWh/MT	KiloWatt-Hour/Metric Tonne
MBBL	Model Building Bye-Laws
MEPS	Minimum Energy Performance Standards
MHE	Material Handling Equipment
MIDH	Mission for Integrated Development of Horticulture
MNRE	Ministry of New and Renewable Energy
MoA&FW	Ministry of Agriculture & Farmers' Welfare
MoCI	Ministry of Commerce and Industry
MoEF&CC	Ministry of Environment, Forest & Climate Change
MoFPI	Ministry of Food Processing Industries
MoHUA	Ministry of Housing and Urban Affairs
MoP	Ministry of Power
MP	Montreal Protocol
MRIN	Marketing Research and Information Network
MSAMB	Maharashtra State Agricultural Marketing Board
NCCD	National Centre for Cold chain Development
NCDC	National Cooperative Development Corporation

NHB	National Horticulture Board
NHM	National Horticulture Mission
NIAM	National Institute of Agricultural Marketing
NIFTEM	National Institute of Food Technology Entrepreneurship and Management
NPC	National Productivity Council
NWR	Negotiable Warehouse Receipt
O&M	Operation and maintenance
ODP	Ozone depleting potential
ODS	Ozone Depleting Substances
PAGREXCO	Punjab Agri Export Corporation Limited
PCM	Phase change material
PDF	Project Development Facility
PLC	Programmable Logic Controller
PMKSY	Pradhan Mantri Kisan SAMPADA Yojana
PMS	Periodic maintenance schedule
RKVY	Rashtriya Krishi Vikas Yojana
S&L	Appliance Standards and Labelling
SAGF	Strengthening of Agmark Grading Facilities
SDAs	State Designated Agencies
SDG7	Sustainable Development Goal 7
SFAC	Small Farmers Agribusiness Consortium
SHM	State Horticulture Missions
VCA	Venture Capital Assistance
WBG	World Bank Group
WDRA	Warehouse Development and Regulatory Authority

Conversions

1 lakh = 100,000

1 crore = 10 million

EXECUTIVE SUMMARY

Food waste represents a loss of value, avoidable greenhouse gas (GHG) emissions, and a challenge to food security. India is the second largest producer of fruits and vegetables in the world. The country's horticultural produce output stood at ~312 million tonnes from an area of ~25 million hectares in 2017-18[1], of which 1% was exported. There are varying estimates of post-harvest food losses for fruits and vegetables across India[2]. A comprehensive study conducted by the Indian Council of Agricultural Research (ICAR) estimates that in the case of fruits, overall losses range from 5.8% to 18% while in the case of vegetables this range is between 6.8% to 12.98%[3]. The food loss that occurs post-harvest and before connecting to markets, due to the inadequate and inefficient cold chain infrastructure, is effectively a loss of saleable volume and value. It is therefore an economic burden on the food supply system, in addition to leading to avoidable energy use and direct as well as indirect GHG emissions for the country.

Cold chain infrastructure can reduce food waste, preserve quality and increase shelf life of perishable goods. The Government of India, recognizing the importance of the cold chain sector, has formulated multiple missions, schemes and committees under the Ministry of Agriculture and Farmers' Welfare. The inter-ministerial committee on Doubling of Farmers' Income (DFI) has emphasized the importance of agri-logistics, of which some cold chain components could also be a part, which would form the backbone of future agricultural development as part of reforms in the market architecture. The India Cooling Action Plan (ICAP), launched in March 2019, projects significant growth in cold chain infrastructure development. This is an opportune time to reflect on measures that could ensure a sustainable trajectory for India's cold chain development.

Cold chain forms a critical link between farm and market. An integrated cold chain is critical for connecting farmers to markets near and far, allowing them to extract more value from their produce, and helping improve their livelihoods, while reducing post-harvest food loss and waste. A packhouse is the first step in the cold chain infrastructure, and a key element of value chains for produce for which maintaining cold temperature is a necessity. While cold chain infrastructure can preserve quality of the produce, it cannot reverse any damage or quality loss that happens before the produce reaches the first point of cold chain. Therefore, pre-cooling the produce to ensure early removal of field heat is one of the most critical steps for preserving quality and extending the shelf life of produce. In this context, packhouses have

1 MoA&FW. 2018. Horticultural Statistics at a Glance 2018. [online] Available at: <http://agricoop.nic.in/sites/default/files/Horticulture%20Statistics%20at%20a%20Glance-2018.pdf>.

2 Depending on the study, data source and methodology used, estimates range from around 6 percent on the low end to 25% high side in India.

3 MoA&FW. 2017. Report of the Committee for Doubling Farmers' Income: Volume III. [online] Available at: <http://farmer.gov.in/imagedefault/DFI/DFI%20Volume%203.pdf>.

a critical role to play – in addition to serving as collection centres for fruits and vegetables prior to distribution and marketing, they provide preparatory functions such as sorting, grading, washing, drying, packaging, pre-cooling, etc, which are essential to support downstream processing of produce.

India's packhouse infrastructure is expected to grow significantly in the coming years. There were about 500 packhouses across the country in 2019, while ICAP estimates that ~55,000 packhouses will be developed over 2027-28. While actual trajectory of packhouse infrastructure development may vary depending on several factors such as market dynamics, consumer demand, and uptake of government policies, the estimates suggest that much of the investment for meeting the demand for packhouses is yet to be made. This presents an excellent opportunity for early action to ensure that packhouse infrastructure development happens in a resource-efficient and sustainable manner.

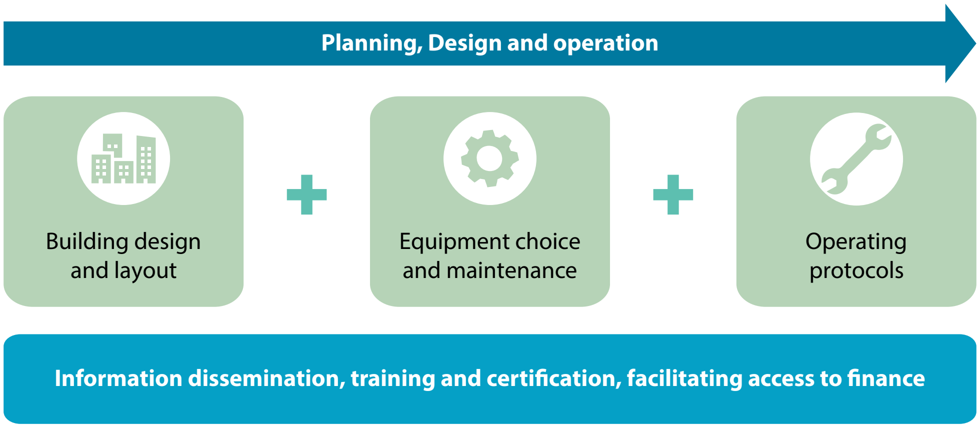
The maintenance of required conditions in cold chain infrastructure is energy intensive. The cold chain requires strict temperature control to maintain the safety and quality of produce. In addition to energy use, refrigeration and air conditioning also require refrigerants which result in GHG emissions that are significantly more potent than carbon dioxide. ICAP estimates that energy consumption by packhouses alone could grow from 2.4 TWh in 2017-18 to 5.2 TWh by 2037-38, while energy consumption from cold storage warehouses could grow from about 4.5 TWh to 4.9 TWh over the same period, in its reference scenario.

With careful design choices, cold chain infrastructure can deliver the same level of service with lower energy consumption and GHG emissions. Choosing the right equipment for functions such as pre-cooling, refrigeration, sorting, and packing can reduce energy demand and the use of low global warming potential (GWP) refrigerants can limit adverse environmental outcomes. In addition to equipment-level efficiency, the design of the building and use of appropriate materials can improve insulation, and system and process layout optimization can further reduce overall refrigeration demand. Other factors such as preventive maintenance of equipment and following proper protocol for performing operations and handling produce also contribute to improving energy efficiency.

Cold chain infrastructure development in India is governed by several institutions at the central, state and local level. Over the last decade, various infrastructure development and financial assistance schemes have been launched by the Ministry of Agriculture & Farmers' Welfare (MoA&FW), Ministry of Food Processing Industries (MoFPI), and Ministry of Commerce and Industry (MoCI), including the Mission for Integrated Development of Horticulture (MIDH), Pradhan Mantri Kisan SAMPADA Yojana, and the financial assistance scheme of Agricultural and Processed Food Products Export Development Authority (APEDA) under the supervision of the respective line ministries. The National Centre for Cold chain Development (NCCD) is an autonomous body under the MoA&FW to promote and develop an integrated cold chain in India for perishable agriculture and horticultural products, including perishables from allied sectors. While there are various efforts in place under the existing institutional arrangements, there is opportunity to directly tackle energy and environmental aspects in a holistic way, through coordination and collaboration.

Recognizing the potential scale of cold chain infrastructure development in India and the need for a holistic approach on different development pathways, the BEE and the World Bank have collaborated on a study on energy efficiency in the cold chain. The specific focus

Figure 1: Measures to enhance energy efficiency in packhouses



of the study, which was funded by ESMAP, was chosen to be packhouses, as the segment of the cold chain that is expected to see the most significant capacity addition over the next two decades, according to currently available projections. Accordingly, the objective of the study was to support BEE in developing policy and regulatory options for enhancing energy efficiency in packhouses in India. To this end, the study comprised three main tasks, namely stocktaking and initial assessment, in-depth data collection and analysis, and development of policy and regulatory recommendation for action by BEE, in coordination with other stakeholders.

Primary and secondary research carried out under this study indicates that there is untapped potential for energy performance improvement in packhouses. Under this study, site visits to 21 packhouses across six states – Maharashtra, Haryana, Uttar Pradesh, Punjab, Tamil Nadu, and Himachal Pradesh – covering different varieties of fruits and vegetables, major agro-climatic zones for horticultural produce in India, and different types of packhouse ownership models including private, state government, and cooperative societies – were conducted to assess current energy efficiency practices and examine the potential for future improvements. A mapping of design and operational energy performance indicators, in terms of connected load intensity (kW/MT) and energy use intensity (kWh/MT), respectively, was carried out for the surveyed packhouses handling different fruits (grape, apple, mango, banana, kinnow) and vegetables. Findings from the site visits, energy performance assessments, and stakeholder consultations[4] helped identify the key issues that can be addressed to enable adoption of energy efficiency practices and measures in the design, development, and operation of packhouses.

There is opportunity for early action to guide energy use and incentivize energy efficiency improvements in packhouse infrastructure in multiple levels. This study makes recommendations on specific policy and regulatory measures related to building design and layout, equipment choice, and operation and maintenance processes, as well as around information dissemination, training and certification, and facilitating access to finance. Some examples are highlighted below, and further detailed across the study.

4 Stakeholders consulted include packhouse owners, operators, design consultants, equipment manufacturers, system integrators, industry associations, start-ups and emerging agri-entrepreneurs, academic institutions, representatives from central and state governments, government think tanks, other national and international cold chain experts.

Establishing guidelines for operation and maintenance of packhouses are priority actions that have the potential to influence existing and new packhouses across India. These guidelines can draw on applicable codes and laws such as ECBC, Model Building Bye-Laws (MBBL), as well as relevant guidelines and best practices from various initiatives of agencies in the energy and agriculture sectors. The experience with developing and implementing national energy efficiency policies highlights the need for alignment across different schemes and early consultation across relevant ministries and broad-based engagement with key stakeholders across the cold chain sector. These guidelines can eventually be incorporated to existing Government schemes under MoA&FW, MoFPI and MoCI, where over time, recipients of support can be required comply with the energy efficiency specifications for packhouses can increase the adoption of the guidelines and facilitate greater integration across initiatives.

Providing clear guidance on design and material selection for the packhouse building can guide the development of new infrastructure and enable energy efficiency to be built in from the ground level. The study findings highlight the need for addressing energy efficiency improvements at multiple levels when designing a new packhouse and/or operating an existing one. Energy efficiency considerations can be incorporated at the design and planning stage, for example, in decisions related to orientation, natural lighting, insulation and shading of wall and roof. These first principle-based building design considerations not only reduce the cooling load of the facility, but also enhance thermal and visual comfort for packhouse operators and workers, and, as such could have positive implications for overall productivity. Selecting appropriate building materials for roofing and walling can minimize solar heat gains arising from the high temperature difference between the outdoors practices and indoors. At present, the Energy Conservation Building Code (ECBC) specifies the thermal performance of the wall and roof, which can also be adapted for building materials to be selected for the construction of packhouses. In addition to the external building envelope, the walls, ceiling and flooring of all temperature-controlled areas such as pre-cooling, staging, and cold rooms should be selected with high thermal resistance to minimize heat ingress, especially where there is direct exposure of walls/ceiling to hot outdoor conditions.

Suitable equipment selection and measures to ensure operational efficiency are critical factors. Ensuring that the layout of the packhouse facility focuses on optimal flow of produce and operations can bring efficiency to the functioning of the packhouse by minimising people movement and reducing the duration of exposure of the produce to high temperatures, thereby reducing the refrigeration load and increasing shelf life. Refrigeration systems for pre-cooling and staging cold room applications can be designed and selected to maintain the appropriate level of cooling while managing adverse environmental impacts from energy use as well as refrigerant choice. Wherever possible, low energy cooling solutions such as evaporative cooling should be deployed, especially for the packaging hall area. A periodic maintenance schedule should be specified and rigorously followed for efficient operation and maintenance of all packhouse energy systems. Packhouse process design for functions such as cleaning, sorting and grading, fruit-specific treatment, packaging, palletisation, etc. should follow good practice and incorporate energy efficiency considerations.

Enhancing awareness is essential for the success of these proposed measures. A lack of awareness about energy use implications of design, development and operational aspects of packhouses among packhouse owners and operators, and their overall lack of familiarity with energy efficiency solutions available were found to be one of the most important challenges. To bridge the information gap and incentivize the adoption of energy efficient practices by market participants, BEE in collaboration with MoA&FW and its associated institutes, and relevant industry associations, could work towards enhancing awareness about energy efficiency in post-harvest management. BEE could guide the development of tip-sheets on the benefits of energy efficiency in post-harvest management, product catalogues for building material and equipment, a directory of design consultants, and an online portal for information dissemination. BEE can also support demonstration projects to showcase energy efficiency benefits in packhouses and implement a targeted awareness campaign to engage with packhouse owners and operators using popular media such as radio and television to increase visibility. In addition, there is a need for the development of training and certification programs for farmers, packhouse operators, O&M technicians, and design consultants. Institutions such as MoA&FW and its institutes, MoEFF&CC, industry associations, private sector entities, and others may be able to provide valuable inputs toward the development of training and certification programs tailored to the needs of various stakeholders. BEE may also consider integrating cold chain energy efficiency in its National Examination for Certification of Energy Managers and Energy Auditors to expand the skillsets of these professionals.

BEE's standards and labelling program has been effective in incentivizing the use of efficient equipment. Considering the scale of cold chain pack houses to be built in the coming years, the potential energy requirements of those facilities, and the evident opportunity to improve energy efficiency of the cooling systems, BEE may consider expanding its successful standards and labelling program to include pre-cooling and staging cold room refrigeration equipment. Informed by ICAP, recent efforts on the ground in India and around the world, a combined energy and refrigerant use metric may be considered for the labels for such cold room and pre-cooling equipment. Implementation strategies such as linking existing financial incentives with labelling requirements, incorporation of labels in public procurement guidelines, and supporting buy-back or replacement of existing equipment with efficient, labelled alternatives can catalyze demand for labelled equipment in existing and new packhouses.

Energy-use data can facilitate energy performance benchmarking of packhouse buildings. Due to the unique nature of a packhouse building, specific indicators are required for energy performance benchmarking. Energy-use data collection is the first step in the development of an additional set of benchmarks. The inclusion of data disclosure requirements within existing schemes such as MIDH and APEDA could facilitate data collection. BEE could also develop a star rating program for packhouse facilities based on energy performance benchmarks for different categories, depending on the type of produce handled. The state level implementing entities – State Designated Agencies (SDAs) – associated with BEE can play a key role in coordinating with the respective state horticulture agencies as well as packhouse owners and operators to collect energy-use data for effective formulation of benchmarks.

Collaborative effort across various ministries is required to ensure energy efficiency. It is clear that a holistic program of action on improving energy efficiency in packhouses, and the broader cold chain, will require a multi-stakeholder approach. While the study primarily focuses on recommendations for BEE to take action on areas within its authority, some recommendations will require related action in areas where the primary responsibility rests with other agencies, MoA&FW and MOEF&CC in particular, as per the allocation of rules of business of the Government of India. It is recommended that BEE leverages opportunities for collaboration and coordination, and in that context takes advantage of ongoing platforms, including the cold chain thematic group formed for the implementation of ICAP, where MoEF&CC was assigned a coordination role. The recommendations formulated under the study recognize overlapping issues that would require coordination across ministries and state governments, as well as other stakeholders, such as industry, farmers, investors, and think tanks.

This study lays the foundation to further explore energy efficiency opportunities across the cold chain. This is one of the first studies for BEE to explore actions towards energy efficient and climate-friendly development of the cold chain infrastructure in India. While this study focuses on energy efficiency in packhouses, it is important to consider the development of and linkages with other segments of the cold chain. The study approach, findings, and proposed recommendations could potentially be replicated for other segments of the food cold chain, and even the immunization cold chain, which is garnering increasing attention. The suggested framework for the development of O&M protocols, guidelines on energy efficient design and equipment selection, standards and labelling, along with energy-use reporting and benchmarking could be adapted for cold storages and ripening chambers for agriculture and allied sectors. The recommendations could be equally applicable and beneficial to walk-in freezers, walk-in coolers, or ice-lined refrigerators employed in the immunization supply cold chains for vaccine deliveries. Furthermore, the recommendations on enhanced awareness and training and certification would be most effective when integrated with other cold chain components. Energy efficiency and environmental management should be considered as a prerequisite in the design and delivery of the entire post-harvest value chain to reduce food losses and ensure climate-friendly development of India's cold chain infrastructure.

INTRODUCTION

Background

India is the second-largest producer of fruits and vegetables in the world. The production of horticulture crops was about 311.71 million tonnes from an area of 25.43 million hectares in 2017-18,[5] of which 1% was exported from the country. Grapes, Pomegranates, Mangoes, Bananas, Oranges account for a majority of fruit exports and onions, mixed vegetables, potatoes, tomatoes, and green chili contribute to the vegetable export basket. The major importers of Indian fruits and vegetables are Bangladesh, UAE, Nepal, Malaysia, UK, Sri Lanka, Oman and Qatar[6]. India is an agrarian country with more than 50% of its people directly or indirectly depending on agriculture and allied sectors; however, the sector contributes only 17% to the GDP. The share has been declining over the years primarily due to growth in the manufacturing and services sectors, while agriculture growth rates and output have been more variable. The agriculture sector is characterized by instability in income due to the risks involved, including fluctuations in production, market demand and prices.

There are varying estimates of post-harvest food losses for fruits and vegetables across India[7]. A comprehensive study conducted by the Indian Council of Agricultural Research (ICAR) estimates that in the case of fruits, overall losses range from 5.8 to 18% while in the case of vegetables this range is between 6.8% to 12.98%[8]. There are other studies using different methodologies, which suggest losses suggest food losses may be even higher.[9] Food loss that occurs post-harvest and before connecting to markets is effectively a loss of saleable volume and value, is an economic burden on the food supply system, and results in avoidable GHG emissions associated with producing, processing and transporting the food that ends up getting lost and wasted. An integrated, efficient, and clean cold chain can play a significant role in addressing this problem.

The Government of India (GoI), recognizing the importance of the cold chain sector, has formulated multiple missions, schemes and committees under the Ministry of Agriculture and Farmers' Welfare and the Ministry of Food Processing Industries, to bring about a positive change and transform the agricultural sector in India. The Ministry of Commerce and Industry also supports the export development

5 MoA&FW. 2018. Horticultural Statistics at a Glance 2018. [online] Available at: <http://agricoop.nic.in/sites/default/files/Horticulture%20Statistics%20at%20a%20Glance-2018.pdf>.

6 APEDA. n.d. Fresh Fruits and Vegetables. [online] Available at: <http://apeda.gov.in/apedawebsite/six_head_product/FFV.htm> [Accessed 1 May 2019].

7 Depending on the study, data source and methodology used, estimates range from around 6 percent on the low end to 25% high side in India.

8 MoA&FW. 2017. Report of the Committee for Doubling Farmers' Income: Volume III. [online] Available at: <http://farmer.gov.in/imagedefault/DFI/DFI%20Volume%203.pdf>.

9 MoA&FW. 2017. Report of the Committee for Doubling Farmers' Income: Volume III. [online] Available at: <http://farmer.gov.in/imagedefault/DFI/DFI%20Volume%203.pdf>.

of agricultural and processed food products through its financial and infrastructure development schemes. The inter-ministerial committee on Doubling of Farmers' Income (DFI) has emphasized the importance of agri-logistics as part of reforms in the market architecture. A common thread which runs through the DFI committee recommendations is the need for, and the critical role of, uninterrupted and integrated cold chain infrastructure in India.

A well-designed and integrated cold chain can be an enabler for the transformation of the Indian agricultural sector. It is also a means of addressing key issues in the agricultural sector such as low income of farmers due to poor quality of produce reaching the market, lack of storage facilities to cater to the different requirements of different produce in order to enhance their shelf life, lack of mechanization to sort, separate and grade the produce quickly to minimize degradation after picking, and low availability of high value and nutritious fruits and vegetables in the local market owing to the interrupted cold chain being unsuitable for their survival.

According to the 2015 cold chain infrastructure capacity assessment undertaken by the National Centre for Cold Chain Development (NCCD) of the Ministry of Agriculture and Farmers Welfare, there are significant gaps in India's agricultural cold chain infrastructure. The India Cooling Action Plan (ICAP) projects significant growth in cold chain infrastructure. As ICAP notes, the cold chain sector offers an excellent opportunity for managing the cooling demand growth, as well as associated energy consumption and refrigerant requirement, through improved design, building material, cooling equipment and information technology.

Even though there has been significant cold storage warehouse capacity addition in the recent years, development has been relatively limited in the other segments, especially transportation and packhouses, which are the first step in the cold chain, typically providing sorting, grading, washing, packaging, pre-cooling, and staging services. In fact, the 2015 NCCD study estimates there is a need for over 70,000 packhouses in India, compared to the 249 that were in place as of 2015.

With the anticipated development of several thousand packhouses across the country by the government and the private sector, there is an opportunity to build in energy efficiency into the new infrastructure. The sustainable development of an integrated cold chain infrastructure, which is central to advancing farmers' economic well-being, carries important co-benefits such as mitigating food losses, alleviating hunger, while avoiding unnecessary energy consumption and emissions.

Project objective and scope

The Bureau of Energy Efficiency (BEE) under the Ministry of Power (MoP) is a quasi-regulatory body mandated to support the development of policies for energy efficiency in India. In view of the strategic significance of developing an integrated cold chain within the broader context of the India Cooling Action Plan (ICAP)[10], and the anticipated capacity additions in the coming years, which in turn are expected to lead to substantial additional energy needs, BEE, as part of the ICAP platform and as the focal point for the GOI's energy efficiency policies, regulations and initiatives, has been exploring approaches to promote energy efficiency in the cold chain sector.

In this context, BEE and the World Bank collaborated on an assessment of options

10 MoEF&CC. 2019. India Cooling Action Plan. [online] Available at: <http://ozonecell.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf>.

for enhancing energy efficiency in the cold chain. The specific focus of the assessment is packhouses, as the segment of the cold chain that is expected to see significant capacity addition over the next two decades. As per the 2015 NCCD report[11] cited earlier, about 99% of the packhouse infrastructure that would be needed to meet the current consumption demand of fruits and vegetables in urban clusters, each equipped with a pre-cooler[12] and dispatch room for onward transport links is yet to be created. As per ICAP, energy consumption in packhouses in India is estimated to be 21 GWh in 2017. This consumption is projected to grow by over 100 times to 2.4 TWh by 2027 and further to 5.2 TWh by 2037 (ibid). To this end, in support of BEE's work on this subject, the World Bank, with funding from the Energy Sector Management Assistance Program (ESMAP), engaged AEEE in this study on energy efficiency in packhouses. The primary objective of this study is to support BEE in developing policy and regulatory options for enhancing energy efficiency in packhouses in India. The study comprised the three major tasks, namely, stock taking and initial assessment, in-depth data collection and analysis, and recommendations to BEE on policy and regulatory options.

11 NCCD. 2015. All India Cold chain Infrastructure Capacity (Assessment of Status & Gap), Delhi. [online] Available at: <https://www.nccd.gov.in/>

12 It is important to note that the choice of whether to use pre-coolers will be need based, driven by demand and market conditions. Numerous produce would not require pre-cooling, such as potatoes, onions, other tuber crops, pumpkins, garlic, watermelon, aonla, jackfruit, pineapple, etc. Even then, some of these products may need cold storage for the purpose of off-season supply. In addition, the products which lend themselves suitable for pre-cooling but distributed over shorter distances would not get pre-cooled for economic reasons as they can reach the customer in good condition.

Chapter 1

STOCKTAKING AND INITIAL ASSESSMENT

This chapter presents the findings of the stocktaking exercise that covers the following: (i) overview of policy, regulatory and institutional framework in India; (ii) Initial review of the status of packhouses in India, and (iii) review of relevant international experience.

1.1 Approach followed for stocktaking and initial assessment

The team utilized two means to gather relevant data from multiple sources: literature review and structured interviews.

Literature review. As a first step, a literature review was carried out to understand the institutional, policy and regulatory framework and current status of agricultural cold chain development, and in particular packhouses. Information from the India Cooling Action Plan was used as the starting point to assess expected growth in the cold chain sector. In addition, the literature review focused on existing guidelines for packhouses published by various sources such as Ministry of Agriculture and Farmer's Welfare (MoA&FW), NCCD, and Agriculture and Processed Foods Export Development Authority (APEDA). Some of the important published reports that were reviewed are listed below.

- MoA&FW, 2014, Mission for Integrated Development of Horticulture - Operational Guidelines
- APEDA, 2014, Operational Guidelines for Availing Financial Assistance under Agriculture and Processed Foods Export Promotion Scheme
- NCCD, 2015, All India Cold chain Infrastructure Capacity: Assessment of Status & Gap
- NCCD, 2015, Guidelines and Minimum System Standards for Implementation in Cold Chain Components
- MoEF&CC, 2019, India Cooling Action Plan

Semi-structured interviews. The project team conducted semi-structured interviews with sector experts and select senior officials from ministries and regulatory/autonomous bodies, in order to obtain their perspectives and collect relevant information on packhouses. The discussions broadly focussed on understanding the institutional structure for the development and operation of cold chain infrastructure, existing policies and regulations, initiatives on energy efficiency and for post-harvest management requirements for different crops. These discussions facilitated identification of the packhouses for field visits. The list of stakeholders consulted in the interviews is presented in Annex 8.

1.2 Overview of policy, regulatory and institutional framework

Within the broad context of the cold chain and its importance, this section discusses the institutional, policy and regulatory framework governing cold chain and packhouses in India. The topics covered in this section include: articulation on the importance of an integrated cold chain, and packhouses in particular; institutional framework governing cold chain in India; policy and regulatory framework; energy efficiency programs relevant to the cold chain; the potential impact of different policies on future energy consumption; and preliminary gap analysis on the institutional, policy and regulatory framework from an energy efficiency perspective.

1.2.1 Cold chain and its importance

According to the NCCD definition, a cold chain is a temperature-controlled environment logistics chain, ensuring uninterrupted handling of products from source to user, consisting of storage and distribution-related activities in which the inventory is maintained within predetermined ambient parameters. Cold chain does not alter the essential characteristics of the produce or product handled[13] and primarily offers two basic functions, namely preserving a product's quality, and enhancing the product's life.

The use of either function depends on the type of product. For certain product types, the cold chain's function is to only preserve the quality and state of the produce, by maintaining predetermined ambient parameters (such as temperature and humidity). This is true for ice cream, meats, most processed foods, vaccines, many chemicals and plastics, electronic goods, etc. However, in the case of fresh fruits and vegetables, the cold chain has a broader function of enhancing produce life. To cater to this, the cold chain infrastructure needs to offer a more precisely controlled environment in terms of humidity and microbial conditions, oxygen levels, monitoring and control of degenerative gases, and segregation to avoid tainting between living tissues, in addition to maintaining precise temperatures. The flow of produce in a typical cold chain is shown in Figure 2.

Typical Pack-house

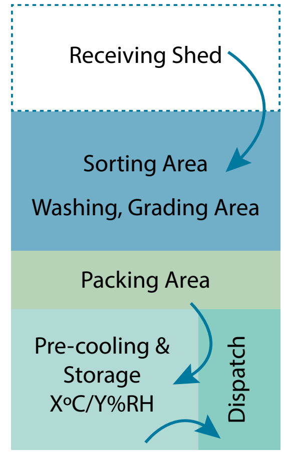
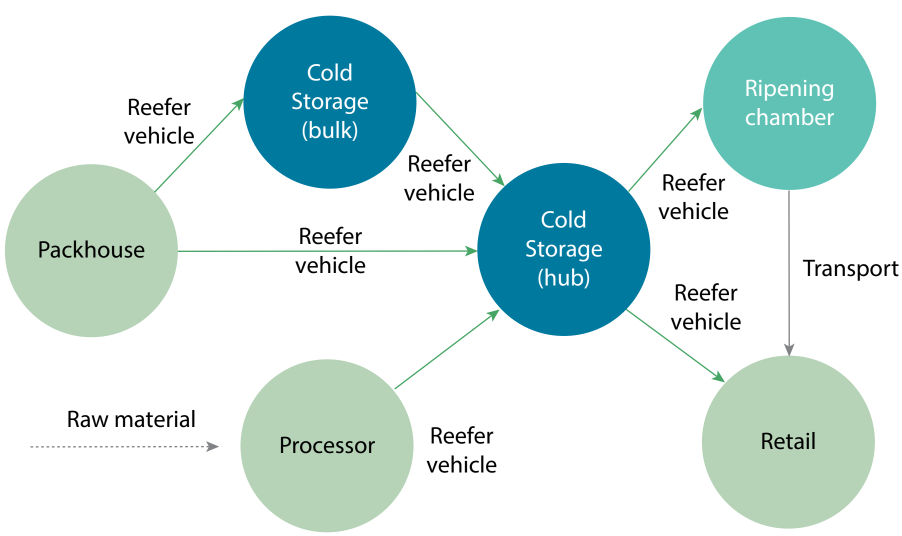


Figure 2: Flow of produce in a typical cold chain



Source: ICAP 2019

13 NCCD. 2015. All India Cold chain Infrastructure Capacity (Assessment of Status and Gap), Delhi. [online] Available at: <https://www.nccd.gov.in/>

Cold chain infrastructure can have strong socio-economic impact when it is integrated, and serves to connect farmers with new and different markets, near the farm gate and beyond. The facilitation of market access through an integrated cold chain can allow farmers to capture greater value from the produce they grow. As such, the cold chain has a critical role to play in increasing farmer incomes.

In India, as in much of the developing world, while there are elements of a cold chain that are present, fully integrated cold chains do not exist, as of today. Too often, cold storage is considered synonymous with the entire cold chain and regarded as the first step in building a sustainable cold chain. However, data shows that majority of food losses related to fruits and vegetables are between the farm-gate and post-harvest handling. No amount of temperature control down the value chain can restore the quality of produce that has already been damaged. Thus, a packhouse facility for appropriate post-harvest handling and packaging presents an unmistakable missed opportunity for minimizing food losses and enhancing farmers' incomes.

Definition of packhouse

According to NCCD, a packhouse is modern infrastructure with facilities for conveyer belt system for sorting, grading, washing, drying, weighing, packaging, pre-cooling (need-based) and staging. Modern packhouses are the first step in organized post-harvest management for horticulture and serve as first-mile sourcing points. A modern integrated packhouse unit enables small lot sourcing of horticultural produce, and should be built close to the farm gate.

Typical packhouse process[14]

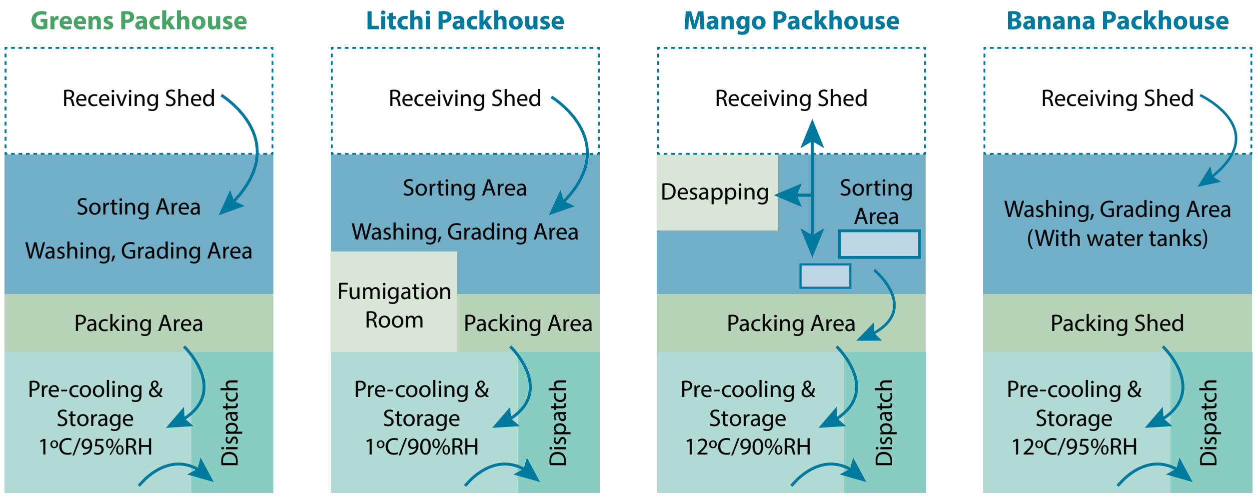
The flow of produce (Table 1) in an integrated packhouse unit includes handling, receiving the harvested goods, preliminary pruning/

Table 1: Typical packhouse process from NCCD

Receiving area	• A covered, shaded area for produce to be off-loaded and undergo pre-selection and weighing
Enclosed covered sorting and grading area	• A food handling hall with mechanised handling and cleaning equipment • Sorting produce into target lots based on qualitative criteria e.g. non-edible, rejects, by quality, by shelf-life, by market value, etc. • Grading is the activity at source for physical segregation of goods into optimal packing lots, after undergoing initial sorting.
Sorting and grading conveyors	• Mechanised roller or belt based system to pick and choose produce for the next activity and capable of handling 16MT output per day
Washing/Drying equipment	• Mechanised washing and drying lines
Packaging area	• Designated area where produce is manually packaged into market lots
Pre-cooling and Storage	• Pre-cooling unit is a specialized cooling system designed to rapidly remove field heat from freshly harvested produce and thereby prepares the cargo for subsequent travel in the cold chain. • Cold Room (Staging) is an insulated and refrigerated chamber which serves as a transient staging space, and is a necessary attachment to a pre-cooling unit.
Electricity generator	• A DG set to produce power for equipment operations; alternate energy options like biomass based generators, solar powered generators, etc. are also used.

14 NCCD. 2015. Guidelines & Minimum System Standards for Implementation In Cold Chain Components. [online]. Available at: <http://nhb.gov.in/pdf/NCCDGuidelines2014-15.pdf> [Accessed 1 May 2019].

Figure 3: Sample layouts for different packhouses



trimming/de-handing, sorting as per market channel and quality assessment, grading as per size and colour, packaging and labelling as first-level pre-conditioning, unitising the load to precool the packaged load, and transient storage in cold room in preparation for onward transport.

Most packhouses are designed to maximize utilization of the infrastructure based on location and harvesting season of the crops, but packhouse layouts may differ depending upon the produce being handled as shown in Figure 3. For example, in the case of mangoes and litchis, a conveyer belt system is used, while water troughs are used in the case of bananas. In a litchi packhouse, a fumigation room is needed for sulphur extraction, ventilation and scrubbing, while a mango packhouse includes a de-sapping rack as part of pre-conditioning.

1.2.2 Institutional framework governing cold chain in India

The institutional framework governing cold chain development in India comprises of various ministries and agencies. There are various government bodies at the central and state levels and other autonomous bodies. An overview of the roles of various organizations shown in the above figure is outlined in Table 2.[15]

1.2.3 Overview of Government schemes for agricultural cold chain

This section is intended to give an overview of the missions, schemes and initiatives that support the development of an integrated farm-to-consumer cold chain. This section doesn't aim to provide a comprehensive treatment of every applicable agricultural policy, regulation and institution, but rather touches upon the aspects of Government scheme that be relevant in the context of the current study, which focuses on energy efficiency. Further, while this section reviews agriculture sector schemes, it should be noted that the Government of India's environmental policies, schemes and international commitments will guide the elements of the cold chain that require cooling – specifically, those related to refrigerant policy and regulation, and commitments around the production and consumption of ozone depleting refrigerants (HCFCs) in the context of the Montreal Protocol.

15 Information gathered from research, outreach to various government officials and organisational websites.

Table 2: Overview of role of organizations in cold chain

Position	Name	About the Organization	Role in Cold Chain
Centre level	Ministry of Agriculture and Farmers' Welfare (MoA&FW)	The Ministry of Agriculture and Farmers' Welfare is the apex body for the formulation and administration of rules, regulations and laws related to agriculture in India. The Department of Agriculture, Cooperation & Farmer's Welfare (DAC&FW) under the Ministry is responsible for the formulation and implementation of national policies and programmes aimed at achieving rapid agricultural growth.	▪ The Mission for Integrated Development of Horticulture (MIDH) is a sponsored scheme by MoA&FW for the holistic growth of the horticulture sector covering fruits, vegetables, root and tuber crops, mushrooms, spices, flowers, aromatic plants, coconut, cashew, cocoa and bamboo.
	Ministry of Food Processing Industries (MoFPI)	The Ministry of Food Processing Industries (MoFPI) is responsible for the formulation and administration of rules, regulations and laws related to food processing in India.	The GoI scheme, Pradhan Mantri Kisan SAMPADA Yojana (Scheme for Agro-Marine Processing and Development of Agro-Processing Clusters) will be implemented by MoFPI. The Ministry aims to: ▪ Minimize wastage at all stages of food processing through the development of infrastructure for storage, transportation and processing; ▪ Introduce modern technology in food processing industries from domestic and international sources; ▪ Encourage R&D in food processing for product and process development and improved packaging; ▪ Provide policy support, and support for the creation of infrastructure, capacity expansion/Upgradation and other support measures for the growth of these sectors;
	Ministry of Commerce and Industry (MoCI)	The Ministry of Commerce and Industry administers two departments, the Department of Commerce and the Department for Promotion of Industry and Internal Trade.	▪ The Agricultural and Processed Foods Export Development Authority (APEDA) was established by MoCI under the Agricultural and Processed Food Products Export Development Authority Act.

Position	Name	About the Organization	Role in Cold Chain
		The Department of commerce formulates, implements and monitors the Foreign Trade Policy which provides the overall policy framework for promoting exports and trade.	▪ APEDA is mandated with the responsibility of export promotion for fruits and vegetables.
Autonomous Bodies	National Centre for Cold chain Development (NCCD)	NCCD is an autonomous body set up by the Government of India with the aim of facilitating cold chain development across all user segments through policy intervention, capacity building and standardization.	▪ NCCD was established to promote and develop an integrated cold chain in India for perishable agricultural and horticultural produce, including perishables from allied sectors. ▪ The main functions of NCCD are to recommend standards and protocols for cold chain infrastructure, suggest guidelines for human resource development and to recommend an appropriate policy framework for the development of cold chain.
	Small Farmers Agribusiness Consortium (SFAC)	Small Farmers Agribusiness Consortium (SFAC) is an autonomous Society promoted by the Ministry of Agriculture and Farmers' Welfare, Government of India.	▪ SFAC is focused on increasing incomes of small and marginal farmers through aggregation and development of agribusiness. ▪ SFAC has pioneered the formation and growth of Farmer Producer Organizations/Farmer Producer Companies. ▪ SFAC promotes the development of small agribusiness through its scheme for value-added processing and market linkages. ▪ SFAC also implements the National Agriculture Market Electronic Trading (e-Nam) platform. The purpose is to provide a single unified market for agricultural products with better price discovery for farmers.
	National Cooperative Development Corporation (NCDC)	NCDC was established by an Act of Parliament as a statutory Corporation under the Ministry of Agriculture & Farmers Welfare.	▪ NCDC supports fruit and vegetable marketing and processing cooperatives; it not only plays a developmental role but also provides financial assistance for creating infrastructure for marketing, processing and storage of agricultural produce in the Cooperative Sector.

Position	Name	About the Organization	Role in Cold Chain
	Agricultural and Processed Food Products Export Development Authority (APEDA)	APEDA is an export promotion organization under the Ministry of Commerce & Industry, Government of India. It is mandated with the responsibility of promotion and development of export of its scheduled products.	▪ For ensuring an appropriate standard in exports, APEDA supports the development of integrated packhouse facilities for fresh fruits and vegetable exports from India. ▪ APEDA grants recognition to packhouses that are found to meet infrastructure and procedural requirements by an inspection committee.
State	State Horticulture Mission	The State Horticulture Mission is a registered society that implements and monitors progress of the National Horticulture Mission, which is one of the sub-schemes of Mission for Integrated Development of Horticulture (MIDH).	
	State Agriculture Marketing Board	The agriculture marketing boards are statutory bodies that develop and coordinate the agricultural marketing system in the State.	
	Farmer Producer Organizations (FPOs)	FPO is a type of producer organization with farmers as its members. FPOs may be established as a company, a cooperative society or any other legal form which allows for sharing of profits/benefits among the members.	

Various assistance and subsidy schemes have been made available by the Government for the development of agricultural cold chain in the country as shown in Figure 4 below.

Figure 4: Schemes available for the development of cold chain in India

Ministry of Agriculture and Farmers' Welfare (MoA&FW)	▪ Mission for Integrated Development of Horticulture (MIDH) ▪ Integrated Scheme for Agricultural Marketing (ISAM) ▪ Rashtriya Krishi Vikas Yojana (RKVY)
Ministry of Food Processing Industries (MoFPI)	▪ Pradhan Mantri Kisan SAMPADA Yojana (PMKSY)
Ministry of Commerce and Industry (MoCI)	▪ Agricultural and Processed Food Products Export Development Authority (APEDA) ▪ Financial Assistance Scheme

1.2.4 The Mission for Integrated Development of Horticulture (MIDH)

MIDH[16] is a centrally sponsored scheme for the holistic growth of the horticulture sector covering fruits, vegetables, root and tuber crops, mushrooms, spices, flowers, aromatic plants, coconut, cashew, cocoa and bamboo. While the government of India (GoI) contributes 85% of the total fund for developmental programmes in all the states except the states in North East and the Himalayas, 15% share is contributed by State Governments. In the case of the North-Eastern States and the Himalayan States, GoI contribution is 100%. At present, the following sub-schemes and entities are relevant for cold chain and packhouses: National Horticulture Mission (NHM), Horticulture Mission for North East and Himalayan States (HMNEH), and National Horticulture Board (NHB).

In terms of flow of support available for packhouses under MIDH, the financial assistance is first released to the State Horticulture Missions (SHMs)/state level implementing agencies. They, in turn, make the funds available to the district implementing agency. Beneficiaries receive the funds from the district implementing agency at the state level. The details of various government schemes relevant for cold chain are shown in Annex 2.

1.2.5 Integrated Scheme for Agricultural Marketing (ISAM)

The Ministry of Agriculture launched this scheme[17] to keep up with the growing production and marketing surplus. It consists of the following sub-schemes:

- Agricultural Marketing Infrastructure (AMI)
- Marketing Research and Information Network (MRIN)
- Strengthening of Agmark Grading Facilities (SAGF)
- Agribusiness Development (ABD) through Venture Capital Assistance (VCA) and Project Development Facility (PDF)

The overall budgetary allocation for ISAM is INR 4,548 crore. The sub-scheme break-up of the budget provision is INR 4,000 crore for AMI, INR 12 crore for MRIN, INR 6 crore for SAGF, INR 500 crore for ABD and INR 30 crore for NIAM. The scheme focuses on the following:

- Enhancing the creation of agricultural marketing infrastructure by providing backend support to State, cooperative and private sector investments.
- Developing storage capacity and promoting pledge financing to boost the farmer's income.
- Promoting integrated value chains to provide vertical integration of farmers with primary processors.
- Using Information and Communications Technology (ICT) as a vehicle extension to sensitise and orient farmers to respond to new challenges in agricultural marketing.
- Establishing a nation-wide information network system for speedy collection and dissemination of market information and data on arrivals and prices for its efficient and timely utilisation by farmers and other stakeholders.
- Supporting the framing of grade standards and quality certification of agricultural commodities to assist

16 MoA&FW. 2014. Mission For Integrated Development of Horticulture. Operational Guidelines. [online] Available at: <http://midh.gov.in/PDF/MIDH_Guidelines(final).pdf> [Accessed 1 May 2019].

17 MoA&FW. 2014. Operational Guidelines: Integrated Scheme for Agricultural Marketing (ISAM). [online] Available at: <https://mofpi.nic.in/sites/default/files/ISAM%20-GuidelinesXII-Plan.pdf> [Accessed 1 May 2019].

farmers in receiving profitable prices for their graded produce.

- Catalysing private investment to set up agribusiness projects and thereby provide an assured market to producers and strengthen backward linkages of agriculture projects with producers and their groups.
- Undertaking and promoting training, research, education, extension and consultancy in the agricultural marketing sector.

1.2.6 Rashtriya Krishi Vikas Yojana (RKVY)

RKVY[18] scheme was initiated in 2007 for ensuring holistic development of agriculture and allied sectors by allowing states to choose their own agriculture and allied sector development activities as per the district/state agriculture plan.

Until 2013-14, the scheme was implemented as Additional Central Assistance (ACA) to the state plan scheme with 100% central assistance. It was converted into a centrally sponsored scheme in 2014-15 with 100% central assistance. Since 2015-16, the funding pattern of the scheme has been altered to the ratio of 60:40 between Central and State governments (90:10 for North Eastern States and Himalayan States). For Union Territories the funding is through 100% central grant.

Under RKVY infrastructure & assets stream, projects can be funded for functional infrastructure for collection, sorting, grading, cold storage, pre-cooling, refrigerated vans, ripening chambers and primary processing units.

18 MoA&FW. 2014. Rashtriya Krishi Vikas Yojana (RKVY). Operational Guidelines For XII Five Year Plan. [online] Available at: <https://rkvy.nic.in/static/download/pdf/RKVY_Guildlines_(XII_Plan)-2014.pdf> [Accessed 1 May 2019].

1.2.7 Pradhan Mantri Kisan SAMPADA Yojana (PMKSY)

PMSKY[19] is a central scheme with an allocation of INR 6,000 crore for the period 2016-20 which will be implemented by MoFPI. It includes the creation of modern infrastructure with efficient supply chain management from farm gate to retail outlet. It is expected to leverage investment of INR 31,400 crore for the handling of 334 lakh MT agro-produce valued at INR 1,04,125 crore, benefiting 20 lakh farmers and generating 5,30,500 direct/indirect employment in the country by the year 2019-20. Following sub-schemes mentioned in Table 3 will be implemented under PMSKY.

1.2.8 Agriculture and processed foods export promotion scheme of APEDA

For the development of export infrastructure, APEDA assistance[20] is available for the establishment of post-harvest infrastructure for fresh horticulture produce as shown in Table 4. Key features of APEDA scheme are mentioned below:

- The financial assistance is provided to the exporters for setting up packhouse facilities with packing and grading lines, pre-cooling units with cold storages and refrigerated transportation, cable system for handling crops like banana, pre-shipment treatment facilities such as irradiation, etc.
- For integrated packhouses, the proposals should meet the technical standards notified by the Central

19 MoFPI, 2017. [online] Mofpi.nic.in. Available at: <https://mofpi.nic.in/sites/default/files/important_notice-sampada-19.05.2017.pdf> [Accessed 1 May 2019].

20 APEDA. 2014. Operational Guidelines for Availing Financial Assistance Under Agriculture and Processed Foods Export Promotion Scheme. [online] Available at: <https://apeda.gov.in/apedawebsite/Announcements/SchemeGuidelinesMTEF27042018.pdf> [Accessed 1 May 2019].

Table 3: Sub-schemes implemented under PMKSY

Sub-scheme	Assistance
Mega Food Parks	• Capital grant @ 50% in general areas and @ 75% in Hilly areas
Integrated Cold Chain and Value Addition Infrastructure	• For storage infrastructure including packhouse and pre-cooling unit, ripening chamber and transport infrastructure, grant-in-aid @ 35% for General Areas and @ 50% for North Eastern States, Himalayan States, ITDP Areas & Islands
Creation/Expansion of Food Processing/ Preservation	• Grants-in-aid @ 35% in general areas and @ 50% in the North Eastern States including Sikkim and Himalayan States
Infrastructure for Agro-processing Clusters	• Grants-in-aid @ 35% in general areas and @ 50% in the North Eastern States including Sikkim and Himalayan States
Creation of Backward and Forward Linkages	• Grants-in-aid @35% in general areas and @ 50% in the North Eastern States, including Sikkim and Himalayan States
Food Safety and Quality Assurance Infrastructure	• Grants-in-aid @ 35% in general areas and @ 50% in the North Eastern States, including Sikkim and Himalayan States
Human Resources and Institutions	• Financial assistance to undertake demand-driven research & development work, promotional activities, skill development (178 lakh persons by the year 2022) and strengthening of institutions
Operation Greens	• Grant-in-aid @ 50% of the eligible project cost in all areas, subject to a maximum of INR 50 crore per project.

Source: MoA&FW

Table 4: APEDA - Pattern of Assistance

Component		Pattern of Assistance
1.	**Setting up sheds for intermediate storage and grading/storage/cleaning of produce.**	40% of the cost of equipment subject to a ceiling of INR 10 lakh per beneficiary
2.(a)	**Setting up mechanized handling facilities such as sorting, grading, washing, waxing, ripening, packaging & palletisation, etc.**	40% of the cost of equipment subject to a ceiling of INR 25 lakh per beneficiary
2.(b)	**Setting up both pre-cooling facilities with proper handling system as well as cold storage**	
2.(c)	**Providing facilities for treatment such as fumigation, X-ray screening and other screening/detection equipment, hot water dip treatment, water softening plant**	
2.(d)	**Setting up integrated post-harvest-handling system (packhouses with any two or more of the above facilities (mentioned in 2(a) to 2(c))**	40% of the cost subject to a ceiling of INR 75 lakh per beneficiary

Government under the Schemes from time to time

- 75% of the assistance shall be released after submission of final claim documents and the balance 25% of the total eligible assistance shall be released after registration of the packhouse as per APEDA packhouse registration scheme.

1.3 Energy efficiency and cooling initiatives relevant to cold chain

1.3.1 Energy Conservation Building Code (ECBC)

The Energy Conservation Building Code was launched as a first step towards promoting energy efficiency in the building sector in India. It is applicable for large commercial buildings with a connected load of 100 kW and above or 120 kVA and above. ECBC focuses on building envelope, mechanical systems and equipment including heating, ventilating, and air conditioning (HVAC) system, interior and exterior lighting systems, electrical system and renewable energy, and also considers the climates zones in the country.

Although ECBC is applicable for buildings, certain aspects of the code like structural design, materials used (wall, roof and window) and efficiency of motors, pumps and chillers could be useful for the design and selection of equipment for the packhouse.

1.3.2 Standards and Labelling Programme

The Bureau of Energy Efficiency initiated the Standards and Labelling programme for equipment and appliances to facilitate an informed choice by the consumer regarding energy savings and cost-saving potential of products. Energy efficiency labelling programs under BEE are intended to help reduce the energy consumption of appliances without diminishing the service they provide to consumers.

Currently, the scheme is available for 26 equipment/appliances including 10 for which it is mandatory. The other appliances are presently under voluntary labelling phase as shown in Table 5. The appliance labels relevant

Table 5: BEE Standards and Labelling Programme[21]

Mandatory Appliances	Voluntary Appliances
1. Room Air Conditioners	1. Induction Motors
2. Frost Free Refrigerators	2. Pump Sets
3. Tubular Florescent Lamp	3. Ceiling Fans
4. Distribution Transformer	4. LPG Stoves
5. Room Air Conditioner (Cassette, Floor Standing)	5. Washing Machine
6. Direct Cool Refrigerator	6. Computer (Notebooks/Laptops)
7. Colour TV	7. Ballast (Electronic/Magnetic)
8. Electric Geysers (link is external)	8. Office equipment (Printer, Copier, Scanner, MFD's)
9. Variable Capacity Inverter ACs	9. Diesel Engine Driven Mono-set Pumps
10. LED Lamps	10. Solid State Inverter
	11. DG Sets
	12. Chillers
	13. Microwave Oven
	14. Solar Water Heaters
	15. Light Commercial Air Conditioners
	16. Deep Freezers

21 BEE, n.d. Standards and Labeling | Bureau of Energy Efficiency. [online] Beeindia.gov.in. Available at: <https://beeindia.gov.in/content/standards-labeling>.

for a packhouse include Room Air Conditioners, Tubular Fluorescent Lamps, LED lamps, induction motors, pump sets, ceiling fans, DG sets and Chillers.

1.3.3 Treatment of cold chain under ICAP

The ICAP[22] proposes the development of integrated cold chain infrastructure with appropriate market linkages, supported by adequate training and up-skilling of farmers and professionals. India has a large inventory of cold storages, or refrigerated warehouses, but the other elements that form an uninterrupted cold chain – packhouses, reefer transport and ripening chambers – are largely missing. The co-benefits include economic well-being of farmers in direct support of the DFI initiative, reducing food losses, strengthening food security and alleviating hunger issues, leading to healthy citizens with nutritious and affordable fruits and vegetables, and a less GHG-intensive diet. The India Cooling Action Plan provides recommendations on the Cold Chain Sector which inter-alia include:

- Encourage development of cold chain infrastructure with use of low-GWP refrigerant based energy efficient cooling systems,
- Development of safety standards for flammable and toxic refrigerants for cold storage and other segments of the cold chain,
- Develop programme for retrofitting of existing cold storage to reduce cooling, refrigerant demand and energy consumption,
- Standardize all design, construction and associated specifications for small, medium and large cold-chain infrastructure components,
- Link the incentives being provided for development of cold-chain infrastructure with adoption of energy-efficient design, construction and maintenance practices and low GWP refrigerant and renewable technologies,
- Provide specialized training facilities for cold chain professionals and technicians to promote proper utilization and operation of technology, as well as energy efficiency,
- The ICAP factors in future use of cutting edge non-refrigerant based technologies for cooling, real-time monitoring systems for cold chains inter alia using internet of things (IOT) use of renewable and alternate energy technologies and
- The cooling action plan integrates sustainable development goals and environment benefits and provides way to connect and synergize with the development of agri-logistics.

As per MoEF&CC, Cooling Action Plans can serve the role of bringing in a sustainability paradigm to a largely logistics issue, in terms of technologies, energy efficiency and providing end-to-end cold through real time monitoring technologies resulting in reduced food loss. As such, they have a useful role to play in guiding the development of the sector.

1.3.4 Review of relevant international experience

As part of the study, a desk review of various international cases in post-harvest management and cold chain energy efficiency was undertaken. Given the unique nature of the subject of packhouse energy efficiency, it was

22 MoEF&CC. 2019. India Cooling Action Plan. [online] Available at: <http://ozonecell.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf>.

found that there is a rather limited of initiatives around the world focusing exclusively on packhouse energy efficiency, and hence limited insights and lessons that could be drawn for this specific segment, from the cases reviewed. Nonetheless, examples of recent literature on cold chain energy efficiency were collected, and the case studies were provided separately as part of the study. The recent examples of Philippines and Thailand in setting up post-harvest infrastructure and its integration with producers led to the produce being delivered to premium markets and building a sustainable business can offer useful insights to India. These examples are summarized in Annex 3. Some key insights emerging from review of recent experience internationally and India are summarized below.

Given the overall purpose of setting up packhouses – i.e. to facilitate the produce reaching the consumer in the best possible condition in a cost-effective manner – temperature management is critical for life of fresh produce which is alive. This critical effort begins with removal of field heat and can involve one or a combination of methods (such as room cooling, forced air cooling, hydro-cooling, vacuum cooling etc.), depending on the nature of produce and affordability of a particular market to pay for certain quality levels. For the final delivery of good quality produce to customers, the pack house operations have to be preceded by proper harvesting, handling and bringing the produce in a manner that it does not warm up thereby reducing cooling costs. High value commodities grown to high quality standards can contribute to optimal use of cold chain infrastructure. When handled through modern cold chain, these products can reach the customers at competitive prices. Opportunities lie not only in export market but also in the higher-end domestic market with more people having larger disposable incomes.

The necessity and importance of developing both backward and forward linkages cannot be overstated. Unless this is done, the physical infrastructure even if it was developed with grant or subsidy support, will not find adequate use as has been borne out by examples in the past.

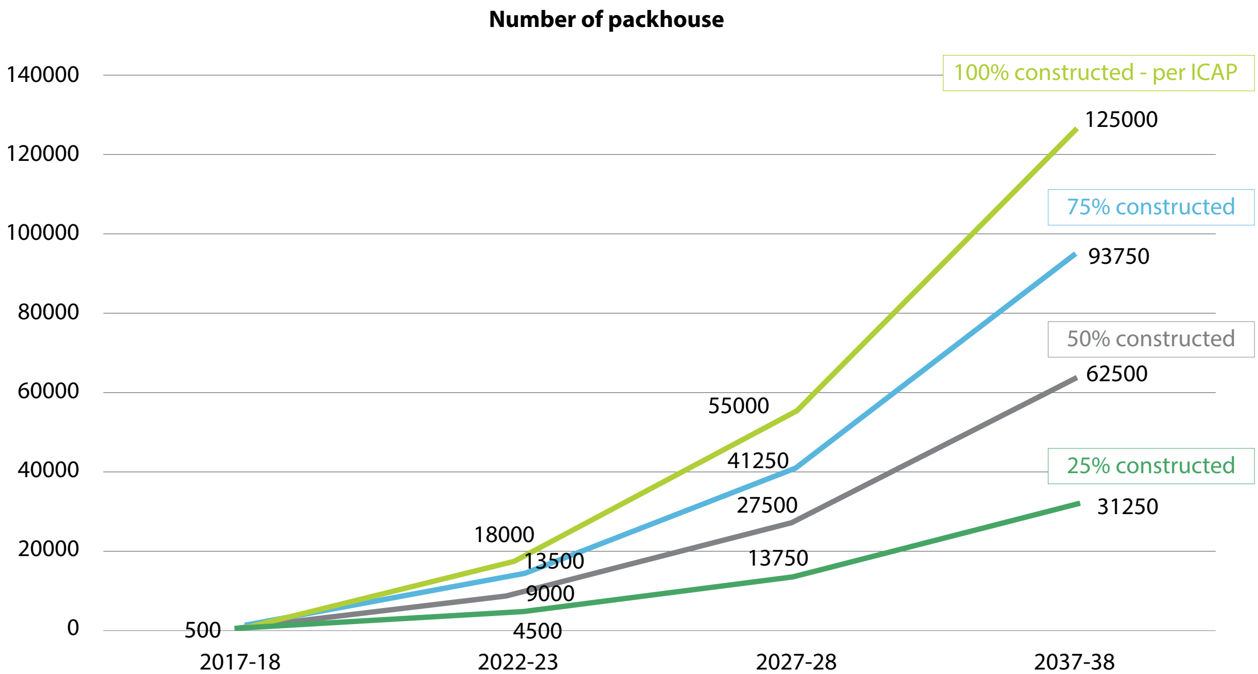
Horticulturally advanced countries have provided intensive support to sector stakeholders, especially farmers and traders, to help develop mutual understanding of requirements, provide training on critical aspects (e.g. cultivation, harvesting, preparation for market, pack house operations, use of packing materials, temperature and humidity control, food safety, handling at destination etc.) Capacity building for farmers for delivering high-quality produce to good markets, through accessing the cold chain starting with packhouses, can help them extract more value from their activities.

1.3.5 Capacity addition projections

As per ICAP, while the cold chain sector represents a small portion of the aggregated cooling demand from all sectors, it is poised for significant growth in the near future. The number of packhouses in India is expected to grow from about 500 packhouses in India at present, the number is likely to grow to 55,000 by 2027 and to 125,000 by 2037, as shown in Figure 5.[23] Even in a slower growth scenario, if only 25% of the expected packhouses are constructed, the number of packhouses will be ~14,000 in 2027 and ~31,000 in 2037.

23 It is worth noting that the ICAP estimates were made in 2019, prior to the COVID-19 pandemic that has impacted the Indian and global economy. Depending on the ultimate extent of such impact, the growth scenarios underlying ICAP projections, and subsequent capacity addition, energy use and emissions expectations may not materialize. Ultimately, the actual trajectory of energy use and emissions will depend on various factors including economic growth, market demand, consumer preferences, agricultural market development, connectivity, pricing and governing policies.

Figure 5: Packhouse stock development trajectories



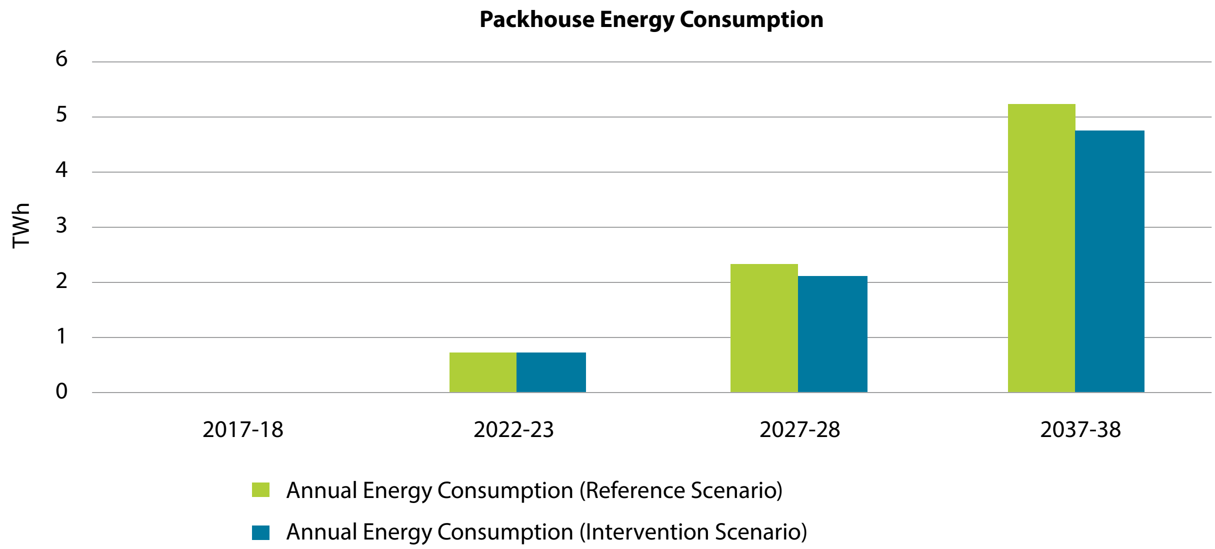
Source: Consultant estimates, based on India Cooling Action Plan, 2019.

1.3.6 Potential impact on energy consumption

According to ICAP, current energy consumption in packhouses in India is estimated to be 21 GWh. Projections show that this will double from 2.4 TWh in 2027 to 5.2TWh in 2037 as shown in the Figure 6. Potential improvements in the energy efficiency of the infrastructure (lighting, motors, pumps, etc) and cooling equipment are possible by employing efficient compressors, improved insulation and optimized operations which can result in energy savings of 8-12% in the next decade. In the figure below, two scenarios illustrated, namely, reference (i.e. current level of effort) and intervention (heightened level of effort) show expected energy consumption from the growth of packhouse infrastructure between 2017-18 and 2037-38. The intervention scenario considers improvements in the energy efficiency of infrastructure and cooling equipment, choice of lower GWP refrigerants[24] and refrigerant-related servicing practices, keeping in mind that for some applications there are trade-offs such has high costs or high safety risks.

24 It is critical to note that in the context of cold chain in India, there currently are challenges in identifying commercially viable, safe and low GWP alternatives to HCFCs and high-GWP HFCs. Even though in an ideal world, the focus should be on low to no-GWP refrigerants, recognizing the challenge in identifying workable solutions at this point in time, this report emphasizes *lower GWP* refrigerants, and emphasizes the importance of at minimum avoiding the growth of stocks of equipment based on high-GWP refrigerants, such as 404A.

Figure 6: Packhouse Energy Consumption



Source: ICAP 2019.

1.4 Initial review of the status of packhouses in India

This section of the report discusses the approach the study took, including selection criteria for packhouses, energy efficiency potential assessments in packhouses, capacity addition of packhouses by the year 2037-38 and initiatives by the private sector in energy efficient packhouses. The details mentioned in this section are based on literature review, interaction with officials of NCCD, officials of MIDH, NHB and APEDA, CII-task force on cold chain, design consultant, and technology providers.

1.4.1 Packhouse development and distribution

Packhouses in India are constructed with assistance from APEDA and MIDH as explained earlier in the report. Financial assistance is available to state governments, private organizations and FPOs. Details of packhouses were compiled through publicly available information consultations with relevant officials of APEDA and MIDH. Main features of the different categories are reviewed below.

Under APEDA, there are around 200 registered packhouses across different states managing a variety of produce. The details are presented in Table 6. The table clearly shows that Maharashtra constitutes over 70% of packhouses under APEDA due to the horticulture belt for various vegetables and fruits.

According to MIDH, there are over 300 pack-houses with pre-cooling facilities that also meet the requirements of integrated packhouses.

1.4.2 Energy efficiency potential assessment approach

The projected increase in energy consumption from the construction of new packhouses in the next two decades could pose a significant load on the electricity system, and could lead to adverse environmental impacts. It is imperative to manage energy consumption by reducing electricity demand through energy efficiency, and where feasible, seek opportunities for reducing the GHG-intensity of electricity consumption through use of renewable energy.

Table 6: List of APEDA packhouses

S.No.	State	Fruits/Vegetable Handled in the Packhouse	Number
1	Andhra Pradesh	Grapes, Mango, Pomegranate, Other Fruits, Okra, Bitter Gourd, Chilly, Herbs, Other Vegetables	5
2	Gujarat	Mango, Pomegranate, Other Fruits, Okra, Chili, Bitter Gourd, Other Vegetables	8
3	Karnataka	Grapes, Mango, Pomegranate, Other Fruits, Okra, Bitter Gourd, Chilly, Herbs	8
4	Kerala	Other Fruits, Okra, Chili, Other Vegetables	3
5	Maharashtra	Grapes and Pomegranate-56 Grapes-51 Others include Mango, herbs	155
6	Punjab	Other Fruits, Okra, Bitter Gourd, Chili, Herbs, Other Vegetables	5
7	Rajasthan	Herbs, Other Vegetables	1
8	Tamil Nadu	Pomegranate, Other Fruits, Other Vegetables	6
9	Telangana	Grapes, Mango, Pomegranate, Other Fruits, Okra, Bitter Gourd, Chili, Herbs, Other Vegetables	4
10	Uttar Pradesh	Mango, Other Fruits, Chili, Other Vegetables,	4
11	West Bengal	Okra, Bitter Gourd, Chili, Other Fruist and Vegetables	3

An integrated approach has been followed to carry out an energy performance overview, and energy efficiency potential assessment of identified packhouses. The overall approach is presented below.

Energy bills

- Review of energy bills for past 3-5 years is important to understand energy consumption trends for different months within a year and establish energy consumption over the last 3-5 years

Functions using cooling

- Pre-cooling: The cooling system is one of the major sources of energy consumption in a packhouse. Assessment of pre-cooling systems was carried out to review the design including requirements of temperature, relative humidity (RH) and CO_2 levels, type of pre-cooling system, size and design efficiency, controls for automation, and operation of the system
- Cold room for staging and temporary storage

Electrical system

- Details of the electricity distribution system, including size and efficiency of diesel generators, size, efficiency and loading of motors

Lighting system

- The lighting system was reviewed to establish lighting power density (W/m^2), type of lamps and controls used for the automation

Structural details of the packhouse

- Composition of wall and roof (material and their properties such as thickness, conductivity, density and specific heat) were reviewed to establish the thermal heat transfer coefficient of wall and roof

Energy-Supply side

- From the energy supply side, details such as peak capacity/load, units consumed and generated, and efficiency of renewable energy systems were reviewed

The project team mapped the flow of energy in various energy consuming systems in a packhouse. An indicative list of various energy consuming systems is presented below in Table 7.

For the site visits, the focus was on following an approach that would enable the collection of relevant information without causing too much disturbance to the packhouse operators' activities, and avoid any additional burden to officials managing and operating the packhouses.

The overall approach to collect data from identified packhouses is presented below and the questionnaire used for collecting the information during the site visits is attached as Annex 9.

Table 7: Illustrative List of various energy consuming systems

S.No.	System Name	System Description	EE indicator
1	Pre-cooling system	▪ Air conditioning system including details of compressor, evaporator ▪ CHW pumps, CDW pumps and refrigerant	▪ COP of the AC and system ▪ Pump efficiency ▪ GWP and ozone depleting potential (ODP) of the refrigerant
2	Motors	▪ Receiving area ▪ Sorting and grading area ▪ Conveyor system	▪ Motor loading (%) ▪ Design efficiency of the motor ▪ Any automation
3	Lighting system	▪ Fixture and lamp details across various sections in the packhouse	▪ Lighting power density (W/m^2)
4	Electricity distribution system	▪ Diesel generators	▪ SEGR (kWh/litre) ▪ Power factor ▪ Sanction load (kW) ▪ Contract demand (kVA) ▪ Load density (W/m^2)
Details of energy systems-Structural			
1	Building design	▪ Orientation, Shading	▪ Temperature and RH requirement of the spaces
2	Building Envelope	▪ Wall composition, Roof composition	▪ U values ▪ Temperature and RH requirement of the spaces

Identification of relevant contact details of officials involved in management of packhouses

↓

Letter from BEE/NCCD/WB to the identified packhouses on the proposed study

↓

Collection of data during site visits

↓

Data analysis

↓

Feedback from facility management: any energy consumption concerns, EE or modernization measures implemented or under consideration, and information available from any energy audits

Chapter 2

DETAILED ASSESSMENT AND OVERVIEW OF ENERGY EFFICIENCY OPTIONS

2.1 Scope

This chapter focuses on presenting the findings of packhouse visits across major agro-climatic zones in India. The data collected during these visits have been analysed to establish the energy consumption patterns in a typical packhouse. This analysis is followed by recommendations for measures that can be adopted for enhancing the energy efficiency in packhouses.

The objective of this chapter is two-fold:

1. Understanding the drivers of energy use in packhouses and analysis of energy data gathered from site visits
2. Developing recommendations for energy efficiency improvements in packhouses

The overall approach followed to achieve the above outcomes is represented in Figure 7.

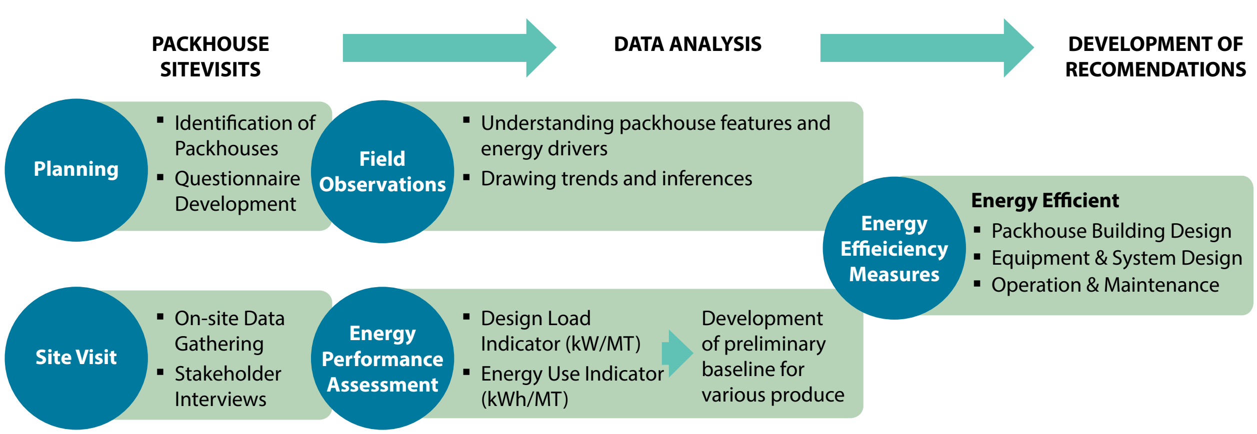
2.2 Packhouse site visit methodology

The approach followed by the project team to identify the packhouse and conduct site visits to collect relevant information is summarised below.

2.2.1 Identification of packhouses

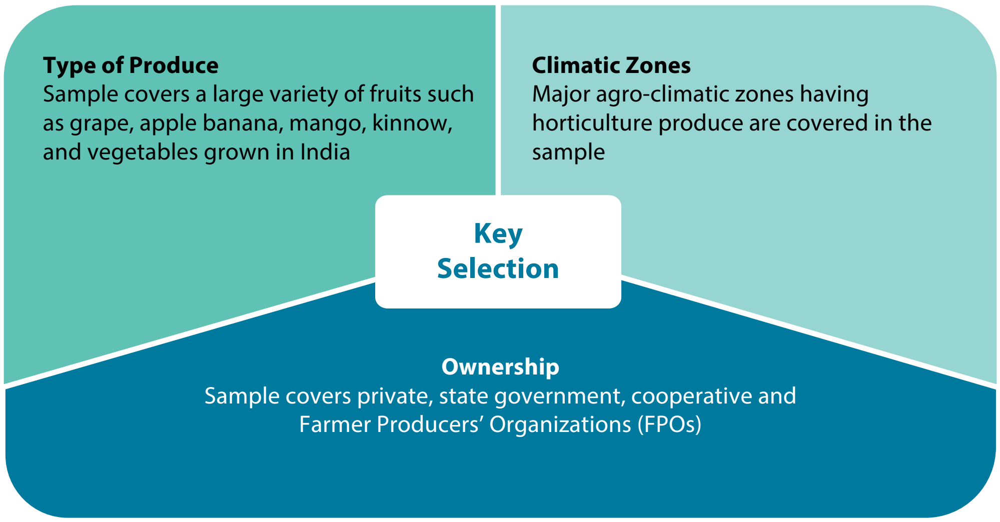
As a first step, a long list of packhouses was created across various states and climatic zones. This list was compiled in consultation with multiple government stakeholders including MIDH, NHB, and APEDA and private stakeholders including individual packhouse owners and retailers. The surveys included semi-structured interviews with government officials at the central and state level, design consultants, equipment manufacturers, industry associations, packhouse owners and operators.

Figure 7: Overall Approach



Selection criteria used for the identification of packhouses was defined in the study Terms of Reference, as presented in Figure 8.

Figure 8: Packhouse: Key Selection Criteria



These criteria were chosen because type of produce, agro-climatic zones and ownership can impact the energy consumption by different facilities. The type of produce is important in determining energy usage as the optimum temperatures and humidity requirements vary from produce to produce. Furthermore, the functions performed and machinery required to perform these functions are driven by the type of produce. The variation of ambient temperature across different agro-climatic zones impacts cooling requirements to remove field heat of produce as part of the processes carried out in the packhouse for the onward cold chain journey. The ownership of packhouses (private, government or farmer producers' organizations or FPO) was also been considered a potential influencing factor governing the key design and operational issues impacting energy usage.

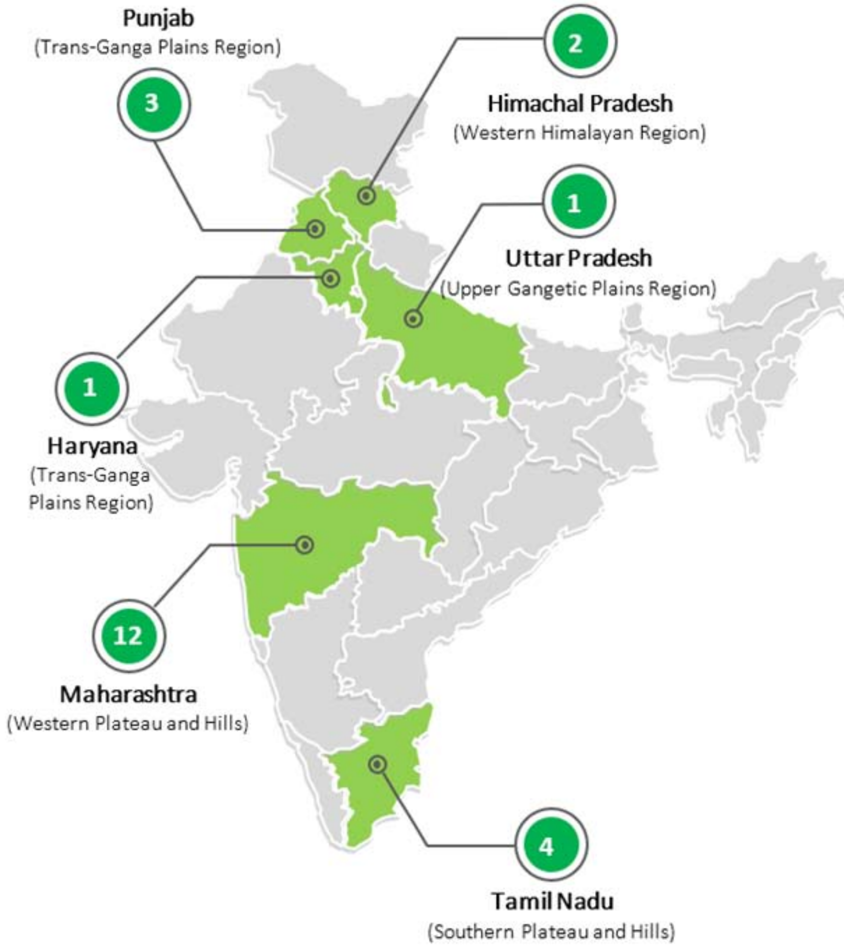
The team conducted site visits to 21 packhouses across six states in India (as shown in Figure 9) covering the major agro-climatic zones namely Maharashtra, Haryana, Uttar Pradesh, Punjab, Tamil Nadu and Himachal Pradesh. Of the 23 packhoused surveyed, detailed energy performance assessments were carried for a sample of 21 packhouses as the requisite data was not available for two packhouses.

2.2.2 Questionnaire development

A detailed survey questionnaire was designed to cover the following aspects that could a direct or indirect impact on the energy performance of packhouses in India.

- General information on the packhouse, including location that determines proximity to the farm gate and access to backward and forward transportation. Other characteristics including type of ownership (private/public/cooperative), age of the facility, financial incentives availed, etc. could have a significant bearing on the design, equipment selection and operation of packhouses.
- Operational information, including the type of produce handled, functions

Figure 9: Geographic distribution of packhouses surveyed



performed, operational hours, is important to study the produce-specific energy requirements and capacity utilisation. The study of current operation and maintenance practices are particularly important to identify and assess the scope for energy efficiency interventions ranging from training and capacity building of operators to automation systems.

- Building details to understand the overall facility design layout and thermal performance of the building envelope. Considering the tropical climate of India, the thermal performance of walling and roofing material, façade/window shading, and provision of natural ventilation has a considerable impact on both the produce being handled and the thermal comfort of the packhouse staff.
- Refrigeration system design and operational details are one of the most critical pieces of information for this energy performance assessment as pre-cooling (other refrigeration application being staging cold rooms) to remove field heat is a highly energy intensive process. Since vapour compression (technology) is the most prevalent refrigeration system for this application, the type of refrigerants

and their combined environmental and energy performance need to be closely assessed.

- Apart from active energy consuming systems such as space lighting, sorting and grading lines, pest treatment facilities, dock-leveller, forklift, air curtains, etc., passive systems such as strip curtains which indirectly impact the refrigeration system performance, have also been included.
- The study of the electricity supply system is critical to understand grid reliability and back-up provisions, as well as scope for renewable energy integration. Historical energy consumption trends are also included to assess seasonal variations and its plausible reasons.
- Feedback from facility owners and operators is also important for a better understanding of the current status and bottlenecks for the uptake of energy efficiency measures.

The questionnaire, along with the project brief, was shared with the packhouse owners ahead of the site visit. The questionnaire is attached as Annex 9.

2.2.3 Site visits: On-site data gathering

A project team consisting of three or four members conducted the site visits at the identified packhouse facilities. The questionnaire was utilized to consistently capture the details during the site visit, along with relevant photographs of the facility. Several data gaps and challenges related to the capacity and efficiency of the cooling system, corroded nameplate of various equipment made it difficult to establish the design rating of motors used for sorting and grading, in such cases the rating was estimated by the team based on estimates of monthly electricity consumption of these equipment, through analysing the electricity bills; unavailability of design data with the packhouse owners and limited or no monitoring/reporting of energy related details in the packhouse. To plug the information gaps and validate the information collected during the survey, the following approach was adopted.

Some additional insights shared by packhouse owners and design consultants are summarized below.

- A few packhouse owners shared concerns regarding challenges faced in identifying suitable design consultants

Table 8: Approach adopted to plug in information gaps

Information Gap	Approach Adopted
Capacity and efficiency of the cooling system Rating of motors used for sorting and grading	▪ In-person interactions with the respective owners, facility managers, and operators and where possible, the design consultants of the packhouse ▪ Inputs from manufacturers, such as Danfoss, Ecozen Solutions, Star Coolers and Condensers, Rinac India Ltd, Bitzer and PLUSS technologies
Monthly energy consumption (kWh)	▪ The electricity tariff in the respective state and the amount of electricity bill paid (INR) was used to calculate the monthly energy consumption (kWh) for few packhouses where the actual electricity bill was not available

for new facilities, as well as difficulties in identifying trained operators and technicians to operate existing facilities.

- Packhouse owners also shared insights related to operational challenges and market connection issues. Some of them were of the view that there is significant scope for improvement in compiling and disseminating postharvest management-related best practices through the concerned central and state government departments. They showed keen interest in receiving guidance on how to optimise their energy usage.
- The packhouse design consultants and cold chain experts shared their experiences on the existing practices followed for the design of packhouses and provided their inputs on good engineering design and O&M practices that can result in substantial energy reduction.

The data gathering focused both on qualitative and quantitative information, with the dual objectives of analysing the information to (a) understand the design and operational characteristics, and energy use drivers in packhouses; and (b) conduct an energy performance assessment of the identified packhouses.

2.2.4 Meeting with other stakeholders

While conducting the site visits, the project team identified other stakeholders to understand the packhouse operations and scope of EE improvements in packhouses. An indicative list of stakeholders includes the State Horticulture Mission, equipment manufacturers (such as Danfoss, Ecozen Solutions, Star Coolers and Condensers, Rinac India Ltd, Bitzer and PLUSS technologies), academic institutions (such as Punjab Horticultural Postharvest Technology Centre) and regional agricultural experts. The key inputs shared by these stakeholders are summarized below.

- The educational institutes shared their insights on ongoing efforts (in terms of research and development in cooling solutions such as using phase change material (PCM), training and capacity building of farmers) on post-harvest management in different regions in India.
- Equipment manufacturers shared information on different energy efficient technologies available for the pre-cooling and staging cold room and the associated energy savings potentials.
- Regional agricultural experts shared their experiences on specific post-harvest requirements focusing on packhouses. They highlighted their concerns on the distant location of packhouses from the farms. Some regional experts expressed reservations about the effectiveness of the FPO model. They were of the view that it will have challenges in the initial years due to the current circumstances and awareness levels. Some emphasized the importance of training and capacity building of FPO members.

Insights from these meetings were utilized to refine the data analysis and energy savings measures presented in the report.

2.2.5 Stakeholder consultation workshops

Two stakeholder consultation workshops were organized as part of the study. The first stakeholder consultation presented the findings and gathered feedback on the site studies and energy performance assessment. The second workshop focused on summarizing overall assessment, and presentation of preliminary recommendations. Both workshops were attended by around 50 delegates with distinguished speakers from the cold chain industry. These were first-of-their-kind workshops focusing on energy efficiency in packhouses in India, providing the opportunity for comprehensive and detailed among the participants and speakers. The agendas and list of participants for both workshops are available in Annex 7.

2.3 Field observations

The parameters observed during the visits included packhouse building details, receiving, sorting and grading area, details of the pre-cooling, and staging cold room, operation and maintenance practices and the electricity supply and distribution system. The parameters that were gathered included: packhouse characteristics (location, ownership, size, age, investment, incentives, if any); building details (layout, materials); equipment used in the receiving, sorting, grading areas, pre-cooling and staging cold room (AC system, capacity, operating hours, refrigerant used); electricity supply features (grid connectivity, reliability, tariffs); and, operations and maintenance practices.

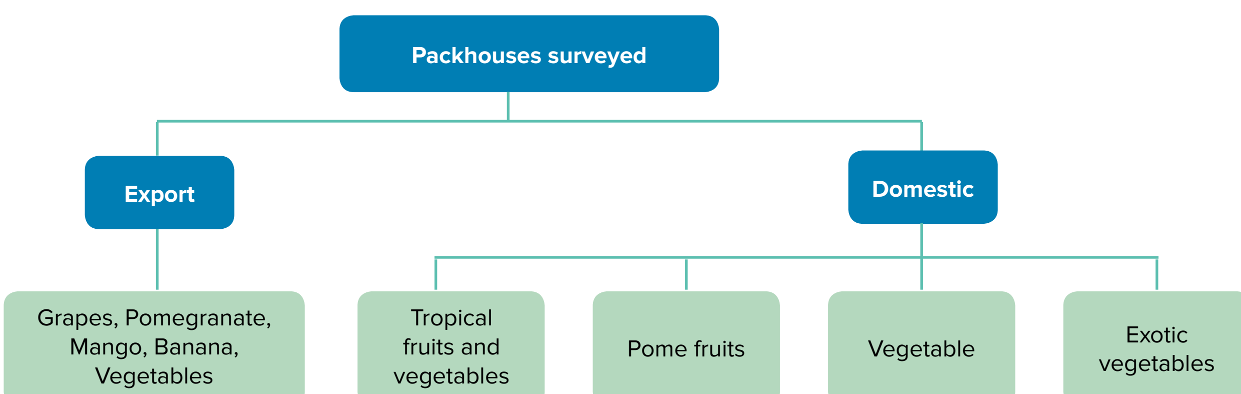
In terms of infrastructure development and operation, the packhouses surveyed were classified into two major categories, namely (i) export-oriented and (ii) domestic market focused. This broad categorization is shown in shown in Figure 10. However, it should be noted that this classification does not imply that packhouses exclusively cater to a single market. There are noticeable differences in terms of the geographic region, size, investment requirements, and operation and maintenance practices of the packhouses catering to export markets compared to those that primarily serve domestic markets. Observations from site visits to packhouses in these categories are provided in the subsequent sections.

2.3.1 Type of produce handled

India's diverse climate and geography ensures the availability of a wide variety of fruits and vegetables spread across different agro-climatic zones. The packhouses sample surveyed included the following fruits and vegetables:

- The export-oriented packhouses include produce such as grape, pomegranate, mango, banana and

Figure 10: Packhouse categorization



vegetables. Grapes were the dominant produce handled in the export-oriented packhouses.

- The domestic packhouses handling tropical fruits and vegetables cover banana, mango and vegetables.
- Apple and pear are the primary produce handled in the pome fruit domestic packhouses category.
- The domestic vegetable packhouses surveyed primarily handled carrots.
- The exotic vegetable packhouses include broccoli, lettuce and mushroom.

The choice of produce handled depends on market demand (domestic and export), harvesting season of the available produce, and cost-benefit of operations. Amongst the packhouses surveyed, roughly half exclusively handled fruits – and typically only one type of fruit. About a quarter of the packhouses exclusively handled vegetables, and the rest handled both fruits and vegetables.

Table 9: Type of Produce and capacity utilization of packhouse surveyed

Type of produce handled	Primary Produce Handled	Capacity utilization	No. of months	Location	Agro-climatic Zone
Both Fruits and Vegetables	Mango and vegetables	Year round	10 to 12	Maharashtra	Western Plateau and Hills
	Grape	Seasonal	4	Maharashtra	Western Plateau and Hills
	Mango	Seasonal	4	Maharashtra	Western Plateau and Hills
	Chilli and Mango	Seasonal	8	Punjab	Trans-Ganga Plains Region
	Chilli, Pomegranate, Tomato	Seasonal	1 to 2	Maharashtra	Western Plateau and Hills
	Banana	Year Round	10 to 12	Maharashtra	Western Plateau and Hills
Only Fruits	Grape	Seasonal	4	Maharashtra	Western Plateau and Hills
	Apple and Banana	Year round	10 to 12	Uttar Pradesh	Upper Gangetic Plains Region
	Kinnow	Seasonal	4	Punjab	Trans-Ganga Plains Region
	Banana	Year round	10 to 12	Tamil Nadu	Southern Plateau and Hills
	Banana	Seasonal	7	Maharashtra	Western Plateau and Hills
	Apple	Seasonal	9 to 10	Himachal Pradesh	Western Himalayan
	Apple	Seasonal	8 to 10	Himachal Pradesh	Western Himalayan
Only Vegetables	Orange, Sweet lime	Year round	10 to 12	Maharashtra	Western Plateau and Hills
	Mushroom	Seasonal	1 to 2	Haryana	Trans-Ganga Plains Region
	Tomato, Chilli, Peas, ladyfinger	Seasonal	6 to 7	Punjab	Trans-Ganga Plains Region
	Carrot	Year round	10 to 12	Tamil Nadu	Southern Plateau and Hills

Based on discussions with packhouse owners, it was observed that packhouses can be designed to handle multiple types of produce depending on the harvesting season, which in turn will also maximise capacity utilization. For example, packhouses that handle both chillies and mango in Punjab were able to double their capacity utilization to eight months, compared to four months for packhouses that only handle mangoes. However, handling multiple produce has its own challenges. Several packhouse owners opted to focus on single produce for a variety of reasons. The refrigeration system for pre-cooling can be designed to maintain varying temperature/RH conditions depending on the type of produce. While it is possible, with proper design and equipment selection of the refrigeration system, to simultaneously manage crops with different cooling requirements in a single packhouse facility, harvesting seasons do not fully coincide for crop combinations that have different cooling requirements.

Some private grape packhouse owners who primarily handle a single crop tried renting out their facilities for vegetables during the off-season to increase facility utilisation. However, owners expressed dissatisfaction with the maintenance of the facilities by tenants, which adversely affected packhouse operations for the owners' cash crop (grape), which needs to meet more exacting food safety and hygiene standards to meet export market requirements.

Capacity utilization of the packhouses surveyed varies from as low as one month in a year to year-round operation depending on the produce handled and its peak harvesting season. Most of the packhouses utilized for handling fruits are only operated during the harvesting season and remain unutilized otherwise. For grapes, the peak season is from February to April (three months); for mangoes, from April to July (four months); and the banana packhouses are operational throughout the year. Packhouses with cold storage facilities (cold room/controlled atmosphere) such as apples are operated beyond the harvesting season as well. September and October are the peak season for apples, but the packhouse operates for eight months each year. This seems to be because the inflow of produce occurs from August to October (three months) and the outflow is from January to May (five months). It was observed in one of the surveyed apple packhouses that during the harvesting season, apples are graded based on their size and stored in segregated bins. During the off-season, the apples are taken out of cold stores (if required) and further graded based on colour and packed accordingly as per buyers' requirements.

Produce wise temperatures and humidity requirements

Optimum temperatures and humidity requirements as defined by UC Davis for major produce surveyed during the visit is shown in Table 10.

2.3.2 Produce wise functions performed

The functions performed in a packhouse primarily depend on two factors: the type of produce handled and the requirements of the target market in terms of consumer demand and the prevailing food safety regulations. Packhouses can range from a simple packing shed with limited equipment and minimal operations to a large facility that is well equipped with systems for specialized activities. Most of the packhouses surveyed consist of minimum provisions to facilitate necessary sorting and grading. The produce first arrives at the receiving area where it is off-loaded and undergoes pre-selection and weighing. After sorting, grading, washing (as per produce requirement) and packaging, the produce is pre-cooled to remove field heat, if required. Thereafter, the packaged fresh produce is placed in a transitory staging room

Table 10: Optimum temperature and relative humidity (RH) for produce[25]

Produce	Optimum temperature (°C)	Optimum relative humidity
Grape	(-1)–0	90-95%
Apple	0 ± 1	90-95%
Banana	13-14	90-95%
Mango	10-13	90-95%
Carrot	3-5	98-100%
Mushroom	0-1.5	95-98%
Okra	7-10	95-100%

(cold room if required) until further transport to various markets as per demand. Travel time and distance are generally determined by market demand and vary in the case of domestic and export markets. Market demand for produce from a particular growing area varies across seasons and is also dependent on the quantity produced in other production centres across different geographical locations.

The following section describes packhouse facility requirements for different produce, as observed during site visits under the study. The summary of produce-wise functions performed in the packhouses surveyed is shown in Table 11.

Figure 11: Typical set-up of a packhouse with pre-cooling

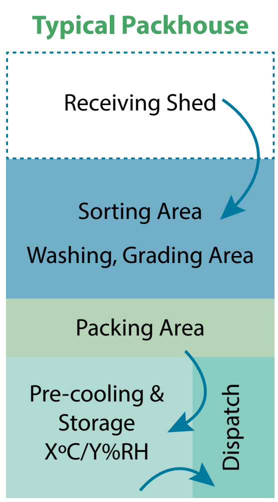


Table 11: Produce wise functions performed in the surveyed packhouses

Produce	Sorting and Grading	Polishing and washing	Other treatment (Hot water/ de-latexing)	Packaging	Pre-cooling and staging	Optimum Temperature (°C)
Grape	●			●	●	(-1)–0
Apple	●			●	●	0 ± 1
Banana	●		●	●	●	13-14
Mango	●		●	●	●	10-13
Carrot	●	●		●	●	3-5
Mushroom	●			●	●	0-1.5
Okra	●			●	●	7-10

25 University of California, D., n.d. Produce Fact Sheets. [online] Postharvest.ucdavis.edu. Available at: <http://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/index.cfm> [Accessed 1 October 2019].

Key observations: Packhouses handling delicate produce like grape, which require lower temperatures, consume the most energy. In mango packhouses, additional energy is used for hot water treatment, while automated sorting and grading and pre-cooling performed in the cold rooms are the most energy intensive functions in apple packhouses. Vegetable packhouses generally have the lowest energy use intensity owing to minimum process loads. Specific details about packhouses catering to select produce are discussed below. The detailed energy performance analysis is described in Section 2.5 of this report.

Grape Packhouses: Grapes are among the more delicate commodities that start to deteriorate as soon as they are harvested, and hence pre-cooling and proper packaging are critical to preserve their quality and extending their shelf life. Considering the fragility of grapes, cooling systems are installed in the receiving area, sorting and grading area and despatch area (in addition to the pre-cooling and staging cold rooms) to avoid deterioration in quality from exposure to high temperatures. This also distributes some of the load from pre-coolers to other packhouse areas where the produce is being prepared before it is pre-cooling.

Apple Packhouse: The primary functions performed in an apple packhouse are washing, sorting, drying, and grading. The preliminary sorting of low-quality produce is generally performed manually, followed by grading by colour and size in automatic lines. Apple packhouses are typically accompanied by cold storages with controlled atmosphere functionality.

Figure 12: Sorting and Grading area in a Grape packhouse

Figure 13: Sorting and grading area in an apple packhouse

It was observed that the pre-cooling function of apples was performed in the cold rooms and no dedicated pre-coolers were installed in any of the packhouses visited. In this analysis, only the energy requirement for pre-cooling was considered, while energy consumption for cold storage was not considered a part of the packhouse.

Banana Packhouse: Considerable variation in post-harvest practices for bananas was observed across India. For domestic consumption, the de-handing (separation of banana hands from the bunch), washing, sorting, and packaging in plastic crates are carried on the field itself, as shown in Figure 14. These bananas are transported directly to the ripening chambers and subsequently to the markets. On the other hand, for the export market, packhouses facilities are constructed with water tanks and conveyor belts for washing, de-latex, sorting/grading, cauterization, and packaging of bananas.

Mango Packhouse: In addition to sorting and grading, mangoes require specialised packhouse functions, including fruit fly treatment, the procedure for which is determined based on the buyers' requirements. All export produce

Figure 14: On-farm handling of bananas

Figure 15: **Sorting and grading area in a mango packhouse**

is required to meet certain norms stipulated by the importing countries and updated from time to time. These guidelines are compiled and provided to the export packhouse operators by APEDA[26] and regularly updated. For example, mangoes exported to Europe and the Middle East only require hot water (heat) treatment, whereas US markets also require irradiation treatment[27]. Hot water treatment is commonly used in several countries to disinfect mango of fruit flies by dipping the fruit in 40-50°C water for 5-10 minutes, depending on the type and size of mango.

Vegetable Packhouse: In the vegetable packhouses surveyed, functions performed include cleaning and trimming of certain

Figure 16: **On-farm handling of carrots**

26 Apeda.gov.in. n.d. Export Regulations. [online] Available at: <https://apeda.gov.in/apedawebsite/menupages/Export_Regulations.htm> [Accessed 1 September 2019].

27 APEDA. 2007. Guidelines for Export of Indian Mangoes to USA

vegetables on a need basis. Sorting and grading, weighing and packaging are performed manually by the packhouse staff. Considering the large variation in size and unevenness in shape (e.g. ladyfinger, okra, brinjal, drumstick, etc.), vegetables are best handled manually in packhouses. Automatic sorting and grading lines are not feasible as they are generally designed to handle round or oblong produce and may damage fragile vegetables.

Vegetable packhouses visited as part of the study included those that handled chilli, tomato, carrot, okra, peas, French bean, ladyfinger, sweet lemon and mushroom. In the case of carrots, most of the surveyed packhouses had installed a washing machine in an open area near farms for sorting, grading, washing, and in some cases polishing, as shown in Figure 16.

2.3.3 Packhouse characteristics

2.3.3.1 Location

The selection of location is one of the most critical infrastructure planning considerations. Factors such as proximity to the farm gate, access to critical infrastructure (e.g. roads, transportation system, and power supply) all have a significant impact, not only on energy consumed for bringing produce from farm to fork, but also on commercial viability of packhouses. Observations on the location of packhouses captured through site-visits, stakeholder interactions and literature review are compiled below.

- The domestic packhouses handling tropical fruits and vegetables are spread across the states of Punjab and Haryana (Trans-Ganga Plains), Uttar Pradesh (Upper Gangetic Plains Region and Middle Gangetic Plain Region), Gujarat (Gujarat Plains and Hills), Maharashtra (Western Plateau and Hills), and Karnataka, Andhra Pradesh, & Tamil Nadu (Southern Plateau and Hills) covering a majority of the agro-climatic zones of India.
- The export-oriented packhouses are mainly located near the western coast in Maharashtra, Karnataka, & Kerala (Western Coastal Plains and Ghats), and Gujarat (Gujarat Plains and Hills).
- A significant number of the export packhouses surveyed operate in grapes and are concentred in the state of Maharashtra in the vicinity of a port.
- The packhouses that handle pome fruits are located in Himachal Pradesh, Jammu & Kashmir, and Uttarakhand in the ‘West Himalayan Region’.
- Domestic vegetable packhouses that handle carrots are located in the states of Tamil Nadu, Uttar Pradesh, Karnataka, and Andhra Pradesh.
- Domestic packhouses that handle exotic vegetables are located in North-Eastern states (Eastern Himalayan Region), Haryana (Trans-Ganga Plains), Maharashtra (Western Plateau and Hills), and Tamil Nadu (Southern Plateau and Hills)

As per NCCD[28], if the distance between production and consumption centres is less than 300 km, or the travel time is less than 48 hours, then the produce could be delivered to markets even without packhouse intervention. It should be noted that with improved road infrastructure and better transportation facilities, distances even beyond 300 km could be easily travelled overnight. However, where produce need to be transported over longer distances or durations, cooling is one of the pre-requisites, which implies the need for additional energy use to bring the produce fresh to the market. The project

28 NCCD. 2015. Guidelines & minimum System Standards for Implementation in Cold chain Components.

team's discussions with stakeholders reveal that typically pre-cooling is only done if there is market demand that justifies it. In the case of low commercial value produce, pre-cooling may not be commercially viable for price-sensitive domestic markets. Ideally, once pre-cooled in the packhouse, the produce thereafter should remain in an uninterrupted cold chain until it reaches the consumers. It was further revealed during stakeholder consultations that the current unavailability of requisite refrigerated retail outlets in India may render pre-cooling counter-productive in certain circumstances. However, for high-value fruits and vegetables, travelling long distances particularly to overseas markets, pre-cooling is critical.

Some of the surveyed packhouses were not located close to the farm gates. They are sometimes constructed at locations far from the farms, thereby increasing chances of under-utilization due to transport-related challenges such as road connectivity, transportation availability and the associated costs. This problem is further intensified in hilly areas where the transportation challenges are more prevalent due to the difficult terrain.

Locating packhouses close to farm gates also has its share of challenges. It was revealed during packhouse site visits in rural areas that it is difficult to hire and retain skilled operators and technicians if the facility is located away from the urban centres. In addition, reliability and quality of power supply was a concern in some rural areas. Grid connectivity is a non-negotiable infrastructure requirement while selecting the location of the packhouse.

2.3.3.2 Ownership

The packhouses surveyed were either owned by private limited companies, state government, cooperatives or FPOs. Private limited companies own and operate most of the packhouses surveyed. At the state level, organizations like Maharashtra State Agricultural Marketing Board (MSAMB) and Punjab Agri Export Corporation Limited (PAGREXCO) operate the packhouses, and some of these packhouse facilities have leased to private players, individual owners, exporters, cooperative societies or FPOs. Of the surveyed packhouses:

- Most of the export-oriented packhouses are owned by private companies. Very few packhouses are owned by the state government or cooperative organizations.
- The domestic packhouses handling tropical fruits and vegetables are owned by either private, state government or cooperative organizations.
- The domestic packhouses handling hill fruits (apple) are mainly owned by private traders. Some of the packhouses are also operated by the state government.
- The domestic vegetable (carrot) packhouses are all operated by private limited companies.
- The packhouses handling exotic vegetables are owned and operated both by private and farmer cooperatives.

2.3.3.3 Age and Size

Majority of the packhouses surveyed are relatively new, i.e. constructed after 2014 and less than five years old. It was observed that few of the initial set of packhouses built in India used outdated technology compared to newly constructed packhouses. This is not surprising considering that awareness about cold chain elements is relatively new in India, and about a decade ago cold chain was typically synonymous with cold storage facilities. However, some of the recent additions built in the last couple of years have even employed state-of-the-art sorting and grading machinery with skilled technicians managing the facility.

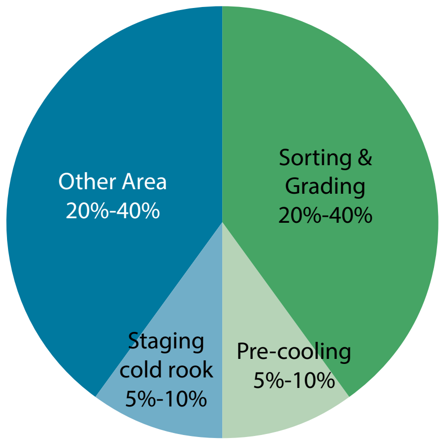
The facilities visited as part of the study vary from ~200 m^2 to ~5,000 m^2 in terms of built-up area. Size variation in packhouses and the equipment required to perform different functions is mainly governed by the quantity of produce handled in a packhouse, and whether there is a need for pre-cooling and storage. Aggregate energy consumption in large packhouses is likely to be high compared to small packhouses, however, specific energy consumption in large packhouses could be similar to a small packhouses, depending on the requirements of the produce.

- Based on the area, packhouses have been classified into three broad categories – small (<500 m^2), medium (500 to 2000 m^2) and large (above 2000 m^2).
- The domestic pome fruit packhouses are medium to large in size.
- Domestic vegetable (carrot) packhouses ranges from small, medium to a large-sized integrated facility.
- Packhouses handling exotic vegetables are small to medium-sized facilities.

For the large integrated packhouses[29] with a pre-cooling unit, the sorting and grading area constitutes up to 50% of the overall size of the facility. The pre-cooling area covers up to 10%, staging cold room up to 10%, and other areas (receiving, dispatch) make up the remaining 30% of the total built-up area. For packhouses without pre-cooling, the sorting and grading area varies from 30% to 60% of the total built-up area.

29 Per NCCD, an integrated packhouse refers to modern packhouse with facilities for conveyor belt system for, sorting and grading, washing, drying and weighing.

Figure 17: Packhouse area distribution



Based on the surveyed packhouses, the average area (average of all 21 facilities) distribution of a typical large integrated packhouse is presented in Figure 17.

Even though the pre-cooling and staging cold room constitute only 10% of the total built-up-area respectively, they are the most energy intensive areas in a packhouse. The details related to energy distribution across different areas in a packhouse is presented in Section 2.5 of this report.

2.3.3.4 Investment requirement

The investment requirement for setting up a packhouse depends on various factors like size, functions performed (with or without pre-cooling) and the produce handled (single or multiple crops).

- The investment required for export-oriented packhouses surveyed is primarily made by private limited companies.
- The investment for domestic packhouses utilized for tropical fruits and vegetables are usually made by small to medium scale farmer cooperatives and FPOs.

- Private trading companies are major investors in domestic hill fruit (apple) packhouses.
- Big farmers and private companies are the major investors in the domestic vegetable (carrot) packhouses.
- The investment for packhouses handling exotic vegetables are made either by small farmers or private traders.

The packhouses requiring larger investment are typically set up by private players such as trading companies.

2.3.3.5 Incentives

The Government of India, through its various incentive schemes, provides financial assistance for packhouse development that can be availed by private owners as well. Twelve of the surveyed packhouse owners have utilised these schemes, as shown in Table 12. Other packhouse owners with sufficient financial resources have built their facilities without any assistance.

2.3.4 Building Design

2.3.4.1 Layout of the facility

The packhouse design is primarily driven by the produce being handled and the buyers' requirements. However, the team observed that the design could vary for the same produce, as there are no available design guidelines, and the design is largely dependent on the experience of the design consultants or turnkey contractors. The orientation of packhouses was mostly determined by the site constraints, and no special care was given to site selection and orientation for reducing solar heat gains.

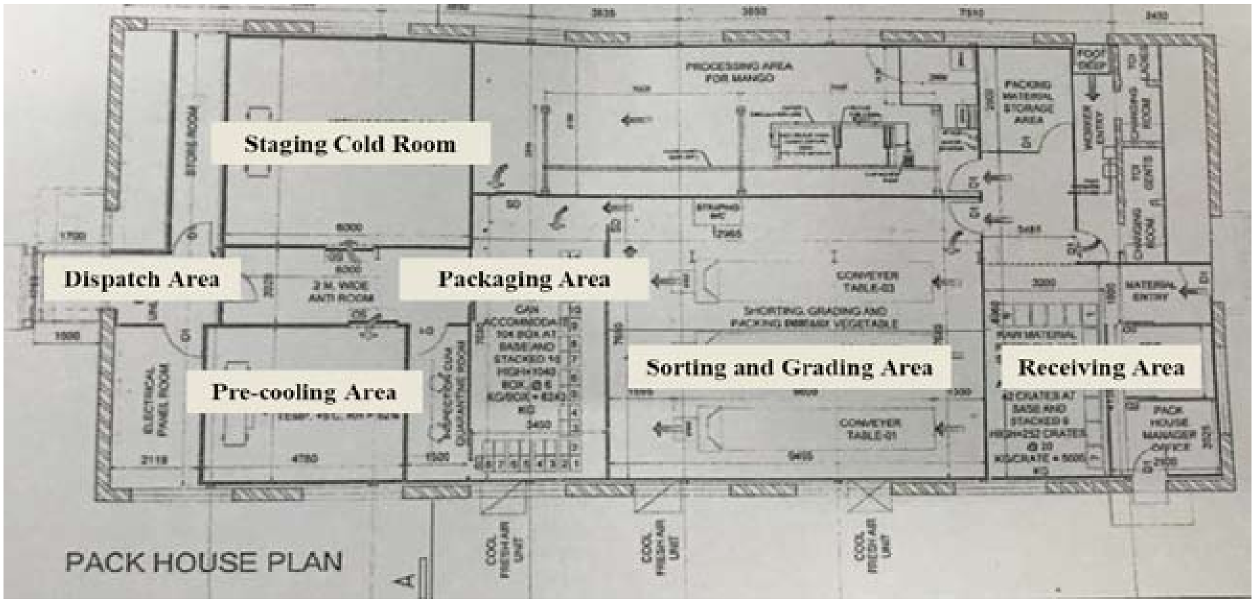
Secondly, the team observed that incorporating energy efficiency measures into the design of a packhouse was typically not a priority due to lack of awareness amongst design consultants and packhouse owners. Any proposed energy efficiency measure is subject to the willingness of the facility owner.

- There is a need for formulation of guidelines for optimal packhouse layout i.e. to optimize the flow of produce and people within the packhouse. This can minimise the total distance travelled by people and produce and reduce the resultant temperature variation across various sections in a packhouse, thereby minimising deterioration of the produce as well as save energy.
- Only the export-oriented and large private domestic packhouses had good design practices with a focus on the optimal flow of produce and people to meet the compliance requirement defined by various buyers.

Table 12: Packhouse distribution across various subsidy schemes

Government Body	Organisation/Scheme	Number of surveyed packhouses
Ministry of Commerce and Industry	Agricultural & Processed Food Products Export Development Authority (APEDA)	2
Ministry of Agriculture and Farmers' Welfare	Mission for Integrated Development of Horticulture (MIDH)	2
Ministry of Agriculture and Farmers' Welfare	Rashtriya Krishi Vikas Yojana (RKVY)	6
Ministry of Food Processing Industries	Pradhan Mantri Kisan SAMPADA Yojana (PMKSY)	2

Figure 18: Sample of packhouse layout



2.3.5 Material Used

During the site visits, it was observed that the material used for the construction of the walls and roof varies across different packhouses, and little to no emphasis appeared to have been given the thermal performance of the material in most cases.

- The walls of most of the packhouses are either made of brick and mortar, prefabricated insulated or tin sheet.
- The roof/ceiling was either made of tin sheet/colour coated metal sheet, RCC, false ceiling or prefabricated insulated.
- Thermal insulation was installed only in a few packhouses.
- Windows are not installed in most of the packhouses surveyed to avoid radiative heat gain inside the building.

Installing an adequate amount of insulation minimizes heat transfer from the outside environment and reduces the cooling load and energy consumption.

2.3.6 Receiving area

As per NCCD, the receiving area is a covered shaded area for arriving produce to be off-loaded and undergo pre-selection and weighing. In most of the packhouses surveyed, the receiving area is well shaded to avoid exposing the fresh produce to the high ambient temperatures.

Fast roll-up doors are used where a section of the facility has to be isolated from the other section. It is a vertically operated door that opens automatically through sensors allowing forklifts to pass through the door to the receiving area and despatch area. The door closes automatically immediately after the forklift has passed. They ensure effective protection against heat, dust and maintaining steady temperature and humidity by preventing colder air escaping/warm air entering. Only in grape export packhouses, fast rollup doors are installed in the receiving and delivery areas.

2.3.7 Sorting and grading area

The sorting and grading line typically had conveyor belts for the produce with staff standing along each side to visually inspect the produce and grade different kinds of fruits and vegetables.

- In most of the fruit packhouses surveyed, a conveyor belt was used for sorting and grading lines whereas in vegetable packhouses, sorting and grading is performed manually.
- The daily operating hours range from 8-10 hours, depending on the season.
- The total capacity of sorting and grading lines varies from 5 MT to 100 MT per day, depending on the size of the facility and the number of lines installed.
- Only in grape packhouses, the sorting and grading areas are air-conditioned. In grape packhouses, cooling systems are installed, as grapes are harvested in fields at around 30°C and they need to be cooled down to around 1°C. This distributes the pre-cooling load across the packhouse area.
- The energy consumption in sorting and grading lines is comparatively low and is mainly attributed to conveyor belt motors and lighting load.
- The capacity of sorting and grading motors in most packhouses surveyed varies from 0.5 HP to 1.5 HP.
- LED lighting was used in almost all the packhouses surveyed.
- In mango packhouses, hot water treatment equipment (for treating fruit flies) was installed as per the buyers' requirement.
- In apple packhouses, automatic machines sort and grade apples based on size and colour.
- For handling carrots, a washing machine was installed in an open area for sorting, grading, polishing and washing.

2.3.8 Pre-cooling and staging cold room

2.3.8.1 Pre-cooling system

As per NCCD, pre-cooling unit is a specialised cooling room that rapidly removes field heat from fresh produce after harvest and thereby prepares the cargo for subsequent shipping. It is one of the most critical steps in preparing fruits and vegetables for the extended cold chain. The component of a pre-cooling unit includes:

Table 13: Sorting and grading equipment detail

Produce	Process Equipment	Equipment Load	Throughput (MT/day)
Apple	Automatic sorting and grading line	25-35kW	20-80
Grape	Conveyor lines (motors)	10-15kW	80-100
Banana	Conveyor lines (motors) and water tank pumps	5-10kW	10-60
Mango	Conveyor lines (motors) and hot water tanks (immersion heaters)	20-25kW	15-25
Vegetable (Carrot)	Washing machine (motors and pumps)	10-15kW	15-95
Other Vegetables (chilli, okra, mushroom etc)	Manual	NA	5-10

- Insulated room: thermally insulated room designed to pre-cool the produce in temperature-controlled conditions and high humidity conditions.
- Pre-cooling unit: Evaporator, condenser, compressor and expansion valve combine to make a pre-cooling unit to supply air at adequate temperature and relative humidity (RH) as per the produce requirement.
- Controls: Electronic controller for controlling refrigeration and for temperature and relative humidity monitoring.

Common cooling systems currently being used in packhouses in India include- room cooling and forced air cooling. Of these systems, forced air cooling was used in most of the packhouses visited by the team. Field heat removal depends on various factors, including:

- The temperature of the commodity when harvested,
- Type of produce, based on which temperature requirement varies,
- Packaging, such as choice of box, bin or bag, which affects the method and rate of cooling.
- Air distribution.

2.3.8.2 Staging cold room

As per NCCD, staging cold room is an insulated, refrigerated chamber and serves as temporary storage while allowing the pre-cooler to be utilised for the next batch of produce. It is essential that the pre-cooling unit have an adjoined staging cold room. Most of the surveyed packhouses were equipped with staging cold rooms. Cold room includes an insulated room, refrigeration equipment and a staging area for dispatch. The design specifications are similar to those of a cold store, with refrigeration design to suit humidity and temperature ranges for horticulture produce.

Based on the site visits, key observations on pre-cooling and staging cold rooms are summarized below.

- Keeping the produce in the shaded area for removing the field heat will complement pre-cooling and reduce energy use.
- Delicate fruits like grapes start deteriorating as soon as they are harvested, hence pre-cooling and proper packaging is essential to extend their shelf life.
- In most of the packhouses, a pre-cooling unit was installed which operates for 4-6 hours in two to three batches per day.
- The pre-cooling and staging cold rooms constitute the majority of refrigeration requirements.
- There are no standard procedures or guidelines for the design of pre-cooling systems, and the design is mainly governed by buyers' requirements and experience of the design consultant.
- The pre-cooling unit and cold room insulation system are installed with low-density insulation (PUF foam) and there are no guidelines and recommendations on the specifications of materials to be used for pre-cooling and cold rooms.
- It was observed that in some cases, there was no emphasis on designing an energy efficient pre-cooling and staging cold room system, and there is no sub-metering of energy consumption. Primary reasons for this can be limited understanding of the of better energy management, and absence of guidelines for design

of energy efficient pre-cooling and staging cold room systems.

- An air-cooled distributed refrigeration system was installed in almost 80% of the packhouses surveyed.
- R-404A was used as the predominant refrigerant in most of the surveyed packhouses for pre-cooling and cold rooms. Other refrigerants used in refrigeration plant include hydrofluorocarbons (HFCs) like R-134a, R-32, R-407C, R-507C and hydrochlorofluorocarbons (HCFCs), namely R-22. R-717 (natural) refrigerant is mostly used in cold storages with or without cold store facility.
- Owners of domestic packhouses expressed reluctance to install pre-cooling systems due to the increase in costs, as well as the additional cost of reefer transport.
- In few packhouses pre-cooling was not used because produce had to travel over a short distance.
- System configuration: Two types of refrigeration system configurations were observed in the packhouses visited: (i) one-to-one, i.e. dedicated compressor (and condenser) for each evaporator is the most predominant system configuration, followed by (ii) centralised compressor rack system with a common compressor bank for different evaporator units.
- Compressor type: Different types of refrigeration compressors, including reciprocating, scroll, and screw, were observed in these systems.
- Heat rejection: The one-to-one systems are generally air-cooled while both air-cooled and water-cooled heat rejection configurations were observed for

Box 1: Environmental impact of various refrigerants

The environmental impact of the different refrigerants typically used in the cold chain in India is shown in Table 14. The table highlights that most of the refrigerant used reflects the impact of the global HCFC phaseout wherein R-22 is gradually under replacement with non-ozone depleting alternatives.

Table 14: Environmental impact of different refrigerants used in India

Refrigerant	Type	ODP	GWP
R-404A	HFC	0	3922
R-134A	HFC	0	1430
R-32	HFC	0	675
R-407C	HFC	0	1774
R-507	HFC	0	3900
R-22	HCFC	0.055	1810
R-717 (ammonia)	Natural	0	0

It is important to note that most of the refrigerants in use today are still far from having low environmental impacts per se, as can be seen from the GWP figures. Rather, in the absence of a specific Government mandate for adoption of stricter standards, these refrigerants tend to be the replacements adopted per industry practice. The GOI is not a party to the Kigali Amendment to the Montreal Protocol on HFC phase-down but is expected to convert the commercial refrigeration sector from HCFCs to lower-GWP alternatives under the Multilateral Fund framework in the near future.

Figure 19: Different Configurations of Pre-cooling Systems

packhouses with rack systems. In a few packhouses, the evaporatively cooled one-to-one system was also observed.

- Most of the packhouses with Direct Expansion (evaporator) refrigeration systems had a conventional thermostatic expansion valve. Electronic expansion valves (EEV) were provided in few export packhouses and none of the packhouses visited had provision for subcooling.
- Most of the packhouses have manual operations for refrigeration plant and room parameter monitoring. Centralised monitoring and control systems are installed only in export packhouses.
- There was a variation in air distribution set up in facilities visited during the study. Some packhouses used pre-cooling systems that had inadequate air distribution while others had adequate air distribution with optimized suction and discharge to ensure uniform flow of air. Different configurations are shown in Figure 19.

2.3.9 Dock levellers, dock shelters

A dock leveller is an adjustable metal ramp designed to bridge the gap between the cargo bed of a transport vehicle and the loading platform.

Dock Shelters seal the gap between the packhouse and the transport container protecting the produce against dust, humidity and temperature conditions outside and thereby optimize the energy consumption required for cooling.

Both dock leveller and shelter ensure smooth transfer of produce and facilitate effective operation during loading and unloading and prevent spoilage. The site visits show that dock levellers and shelters are installed in only 30% of the packhouses surveyed.

2.3.10 Air curtains and strip curtains

Strip curtains and air curtains used to prevent air or contaminants from moving from one open space to another are relatively common and are installed in more than 60% of packhouses surveyed. The curtains help avoid infiltration of hot outdoor air within cooled spaces during material and people movement while loading and unloading.

2.3.11 Operation and maintenance

Most of the surveyed packhouses had adopted in-house maintenance practices. However, the large export-oriented packhouses that primarily handle grapes and the domestic market packhouses that handle apples had outsourced periodic maintenance to third party agencies, generally refrigeration equipment suppliers, through annual maintenance contracts (AMC).

Figure 20: Docking system installed

These grape and apple packhouses also had skilled and qualified technicians/operators compared to the majority of the remaining packhouses operating in the domestic market. Most of the packhouses visited are operated by semi-skilled technicians with a limited understanding of refrigeration plant operation and packhouse processes. There is limited availability of skilled packhouse operators and technicians throughout India and the existing packhouse operations and processes adopted in handling, packaging, palletisation are not carried out following standard operational practices. It should be noted that even when there is an AMC in place, very limited or no emphasis was observed to be given to energy management. In addition to regular maintenance of refrigeration and other equipment through lubrication, defrosting, etc., the AMC or in-house maintenance should also include periodic calibration of sensors/meters, testing of refrigeration plant operating parameters, electrical plant performance, noise levels of fans, etc. – all of which were not observed to be performed periodically and methodically.

In all of the packhouses surveyed, proper O&M is a missed opportunity in terms of avoiding energy wastage. Whether in-house or outsourced, periodic maintenance as per predetermined well-structured protocols taking cognisance of all energy management aspects should be taken up on priority.

2.3.12 Electricity supply and distribution system

In almost all the packhouses surveyed, grid-based electricity is the primary energy source. Diesel Generator (DG) sets are installed as a back-up power source which is operated only on a need basis and does not account for significant energy consumption. The large packhouses surveyed (both export and domestic-oriented) had their own distribution transformers.

Majority of the packhouses surveyed had commercial electricity connections, but the tariffs varied across states. In Maharashtra, the tariff was around INR 5 per kWh or unit while in Punjab, Tamil Nadu and Uttar Pradesh it was around INR 7-8 per unit. A few states also had agricultural tariffs, which were as low as INR 0.25 per unit for one packhouse in Haryana.

It is important to note that low electricity tariffs most likely disincentivise energy efficiency, because the lack of significant potential energy bill savings means the facility owners will not see an obvious financial benefit from the adoption of energy saving measures.

While the reach of electricity is spreading continuously in India, uninterrupted power supply is still a concern in certain states, especially in rural areas. The average daily power supply in rural areas is 24 hours in the states of Himachal Pradesh, Maharashtra, Punjab and Tamil Nadu[30]. However, there are challenges with the availability, quality and reliability of power supply in a few other states. For the upcoming packhouse stock, availability of reliable power supply is an essential infrastructure requirement. A few of the surveyed packhouses had solar-powered cooling systems for pre-cooling and staging cold rooms, which is an effective solution for remote rural areas with limited power supply.

Discussions with packhouse owners revealed that electricity generation from diesel generators (DG) costs them around INR 25 to 35 per unit of electricity, which is quite expensive compared to grid electricity. Hence, packhouse owners are willing to explore alternative sources of energy including solar photovoltaic system. It should be noted that while most of the surveyed packhouses had reliable power supply, and hence higher DG back-up costs were not a major concern, the same may not be true for the upcoming stock whose ideal location could be in an area with power supply reliability and quality challenges. This indicates that there is a clear trade-off for packhouse owners while deciding on the location of packhouses, where they may have to choose between proximity to farm gate and availability, reliability and quality of power supply.

30 Pib.gov.in. 2019. Electrification Of Villages. [online] Available at: <https://pib.gov.in/Pressreleaseshare.aspx?PRID=1592833> [Accessed 1 September 2019].

2.4 Key Takeaways

The key takeaways from site visits carried out under the study are summarized below.

- There are noticeable differences in terms of geographic region, size, investment requirement, and operation and maintenance practices of packhouses catering to export markets relative to those that primarily operate in domestic markets. The functions performed in a packhouse primarily depend upon two factors: the type of produce handled and the requirements of the target market in terms of consumer demand and the prevailing food safety regulations.
- Majority of the packhouses surveyed are relatively new, i.e. constructed after 2014 and less than five years old. However, a few of the initial lot of packhouses built in India were found to be using outdated technology, while newly constructed packhouses typically deploy newer technology.
- The selection of the packhouse location is one of the most critical infrastructure planning decisions. Proximity to the farm gate, access to critical infrastructure roads, transportation system and uninterrupted power supply have a significant impact on not just the energy consumption for bringing the produce from farm to fork but also in the commercial viability of packhouse.
- The packhouse design is primarily driven by the produce being handled and the buyers' requirements. However, the design could vary for the same produce as there are no available design guidelines, and the design is largely dependent on the experience

of the design consultants/turnkey contractors.

- Energy efficiency is generally not considered during packhouse design, which appears to be primarily due to lack of awareness amongst design consultants and packhouse owners. Energy efficiency currently fares quite low in packhouse owners' priorities.
- The orientation of packhouses was mostly determined by site constraints, and no special care was given to site selection and orientation for reducing solar heat gains.
- The material used for the construction of the walls and roof varies across different packhouses, and no emphasis has been given on the thermal performance of the building envelope.
- Very limited emphasis was given on designing an energy efficient pre-cooling and staging cold room system, and sub-metering of end-use energy consumption is non-existent. One of the primary reasons for this is the absence of guidelines for the design of energy efficient pre-cooling and staging cold room systems in India and the limited awareness of the cost-benefit from better energy management.
- Proper O&M is a missed opportunity in terms of avoiding energy waste. Most of the packhouses surveyed, barring a few newer facilities, have employed semi-skilled technicians with a limited understanding of refrigeration plant operation and packhouse processes. There is limited availability of skilled packhouse operators and technicians throughout India.
- The existing packhouse operations, processes and layouts for handling, packaging, and palletisation are performed in highly varied ways across facilities. The formulation of guidelines for good practices in packhouse processes and layouts can help optimize the flow of produce and people, reduce the total distance travelled by people and produce, minimize the temperature variation across different sections, and optimise energy consumption.
- Very low electricity tariffs in a few states are disincentivising energy efficiency as the interest in energy efficiency is a function of potential energy bill savings that could accrue to facility owners or operators by saving energy, which in turn depends on the electricity tariffs they pay.

A summary of observations is presented in Table 15, while Chapter 3 provides a set of recommendations that were informed by these takeaways from site visits.

Table 15: Summary of observations

Category of pack-house	Produce handled	Location	Ownership	Size	Investment	Layout	Operators skillset	Operation	Scope of EE potential
Export	Grape, Pomegranate, Mango, Banana, Vegetables	Mainly western part of India- Maharashtra, Gujarat, Karnataka, Kerala	Private, Public, Cooperative	Large integrated	Mostly private	Good design including hygiene and food safety	Trained operators	Semi-automatic	Pre-cooling and cold room
Domestic	Tropical Fruits and Vegetables (Banana, Mango, Vegetables)	Punjab, Haryana, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, Maharashtra, Gujarat, Karnataka	Private, Public, Cooperative	Small to Medium	Small to medium scale farmer cooperatives and FPOs	Moderate	Unskilled operators	Manual and semi-automatic	Building design, process and refrigeration system for pre-cooling and cold room
Domestic	Pome Fruits (Apples)	Himachal Pradesh, Uttarakhand	Private, Public	Medium to Big	Private trading companies	Good	Trained operators	Automatic and semi-automatic	Innovative process and facility design
Domestic	Vegetable (Carrot)	Tamil Nadu, Uttar Pradesh, Karnataka, Andhra Pradesh	Private	Small, Medium, and Large integrated	Big farmers and private	Moderate	Unskilled operators	Manual and semi-automatic	Building design, process and refrigeration system for pre-cooling and cold room
Domestic	Exotic Vegetables (Broccoli, Lettuce, Mushroom, etc)	North-Eastern states, Haryana, Maharashtra, and Tamil Nadu	Private and farmer cooperatives	Small to Medium	Small farmers and private traders	Moderate	Semi-skilled operators	Manual	Building design, process and refrigeration system for pre-cooling and cold room

2.5 Overview of energy use

To understand the energy usage trends and their correlation with packhouse operations, information related to connected load, electricity bills, capacities and efficiencies of various equipment, and produce throughput were collected during the visit based on nameplate data and discussion with packhouse owners and/or operators.

The required data was at best partially and intermittently available, primarily due to the lack of skilled manpower and sometimes the lack of management's attention towards energy consumption. Additionally, due to the absence of energy performance norms even for energy intensive systems such as pre-cooling and cold room, the requisite information on efficiency was seldom available. Data on annual throughput (amount of produce handled) was not shared by the packhouse owners.

In the absence of any industry established energy performance norms, the study used two separate indicators depicting the design and operational energy efficiency, in consultation with various industry experts and extant literature. Any missing data pieces were substituted with informed assumptions from equipment manufacturers and system designers.

2.5.1 Energy Performance Indicators

The following two indicators were developed for evaluating the energy performance of packhouses:

- Connected load intensity (kW/MT) - Design energy performance indicator
  - It is the ratio of total connected electrical load (kW) to the average daily produce handled during peak season (MT)
- Energy use intensity (kWh/MT/day) Operational energy performance indicator
  - It is the ratio of average daily electricity consumption during peak season (kWh) to the average daily produce handled during peak season (MT)

It should be noted that the average produce handled during peak season is an indication of packhouse capacity utilisation. This may be different from the packhouse design capacity, which is the maximum amount of produce that can be handled by the packhouse according to its design considerations and constraints. The energy performance intensity values can be used to effectively determine the overall efficiency of packhouse operation and help facilitate comparison with packhouses with similar operational characteristics. These values will also guide the identification and scope for energy efficiency improvement options.

2.5.2 Connected load intensity across surveyed packhouses

The total connected electrical load of the surveyed packhouses has been broken down into three categories: refrigeration load, process

Table 16: Sources of various essential data points used for the analysis

Parameters	Source
Average daily electricity consumption (kWh)	Derived from actual electricity bills or electricity expenditure shared by the packhouse owner
Connected load (kW)	Based on data shared by packhouse owners
Average daily produce handled (MT)	Average daily throughput was shared by packhouse owners. The annual produce handled was not shared

Figure 21: Typical electrical load distribution across surveyed packhouses

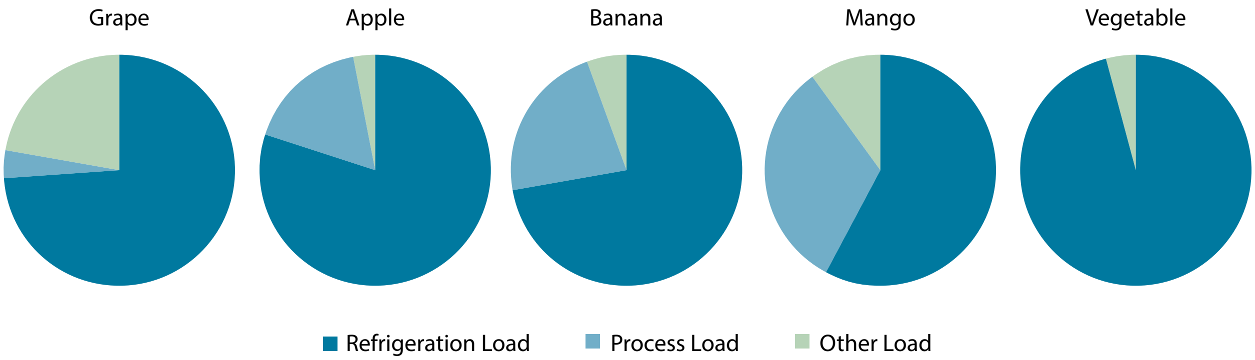
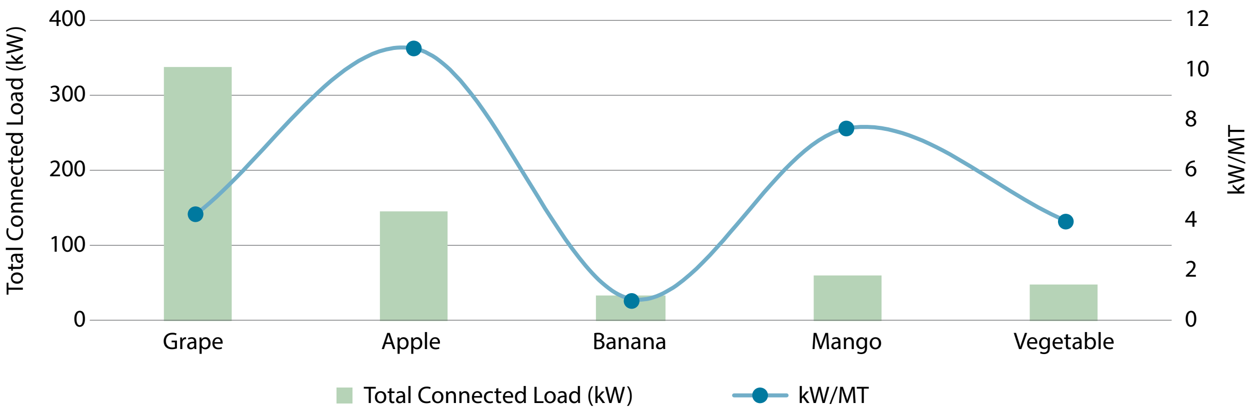


Figure 22: Comparative assessment of the total connected load (kW) with connected load intensity (kW/MT)



load and others (lighting, dock leveller motors, lifts). Alongside the load breakup, the connected load intensity (kW/MT) has been derived from the average produce throughput information.

Figure 21 presents the electric load distribution across various types of produce types, and Figure 22 shows the connected load intensity for these produce types.

Select insights emerging from a review of information available on electrical load distribution and connected load intensity across packhouses are listed below.

- Highest connected load (300-350 kW) was observed in grape packhouses. The load in a grape packhouses is attributed to the sheer size of the facility as well as the requirement of cooling across all operations (receiving area to dispatch area) due to the delicate nature of grapes. This is also reflected in the load distribution in a grape packhouse with refrigeration load constituting up to 75% of the total connected load. Connected load intensity is moderate (4 kW/MT) due to high produce throughput.
- The highest connected load intensity (11 kW/MT) was observed in apple packhouses. 80% of the overall connected load (~150 kW) is attributed to refrigeration alone. Apple packhouses are generally accompanied by cold storages. The pre-cooling for apples is achieved by keeping them in cold rooms for about ~96 hours before initiating the long-term storage.

- Lowest connected load (30-50 kW) and connected load intensity (1 kW/MT) was observed in banana packhouses. Refrigeration load in a banana packhouse constitutes up to 70% of the total connected load.
- Mango packhouses have much lower connected load (60-100 kW) as compared to grape packhouses but comparatively higher connected load intensity (8-10 kW/MT). The comparative share of process loads (60%) is highest in the case of mango packhouses due to hot water treatment (using electric immersion heaters) of mangoes as per the export market requirement.
- The connected load (~50 kW) in a vegetable packhouse is on the lower side as compared to a grape packhouse as most of the processes in a vegetable packhouse are done manually. The connected load intensity (4 kW/MT) of a vegetable packhouse is quite similar to that of a grape packhouse.

2.5.3 Energy use intensity

The availability of pre-cooling and staging cold rooms and their adequate capacity are critical both for appropriate produce care and for driving energy use in a packhouse. If the pre-cooling capacity is more than or equal to the sorting/grading line throughput, then the capacity could be considered sufficient. The staging cold room capacity with respect to pre-cooling capacity represents the number of days up to which the produce could be stored, waiting for onward cold chain journey, during the peak season. Hence while studying the energy use intensity of the surveyed packhouses, the team mapped the availability of sufficient pre-cooling capacity to match sorting and grading lines (Yes/No), and the staging cold room capacity with respect to pre-cooling (number of days) (Figure 23).

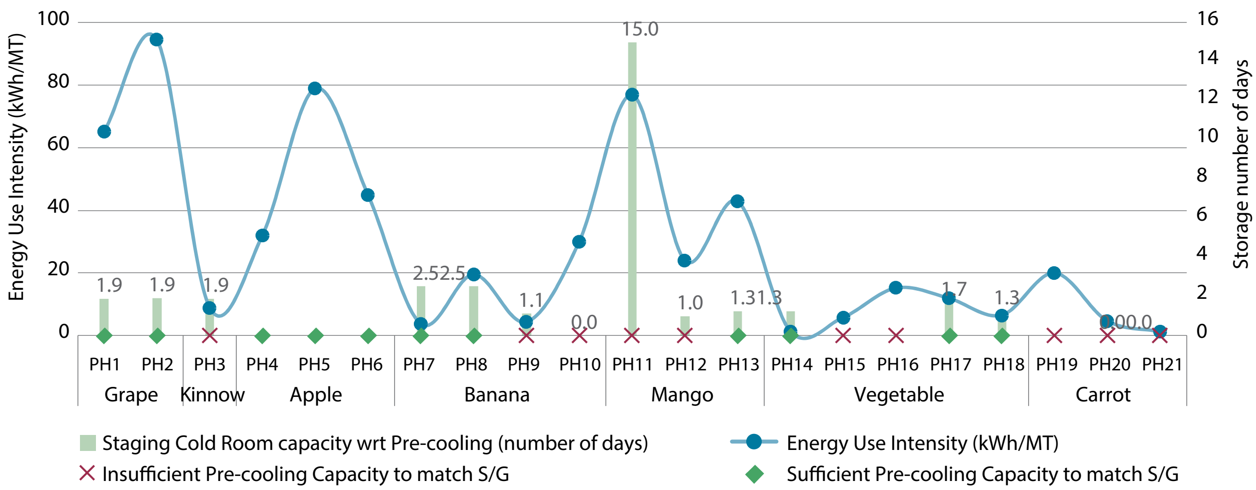
Some emerging insights are listed below.

- Refrigeration load (pre-cooling and staging cold room) is the **most energy intensive** area in a packhouse and constitutes up to 60%-80% of total energy consumption.
- Grape packhouses have the **highest energy use intensity** (60-100 kWh/MT) followed by apple and mango, both varying from 40-80 kWh/MT.
- The **high energy intensity** in mango packhouses is due to the hot water treatment as per the export requirements.
- Vegetable packhouses generally have the lowest energy use intensity (<10 kWh/MT) owing to **minimum process loads** and low capacity utilisation.
- The energy use intensity for apple packhouses varies from 30-80 kWh/MT. Since pre-cooling is done as part of a cold room or controlled atmosphere facility, it is difficult to precisely segregate the energy requirements for pre-cooling vis-à-vis cold room operation. However, since average daily energy consumption during peak season is considered for calculating the energy use intensity, it can be safely assumed that during peak season, the majority of refrigeration load is required for pre-cooling operation.

Figure 23 plots several key energy indicators for the packhouses surveyed under the study, namely, **energy use intensity (kWh/MT)**, **availability of sufficient pre-cooling capacity** to match sorting and grading lines (Yes/No), **and staging cold room capacity** with respect to pre-cooling (number of days) across surveyed packhouses.[31]

31 This study focused on a sample of 21 packhouses covering various types of produce in different agro-climatic zones. The indicators developed based on these packhouses need to be further strengthened with a comprehensive study covering a statistically relevant sample of packhouses for the development of an energy performance baseline.

Figure 23: Key energy indicators for packhouses surveyed



The team analysed and compiled the observations and energy performance analysis of packhouses by produce category. Discussions with industry experts and technology providers revealed that most of the energy efficiency measures are related to building design, system and equipment design and operation and maintenance, and are applicable for various types of produce with the only variation in the energy savings magnitude for each measure.

2.6 Energy Efficiency Measures

Across all the packhouses surveyed, energy efficiency interventions were identified in three broad categories- (i) building design (improving thermal performance), (ii) equipment and system design (optimising refrigeration and cooling system performance), and (iii) packhouse processes and operation and maintenance (process improvement and O&M best practices).

Under each of the three categories, energy efficiency measures (EEMs) are recommended based on a comprehensive assessment of site visit observations, technical features of the proposed measure, energy saving potential (estimated based on the consultants' research and feedback from design consultants and manufacturers), and applicability based on cost-benefit analysis. The cost-benefit analysis of various identified EEMs was carried out against a reference integrated packhouse for each produce studied. The generic specifications of a sample integrated packhouse were assumed based on the packhouse design standards presented in Table 17.

The technical specifications, including the connected load of sorting and grading, refrigeration load for pre-cooling and staging cold room, other loads (such as lighting and forklifts), and their respective operating hours for produce-specific (vegetable, apple, banana, grapes and mango) packhouses were derived from site visit observations and validated with inputs from industry experts. The connected load of the sorting and grading area was determined considering conveyor belt motors, dryers, pumps, air conditioning (only for grapes), automated machines (only for apples), and electrical immersion heaters (only for mangoes) – as applicable. The refrigeration loads have been assumed based on the varying temperature/humidity requirements described in Table 18 for specific produce. The space lighting load was assumed as per

Table 17: Generic specifications for sample integrated packhouse

Packhouse Details	Assumption	Source/Remarks
Daily Produce throughput	16 MT	As per NCCD[32]
Built-up area	640 m^2	40 sqm/MT as per AVRDC[33] guidelines (area of the packhouse including sorting, grading, pre-cooling and staging cold room)
Sorting and grading handling capacity	2 MT/hour	As per NCCD
Pre-cooling capacity	18 MT/day	As per NCCD Guidelines, using 6 MT/batch and 3 pre-cooling batches per day
Staging cold room capacity	30 MT	As per NCCD

levels recommended in ASHRAE Standard 90.1 covering Energy Standard for Buildings Except Low-Rise Residential Buildings[34]. Further, forklift loads were also considered wherever applicable. The total connected load and annual operating hours were used to obtain the annual energy consumption for each of the five produce items. The total cost of produce-specific packhouses was estimated through inputs from technology providers and design consultants. An indicative cost break for a sample integrated packhouse-down is available in Annex 5.

Table 18: Technical specifications for electrical and refrigeration load, operating hours and cost

Packhouse Parameter		Grape	Apple	Banana	Mango	Vegetable
Sorting and Grading	Connected load (kW)	8.0	2.0	9.3	3.5	7.5
	Daily operating hours	10	8	16	8	16
Pre-cooling	Refrigeration load (TR)	10.0	7.0	11.0	9.0	10.0
	Efficiency (ikW/TR)	1.94	1.48	1.98	1.83	1.48
	Connected load (kW)	19	10	22	17	15
	Daily operating hours	10	8	16	8	16
Staging Cold room	Refrigeration load (TR)	5.7	6.3	5.7	6.3	6.3
	Efficiency (ikW/TR)	1.98	1.47	1.98	1.85	1.47
	Connected load (kW)	11	9	11	12	9
	Daily operating hours	16	16	16	16	16
	Lighting Load (kW)	6.6	6.6	6.6	6.6	6.6
	Forklift (kW)	6	0	6	0	0

32 NCCD. 2015. Guidelines & minimum System Standards for Implementation in Cold Chain Components.

33 Acedo AL Jr, Rahman MA, Buntong B, Gautam DM. 2016. Establishing and managing smallholder vegetable packhouses to link farms and markets. Publication No. 16-801. AVRDC – The World Vegetable Center. 46 p.

34 https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards

Packhouse Parameter	Grape	Apple	Banana	Mango	Vegetable
Total Connected Load (kW)	**55**	**51**	**28**	**38**	**39**
Annual operating days	120	240	210	120	210
Annual Energy Consumption (kWh)	**95,571**	**1,25,219**	**57,905**	**73,045**	**84,677**
Cost of sample packhouse (lakh INR)	**197**	**257**	**165**	**189**	**165**

For carrying out the cost-benefit analysis, energy saving potential and incremental costs were derived in consultation with multiple industry players including design consultants, and equipment manufacturers. The energy saving potential and the respective incremental costs for various proposed EEMs were then used to calculate the payback period against each proposed measure as discussed below. Illustrative payback calculations for produce-wise sample packhouses are provided in Annex 6.

2.6.1 EEMs - packhouse building design

Energy efficiency interventions at the packhouse building design level are applicable for both existing and upcoming (new) packhouses for various types of produce and include interventions focusing on building design, materials and different design strategies to reduce heat gain.

1. Natural lighting to reduce lighting load, proper orientation and shading for minimizing solar heat gains

Site visit observation: It was observed that the orientation of packhouses was mostly determined by the site constraints, and no special care was given to site selection and orientation for reducing solar heat gains. Majority of packhouses relied on artificial lighting as the building/window design did not allow natural lighting.

2. Wall and Roof insulation

Site visit observation: The roof/ceiling was either made of colour coated metal sheet, RCC, false ceiling or prefabricated and thermal insulation.

Table 19: Natural lighting, proper orientation and shading

Proposed measure	The orientation of the building should be such that the longer facades face North-South and short facades face East-West. If possible, native trees could be planted along the south-facing walls, maintaining an appropriate distance. Building design could use measures to integrate natural lighting to reduce artificial lighting load through a combination of clerestory windows and polycarbonate transparent roofing patches. Natural lighting will further boost the productivity of the packhouse staff.
Energy saving potential	Indicative energy saving potential can be 1-2% of total energy consumed. The reduction in cooling demand is around 1%.
Applicability of the proposed measure based upon cost-benefit assessment	There is no additional cost as this is a design feature and can be addressed through proper planning and right material selection at the design stage. This measure is recommended for all upcoming (new) packhouses handling different types of produce.

Table 20: Wall and Roof insulation

Proposed measure	▪ Insulation of the roof with adequate insulation (a few examples of insulation include PUF, mineral wool, rock wool) will reduce heat gain inside the building by reducing the conductive heat transfer from the wall and roof.
Energy saving potential	▪ The energy saving potential is 1-2% of the total energy consumed in a packhouse[35].
Applicability of the proposed measure based upon cost-benefit assessment	▪ The additional cost of insulation, including material and labour, is estimated to be around 110-140 INR per m^2. ▪ The payback period for this measure varies from 4 years for apple packhouse to 8 years for banana packhouses. ▪ Since the insulation helps in cutting down the ambient refrigeration and air conditioning loads, more attractive return on investment is observed for packhouses with comparatively higher refrigeration and air conditioning usage and higher packhouse operating hours. ▪ Based on the cost-benefit assessment, this measure is recommended for apple and grape packhouses where the payback period is up to 5 years.

3. Cool roof treatment

Site visit observation: Not observed in any of the packhouses visited by the team.

4. Provision for natural ventilation-ceiling-mounted turbo ventilators

Site visit observation: Steel roofing was provided without any provision of turbo ventilators in most of the packhouses. Windows for cross ventilation were also not provided.

5. Optimized size of pre-cooling and cold rooms

Site visit observation: The surveyed packhouses are designed and set up as per the expertise of the owners, consultants or contractors. There are no specific guidelines

Table 21: Cool roof treatment

Proposed measure	▪ Any cool roof treatment using low-cost interventions like highly reflective china-mosaic tiles or using cost-intensive SRI paint (not considered for this analysis) can significantly reduce the heat gains from the roof.
Energy saving potential	▪ The energy saving potential is estimated at 0.5-1%.
Applicability of the proposed measure based upon cost-benefit assessment	▪ There is no additional cost as this is a design feature for new packhouses and can be addressed through proper planning and right material selection at the design stage. ▪ For retrofit applications, the benefits will vary based on the type of roof treatment applied. Reflective tiling (with comparatively higher costs) would give better results than low-cost reflective (silver colour/plain whitewash) paints. ▪ This measure is recommended for all types of packhouses handling different types of produce.

35 P.C. Koelet. n.d. Industrial Refrigeration: Principles, Design and Applications.

Table 22: Provision for natural ventilation- ceiling-mounted turbo ventilators

Proposed measure	▪ Providing windows for cross ventilation and turbo-ventilators on the roof will ensure adequate ventilation (5 to 8 air changes per hour) and help remove built-up heat in the sorting/grading or packing areas, thereby removing the accumulated built-up loads due to air-stagnation. Additionally, natural ventilation will also have positive impacts on the health and productivity of the packhouse staff.
Applicability of the proposed measure based upon cost-benefit assessment	▪ The incremental cost for additional turbo ventilator with accessories and labour would be around INR 6-7 per sq.ft. (Source: Manufacturers' catalogues) ▪ Though there may not be any measurable reduction in energy usage against the marginal additional investment required, this measure is still recommended for all (new) upcoming packhouses across different types of produce wherever active air conditioning is not installed in the sorting/grading or packing areas.

available for sizing the chambers for pre-cooling and cold room applications with respect to produce handled. The heights of the pre-cooling and cold rooms were in many cases observed to be oversized, leading to energy wastages.

6. Airtight doors for pre-cooling and cold rooms

Site visit observation: In many of the packhouses, air infiltration was observed in pre-cooling and cold rooms which leads to hot and moist air ingress into the low-temperature areas and thereby increasing the refrigeration energy requirement.

7. Fast roll-up doors to prevent hot/moist air infiltration

Site visit observation: The fast roll-up door is a vertically operated door which opens automatically through sensors allowing forklifts to cross the door at the receiving area and despatch area and closes automatically immediately after the forklift crosses the door. The fast rollup doors were observed to be installed only in grape packhouses in the receiving and delivery areas.

Table 23: Optimized size of pre-cooling and cold rooms

Proposed measure	▪ Optimum sizing of the pre-cooling and cold room as per the throughput requirement.
Energy saving potential	▪ As per an energy assessment of a banana pre-cooling chamber in Tamil Nadu, a reduction of one-meter height of the pre-cooling chamber resulted in energy savings of 10 to 12%[36].
Applicability of the proposed measure based upon cost-benefit assessment	▪ There is no additional cost as this is a design feature and can be addressed through proper planning at the design stage. ▪ This measure is primarily recommended for all upcoming (new) packhouses handling different types of produce; however, existing packhouses wherever over-sized could also be easily refurbished without imposing significant costs.

36 Danfoss. 2013. Energy assessment of Banana Packhouse in Tamil Nadu.

Table 24: Airtight doors for pre-cooling and cold rooms

Proposed measure	▪ Improvement in the quality of the construction of the doors by using gaskets (neoprene), hinges and latches made of industrial grade stainless steel material. ▪ Strip curtains can be a complementary solution for cooling loss prevention alongside airtight doors.
Energy saving potential	▪ The saving potential in overall energy consumed in cooling is around 2%.[37]
Applicability of the proposed measure based upon cost-benefit assessment	▪ The additional cost is around INR 25,000-30,000 per packhouse ▪ The payback period varies from ~2 years for apple packhouses to ~4 years for mango packhouses, with vegetable, grape, and banana packhouses having payback periods between 2 to 4 years. Hence, this measure is recommended for all types of packhouses. ▪ Where airtight doors may not be financially feasible, strip curtains, complementing regular doors, can be considered as a cheaper alternative.

8. Pre-cooling and staging cold room insulation with optimum thermal performance

Site visit observation: The pre-cooling and cold room insulation are installed with low-density insulation (PUF foam) and there are no guidelines and recommendations on the specifications of materials to be used for pre-cooling and cold rooms.

2.6.2 Summary of EEMs - Packhouse building design

The prioritised list of EEMs under the packhouse building design category are compiled in Table 25. Both the energy saving potential and the incremental cost are calculated at the packhouse building level. The prioritisation is based upon the cost-effectiveness of the suggested measures reflected by the

Table 25: Fast roll-up doors to prevent hot/moist air infiltration

Proposed measure	▪ Installation of fast roll-up doors will reduce hot air and moisture infiltration to the receiving and dispatch area and cold area.
Energy saving potential	▪ Based on various manufacturers' catalogues, the saving potential in overall energy consumed in cooling is estimated to be around 6-8%.[38]
Applicability of the proposed measure based upon cost-benefit assessment	▪ The cost of the Rollup door will be INR 125,000 per door with a standard size of 2.4 m x 3.5 m. ▪ The payback period varies from ~3 years for apples to ~5 years for mango and banana packhouses. This measure is recommended for large facilities operating in the peak-summer season, such as mango packhouses. This is also recommended for the large export-oriented grape packhouses. ▪ Strip curtains can be considered as a complementary solution to maximize loss prevention, or as a cheaper alternative, where fast roll-up door is not financially feasible.

37 GCCA. 2010. Presentation on Cold Storage Doors by Dr. Andy Pearson, UK

38 GCCA. 2010. Presentation on Cold Storage Doors by Dr. Andy Pearson, Star Refrigeration Ltd, UK

Table 26: Pre-cooling and staging cold room insulation with optimum thermal performance

Proposed measure	▪ Insulated panels with minimum 40 kg/m³ density for PUF or PIR panels and double tongue and groove system will ensure airtight pre-cooling and cold rooms.
Energy saving potential	▪ The energy saving potential is around 3-5%[39] of the overall refrigeration (cooling) energy consumption.
Applicability of the proposed measure based upon cost-benefit assessment	▪ The incremental cost will be in the range of 5%. ▪ The payback period for this recommendation varies from ~3 years in case of vegetable and apple packhouses to ~5 years for mango packhouses. This measure is recommended for all existing and (new) upcoming packhouses handling different types of produce.

simple payback calculations. The ranges for energy saving potential, incremental cost, and associated payback period are based upon the calculated variation across different type of packhouses considered for different produce. An illustrative cost-benefit analysis for sample packhouses is available in Annex 6.

2.6.3 EEMs - equipment and system design

Energy efficiency interventions at equipment and system design are generally applicable for both existing and upcoming (new) packhouses for various types of produce and include interventions focussing on – low energy cooling systems, efficient equipment and refrigerants, adequate metering and monitoring and controls and automation.

1. Low energy evaporative cooling system for temperature control in the packing hall

Site visit observation: Air conditioning system for packing hall is installed in a few packhouses such as the case of grapes. However, the majority of the packhouses do not have any cooling system for the packing hall area.

Table 27: Prioritised set of EEMs: Packhouse building design

S.No.	Energy Efficiency Measure	Prioritisation remarks
1	Natural lighting to reduce lighting load, proper orientation and shading for minimizing solar heat gains	Minimal cost measure. Applicable for all types of upcoming (new) packhouses
2	Cool roof treatment	No-to-low cost measure. Applicable for all types of existing and upcoming (new) packhouses
3	Optimized size of pre-cooling and cold rooms	No-to-low cost measure. Applicable for all types of existing and new packhouses.
4	Provision for natural ventilation- ceiling-mounted turbo ventilators	Low cost measure. Applicable for all types of upcoming new packhouses having no active air conditioning in the sorting/grading or packing areas.

39 P.C. Koelet. n.d. Industrial Refrigeration: Principles, Design and Applications.

S.No.	Energy Efficiency Measure	Prioritisation remarks
5	Airtight doors for pre-cooling and cold rooms	Low cost measure. Applicable for all types of existing and new packhouses without active air conditioning in the sorting/grading or packing areas.
6	Pre-cooling and staging cold room insulation with optimum thermal performance	Medium cost measure. Applicable for all types of new packhouses and existing packhouses, where feasible.
7	Wall and roof Insulation	Medium cost measure. Applicable for large upcoming (new) packhouses with high refrigeration loads and operating hours, such as apple and grape.
8	Fast roll-up doors to prevent hot/moist air infiltration	High cost measure. Applicable for large facilities operating in the peak-summer season, such as mango. Also recommended for large export-oriented grape packhouses. May be applicable for existing and upcoming (new) packhouses.

Table 28: Low energy evaporative cooling system for temperature control in the packing hall

Proposed measure	▪ Installing low energy evaporative cooling system, utilizing the cooling effect of water evaporation, for packing hall area can effectively provide favourable post-harvest environmental conditions required for fruits and vegetables. Evaporative cooling is more suitable for the hot & dry and composite climatic conditions prevalent in major horticulture production zones in India growing bananas, mangoes, grapes, kinnows, etc.
Energy saving potential	▪ The energy saving potential of evaporative cooling over an air-conditioned space can be up to 40-50%.[40]
Applicability of the proposed measure based upon cost-benefit assessment	▪ Cost for evaporative cooling is around INR 40-50 per sq.ft. of the packing area. ▪ This measure having very attractive payback (less than a month) is recommended for all grape packhouses having an air conditioning system in the sorting/grading area and packing hall. ▪ In case of other packhouses where there is no air conditioning/cooling system in the sorting/grading area & packing hall, the evaporative cooling solution is recommended for all existing and upcoming (new) packhouses located in the hot & dry and composite climatic zones of India.

2. Selection of refrigerants with better environmental and thermal performance

Site visit observations: Based on site visits and discussions with various stakeholders, it appears as though the decision on the choice of refrigerant for a packhouse is driven primarily by the turnkey contractors' knowledge and experience. The choice is typically governed by the availability and cost of the refrigerant rather than its environmental impact. Currently, the market lacks guidance on using environment friendly refrigerants as there are no recommended guidelines on the right choice of refrigerant for a particular refrigeration application specifically related to pre-cooling and staging cold room. Most of the packhouses visited have deployed HFC refrigerants such as R-134a, R-404a, and R-507, for the pre-cooling

40 Acedo AL Jr, Rahman MA, Buntong B, Gautam DM. 2016. Establishing and managing smallholder vegetable packhouses to link farms and markets. Publication No. 16-801. AVRDC p. 46.

and staging cold room refrigeration systems. However, a few packhouses are still using ozone depleting HCFC refrigerants such as R-22. These refrigerants are being phased out of several markets not just due to associated environmental concerns and obligations under the Montreal Protocol on Substances that Deplete the Ozone Layer but also due to the availability of commercially viable alternative refrigerants, including some that are less environmentally harmful.

In terms of replacements, the Montreal Protocol's Refrigeration, A/C and Heat Pumps Technical Options Committee (RTOC) states in its 2018 report that for this sector, it depends greatly upon the type of equipment. Natural refrigerants, such as R-744, HC-290, HC600a and R-717 are growing in use but safety standards and codes are needed per the RTOC, given that these refrigerants can have high safety risks (high pressures, flammability, toxicity).

According to inputs from refrigerant producers, the overall environmental impact and safety risks of the refrigeration system can be reduced by choosing refrigerant that leads to higher equipment energy efficiency and is non-flammable with lower GWP than some of the most commonly used, extremely high-GWP HFCs while not depleting the ozone layer as do HCFCs. For example, the R407 series of gases, R448A, and R449A which have GWPs in the 1,400-1,800 range have been increasingly used in countries to replace R404A (GWP of nearly 4,000) and R-22[41]. Besides their use in new equipment, these refrigerants are also what are commonly referred to as "drop-in" options, meaning they do not require substantial equipment replacement to change refrigerants, thereby allowing the packhouse to retain existing refrigeration equipment. According to suppliers, these refrigerants do not come with a significant energy performance deterioration compared to R404A. Retrofits may at minimum and in specific cases help countries comply with Montreal Protocol mandated reductions in R-22. The RTOC provides an overview of proposed measures at a higher level of available alternatives, but each with trade-offs (cost, safety, availability, climate impact).

3. Selection of energy efficient equipment for pre-cooling and cold room operation

Site visit observation: As noted earlier, two types of refrigeration system configurations were observed in the packhouses visited (i) one-to-one, i.e. dedicated compressor (and condenser) for each evaporator is the most predominant one, and (ii) centralised compressor rack system with common compressor bank for different evaporator units. Different types of refrigeration compressors, including reciprocating, scroll, and screw, were observed in these systems. The one-to-one systems are generally air-cooled while both air-cooled and water-cooled heat rejection configurations were observed for packhouses with rack systems. In a few packhouses, the evaporatively cooled one-to-one systems were also observed.

4. Sub-metering individual energy loads, including pre-cooling, staging cold rooms, process machinery, etc.

Site visit observation: None of the packhouses visited had the provision of sub-metering individual loads.

5. Electronic expansion and subcooling

Site visit observation: Most of the packhouses with Direct Expansion (evaporator) refrigeration system had a conventional thermostatic expansion valve. Electronic expansion valves

41 GWP figures for these gases are 1825, 1387, and 1397. While these levels are far from making them low GWP refrigerants, they are about half the GWP of 404A. So, for low-temperature applications, and absent any non-flammable, non-toxic, commercially viable low GWP refrigerant – many industries appear to be adopting on an interim basis 448A/449A.

Table 29: Selection of energy efficient equipment for pre-cooling and cold room operation

Proposed measure	▪ System configuration and compressor type: Semi-hermetic reciprocating or scroll compressors in a rack system offer best energy performance for pre-cooling and staging cold room refrigeration applications. The compressor rack system works more efficiently compared to independent one-to-one compressors to meet the varying refrigeration demand. ▪ Heat rejection: Contingent upon the availability of water (with TDS levels < 1000 PPM and PH < 8% PH), water-cooled heat rejection system or evaporatively cooled (adiabatic) condensers are proposed.
Energy saving potential	▪ System configuration and compressor type: Semi-hermetic reciprocating or scroll compressors in a rack system can potentially reduce energy consumption by 15-20% over the one-to-one system[42]. ▪ Heat rejection: Water-cooled/evaporative condenser can potentially reduce energy consumption by 20% over the air-cooled system.
Applicability of the proposed measure based upon cost-benefit assessment	▪ System configuration and compressor type: The cost for a compressor rack system is 10% lesser than one to one system. ▪ Heat rejection: The cost increment for water-cooled/evaporatively cooled system over the air-cooled system will be around 10-15%. ▪ The payback for all types of packhouses is less than 6 years for this measure. It is as low as ~3 years in case of apple packhouses. A rack system with water/evaporatively cooled compressor is recommended for all upcoming (new) packhouse contingent upon the availability of water.

Table 30: Sub-metering individual energy loads

Proposed measure	▪ Sub-metering for pre-cooling, staging cold rooms, sorting and grading machinery, lighting loads, and other miscellaneous loads are recommended.
Energy saving potential	▪ No direct energy saving; however, it will help track the energy performance of individual loads, flag inefficiencies and unexpected performance deviations, if any, during the course of operation. These meters can help the facility operator quickly identify any abnormal energy use performance deviations, hence prevent further energy waste that can be remedied relatively quickly by corrective measures.
Applicability of the proposed measure based upon cost-benefit assessment	▪ The additional cost of sub-meter can be about INR 25,000 per meter. ▪ This measure is recommended for all upcoming (new) packhouse, to be able to monitor the performance of main energy using equipment, identify any issues, troubleshoot and remedy avoidable energy waste at the operation stage. For existing packhouses, it is only recommended in case of packhouses having dedicated electrical feeders for different end-use categories – pre-cooling, staging cold rooms, process machinery, etc, and where the investment cost is justified, depending on the produce and market prices.

(EEV) with automatic conventional were provided in a few export oriented packhouses while none of the packhouses visited had subcooling provision.

42 Based on manufacturer's software such as Bitzer Compressor Selection software and Star Coolers and Condensers software (Tested as per Eurovent Certification standards). [online] Available at: <https://www.bitzer.de/websoftware/Default.aspx?cid=> [Accessed 1 September 2019].

Table 31: Electronic expansion and subcooling

Proposed measure	▪ EEVs are proposed for all DX systems as it dynamically allows the right quantity of subcooled liquid refrigerant required for the evaporator based on superheat measurement.
Energy saving potential	▪ Installation of EEV and subcooling arrangement can potentially reduce the energy consumption of refrigeration load by 20 to 25% depends upon the type of condensing system and refrigerant[43,44].
Cost of the proposed measure	▪ The additional cost of installation of EEV and subcooling provision will be INR 60,000 to 80,000 per evaporator. ▪ This measure is recommended for all existing and upcoming (new) packhouses as the payback would be realised for all analysed packhouses within ~2 years.

6. Energy Management Systems (with control and automation) to effectively manage refrigeration plant and indoor environmental parameters

Site visit observation: Most of the packhouses have manual operations for refrigeration plant and room parameters monitoring. Centralised monitoring and control systems are installed only in export packhouses.

The adoption of monitoring, control mechanisms and automation in data capturing can be a very useful tool in moving the cold chain sector forward. As indicated in MoEF&CC comments on the draft version of this report, a key element of transforming this aspect could include localizing the technologies to suit the scale of industry, and creating flexibility in the system to accommodate and modify the elements of complex supply chains on a need basis.

Table 32: Energy Management Systems to effectively manage refrigeration plant and indoor environmental parameters

Proposed measure	▪ Programmable Logic Controller (PLC) based refrigerated plant operation will enable real-time monitoring of the refrigerated plant and help optimize the cooling demand in the pre-cooler and cold room.
Energy saving potential	▪ The accurate setting of plant operation parameters including right suction and discharge pressure can potentially improve the overall system efficiency by 8 to 10%.[45]
Cost of the proposed measure	▪ The cost of PLC based Energy Management Systems will be INR 2,00,000 to 3,00,000 per packhouse including sensors and transducers to control and monitor temperature and RH levels as well. ▪ This measure is recommended for all existing and upcoming (new) packhouses as the payback would be realised for all analysed packhouses within ~5 years. The payback varies from ~2 years in case of apple packhouses to 5 years in case of banana packhouses.

43 Carl Peat. 2005. Energy Efficiency in Refrigeration Systems. [online] Available at: < http://www.hysave.com/wp-content/uploads/2010/05/EDF-ENERGY ENERGY Efficiency-in-Refrigeration-Systems-Liquid-Pressure-Amplification.pdf > [Accessed 1 September 2019].

44 Carel. (2008). Integrated solution for control and energy savings in commercial refrigeration. [online] Available at: <https://www.carel.com/documents/10191/0/+302240481/f2579142-154a-4084-8e90-4ca80142fdbf?version=1.0 > [Accessed 1 September 2019].

45 Thompson, J. & Mejia, D. & Singh, R. (2010). Energy Use of Commercial Forced-Air Coolers for Fruit. Applied Engineering in Agriculture. [online] Available at: <https://pdfs.semanticscholar.org/5679/8fd929d2e26b61168f8778f75c0df02b80ef.pdf> [Accessed 1 September 2019].

Table 33: Prioritised set of EEMs: Equipment and System Design

S.No.	Energy Efficiency Measure	Prioritisation remarks
1	Sub-metering individual energy loads, including pre-cooling, staging cold rooms, process machinery, etc.	Low cost measure. Applicable for all types of upcoming (new) packhouse. Also applicable for existing packhouses having dedicated electrical feeders for different end-use categories.
2	Low energy evaporative cooling system for temperature control in the packing hall.	Low cost measure. Applicable for all types of existing and upcoming (new) packhouses located in the hot & dry and composite climatic zones of India.
3	Electronic expansion and subcooling.	Low cost measure. Applicable for all types of existing and upcoming (new) packhouses
4	Energy Management Systems (with control and automation) to effectively manage refrigeration plant and indoor environmental parameters.	Medium cost measure. Applicable for all types of existing and upcoming (new) packhouses.
5	Selection of energy efficient equipment- Semi-hermetic reciprocating or scroll compressors in a rack system.	Medium cost measure. Applicable for all types of upcoming (new) packhouses.
6	Selection of energy efficient equipment- Water-cooled/evaporative condenser.	Medium cost measure. Applicable for all types of upcoming (new) packhouses contingent upon the availability of water.
7	Refrigerant selection meeting environmental and thermal performance requirements.	High cost measure, sometimes, due to safety measures needed if the refrigerant is flammable or toxic, with respect to energy savings and safety but recommended for better environmental performance.

2.6.4 Summary of EEMs - Equipment and System Design

The prioritised list of EEMs under the packhouse equipment and system design are compiled below. Illustrative pay-back ratio analysis for different produce are presented in Annex 6.

2.6.5 EEMs - operation and maintenance processes

Energy efficiency interventions at operation and maintenance level are applicable for existing packhouses for various types of produce and include interventions focussing on training and capacity, operational manuals with EE in perspective.

1. Development of packhouse operation manual

Site visit observation: The existing packhouse operations and processes adopted in handling, packaging, and palletisation are not carried out following standard operational practices.

Proposed measure: Packhouse operation manuals developed for produce wise or categorising tropical/subtropical/temperate produce in vernacular languages shall ensure better execution of the desired packhouse protocols. Amongst other operational aspects, the manual should describe packaging and palletisation protocols as well. Proper packaging in boxes/cartons with adequate holes and palletisation along airflow direction is required for attaining uniform cooling in the pre-cooling and cold rooms operations.

2. Guidelines for Periodic Maintenance Schedule

Site visit observation: The periodic maintenance of energy systems (particularly the refrigeration system) are either outsourced through an Annual Maintenance Contract (AMC) or carried out in-house. It was observed that in both cases, there were no defined protocols for periodic maintenance to be carried out by either an external agency or the in-house technicians. It was observed that in the absence of an appropriate periodic maintenance schedule (PMS), various energy systems including refrigeration plant and packhouse equipment were operating and sub-optimal efficiency levels.

Proposed measure: In order to ensure energy efficient operation of all energy systems, it is proposed first to develop a rigorous periodic maintenance schedule. The PMS should cover equipment/system-wise check-points, frequency, and maintenance procedure including:

- Daily checks on refrigeration plant operating parameters, compressor motor current consumption, oil level, refrigerant level, pre-cooling and cold room temperature & RH, air inlet and outlet, temperature of the coil
- Monthly inspection checks covering operating of expansion valves, filters, cleanliness of the condenser, water quality, oil quality, defrost lines, vibration and noise levels, door gasket condition, integrity of insulation etc.
- Periodic inspection of product process flow adopted in the packing hall, water drainage, door opening in receiving and delivery areas.

Secondly, the proposed PMS should be enforced through appropriate government guidelines and regulations.

3. Training of packhouse operators and technicians

Site visit observation: As noted earlier, most of the packhouses visited are operated by semi-skilled technicians with a limited understanding of refrigeration plant operation and packhouse processes. There is limited availability of skilled packhouse operators and technicians throughout India.

Proposed measure: Training program for refrigeration plant operation: In order to plug the need for skilled packhouse operators and technicians, a training program should be developed focused on packhouse operation including refrigeration plant for pre-cooling and staging cold room.

2.7 Approach to develop an energy efficient packhouse

This study highlights that energy efficiency should be addressed at multiple levels while designing a new packhouse and/or operating an existing one. The insights gathered from packhouse visits and interactions with various stakeholders including equipment suppliers, designers, research institutions, and policymakers reveal that while there are significant opportunities for energy efficiency improvements, at the same time the cost of inaction is equally substantial.

In order to ensure integration of energy efficiency aspects during the design and operation of a packhouse, this study proposes a series of steps as outlined below.

Step 1: Design of the building. Design of the building including orientation, natural lighting, shading of wall and roof should be considered at the design and planning stage. These no-cost considerations not only reduce the cooling load, but also enhance the thermal and visual comfort for the packhouse operators and workers thereby enhancing their productivity as well.

Step 2: Choice of building materials. The building materials used for roofing and walling should be selected to minimize the solar heat gains. At present, ECBC specifies the thermal performance of the wall and roof and the same can be referred for building materials to be selected for the construction of packhouse. Apart from the external building envelope, the walls, ceiling and flooring of all temperature-controlled areas such as pre-cooling and staging cold rooms should be selected with appropriate insulation levels to minimize heat ingress.

Step 3: Packhouse facility layout. The layout of the packhouse facility should focus on optimizing the flow of produce and people within the packhouse to reduce the temperature variation and energy requirement.

Step 4: Packhouse process design. Good practices for packhouse process design for functions such as cleaning, sorting and grading, fruit-specific treatment, packaging, palletisation, etc. from the point of view of fruit care should be aligned with energy efficiency considerations as well.

Step 5: Refrigeration system design and equipment selection. The refrigeration systems for pre-cooling and staging cold room applications should be designed and selected for maintaining the right environmental parameters for given produce along with keeping EE considerations. Apart from EE, the selection of refrigerants (low Global Warming Potential where possible) should be done to avoid/minimize the environmental consequences resulting from any inadvertent leakage of the refrigerants. Wherever possible, low energy cooling solutions such as evaporative cooling should be deployed, especially in the packing hall area.

It is important to note that the EEMs discussed in this report were identified based on the survey carried out in 21 packhouses. Going forward, it is recommended that the preliminary analysis provided with respect to EEMs be further strengthened, based on detailed energy performance assessment (as per BEE energy audit guidelines) of a statistically relevant sample of packhouses.

Chapter 3

POLICY AND REGULATORY RECOMMENDATIONS

The chapter presents the recommendations to BEE on policy and regulatory options, building upon the research and analyses presented in the previous chapters of the report. The recommendations have taken into account relevant energy efficiency policies, standards, guidelines for buildings and appliances that are in place. They also take into consideration ICAP recommendations for reducing cooling demand, energy consumption and refrigerant requirement, through improved design, including proper insulation and use of energy efficient cooling equipment in the cold chain sector.

While the focus of this study was to develop options to enhance energy efficiency of packhouses in India, many of the policy and regulatory recommendations have replication potential in other cold chain components, and as such can help BEE promote energy efficiency across the entire cold chain.

3.1 Present Landscape for Energy Use in Packhouses in India

Various aspects of the existing institutional policy framework in the agriculture, food processing and energy sectors that may be applicable or relevant for the development of an integrated cold chain in India were reviewed and presented in Chapter 1. The purpose was to understand if and how energy efficiency considerations can be incorporated into existing policies, regulations, or guidelines governing the design, construction and operation of packhouses. This assessment is summarized in Table 34.

Table 34: Options for mainstreaming energy efficiency in existing guidelines, codes, and standards in India's packhouses

Codes/Standards/ Guidelines	Present Scope relevant for packhouses	Suggested actions to integrate energy efficiency in Packhouses
National Cold Chain Development (NCCD) guidelines	NCCD operational guidelines specify the minimum investment required for development and setting up of pre-cooling unit and cold rooms. They set out the possible options focusing on materials, lighting system, cooling system and automation.	The NCCD operational guidelines can be updated to capture energy efficiency measures. It is further possible to include operation and maintenance protocols in the guidelines to enable energy savings.

Codes/Standards/ Guidelines	Present Scope relevant for packhouses	Suggested actions to integrate energy efficiency in Packhouses
Mission for Integrated Development of Horticulture (MIDH) Guidelines	For integrated packhouses, MIDH operational guidelines in concurrence with NCCD, suggest a typical layout, produce-wise alterations in the building layout, other specifications like roof details, outer walls and flow details, artificial lighting, power generating unit and door/window details.	The operational guidelines could include recommendations on energy efficiency, wherever the specifications of individual components are highlighted. Energy efficient building design guidelines for packhouses may be incorporated into the operational guidelines.
Agricultural and Processed Food Products Export Development Authority (APEDA) Standards and specifications	APEDA aims to ensure appropriate standards in exports of horticultural produce, ensuring standards in terms of quality of produce with quarantine safety. For all the technical specifications, they refer to NCCD operational guidelines.	APEDA, while providing accreditation to the packhouses, may ensure compliance with energy efficiency measures, in conjunction with NCCD operational guidelines, if and when operation and maintenance protocols are included to enable energy savings.
Model Building Bye-Laws (MBBL)	MBBL are legal tools used to regulate coverage, height, building bulk and architectural design and construction aspects of buildings to achieve orderly development of an area. MBBL addresses architectural design parameters for Storage Buildings, including cold storages and warehouses.	Design and construction parameters for packhouses can be added to MBBL. Similar to the building sector where ECBC has been integrated in MBBL, energy efficient building design features related to packhouses can also be added in MBBL.
Energy Conservation Building Code (ECBC) of BEE	Applicable for large commercial buildings with a connected load of 100 kW and above.	At present none of the building typologies in ECBC fully reflect the characteristics of a typical packhouse. BEE may consider, either (i) incorporation of packhouses in the existing ECBC, or (ii) developing a new energy code for packhouses.
Appliance Standards and Labelling (S&L)	Appliances used in packhouses include air conditioners, tubular fluorescent lamps, LED lamps, induction motors, pump sets, ceiling fans, DG sets and chillers	The use of appliances already included under the S&L scheme (such as fans, motors, pumps, etc.) should be encouraged wherever applicable in packhouses. For other energy intensive equipment such as for pre-cooling and staging cold rooms that are specifically used in packhouses, labelling schemes, followed by MEPS can be developed.
India Cooling Action Plan (ICAP)	Implementation of ICAP is expected to contribute to enhanced cooperation and coordination across various Ministries and relevant agencies, that can help better integrate energy efficiency in cold chain infrastructure design and operation. For ICAP implementation, a cold chain thematic group has been formed. The findings and recommendations emerging from this study can be presented to the thematic group for an actionable set of activities by MoEF&CC, MoA&FW, and BEE under the ICAP platform.	

3.2 Site visit observations

As part of the study, a sample 21 packhouses were visited to understand energy consumption patterns across different types of produce, agro-climatic zones, and ownership. Detailed observations are presented in Chapter 2, and key highlights are summarized below. Observations related to energy use were grouped by building design, equipment and system, and operation and maintenance.

3.2.1 Packhouse building design

It was observed that the packhouses are designed and set up as per the subjective perspectives or experiences of the owners, consultants or contractors – all of whom have different sets of priorities, backgrounds, skills and motivation. For packhouse owners, minimising upfront investment cost and meeting market requirements often appear to be the top priorities. Semi-structured interviews with packhouse owners and other stakeholders suggested that the consultants appear to focus on meeting (or even exceeding) the owners' cooling or other functional requirements, without necessarily optimizing for cost or energy performance, and prefer working with known contractors or vendors for the job. From the site visits, it was observed that adhering to a specific set of design parameters was not the primary focus for most of the stakeholders. There appears to be a lack of awareness amongst design consultants and packhouse owners about the passive design strategies (related to the orientation of the building, shading, use of daylight, ventilation) which can significantly reduce the energy consumption for operating the packhouse, just like any other category of buildings. In cases where there is interest in these aspects, there is minimal guidance on packhouse building design and material selection for incorporating energy efficiency in the design and construction of packhouses. The site visits also suggested a minimal emphasis on internal layouts for the flow of produce and people, which could further optimise energy utilisation, as described in Chapter 2.

3.2.2 Equipment and system design

Majority of the packhouses surveyed were relatively new facilities (up to five years old) and therefore fitted with relatively newer equipment and systems. Among the older packhouses visited, most were found to be using dated equipment and system design. The owners of these older facilities were not familiar with newer and more efficient technologies, their benefits or cost-effectiveness.

3.2.3 Operation and maintenance process

Most of the packhouses visited are operated by semi-skilled or unskilled technicians with limited understanding of refrigeration plant operation and packhouse processes. The site visits and subsequent stakeholder consultations indicated that there may be limited availability of skilled packhouse operators and technicians throughout India. It was observed that in the majority of packhouses visited (with a few exceptions of large export-oriented packhouses) operations and processes for handling, packaging, and palletisation are carried without explicit emphasis on energy efficiency and good refrigerant management practices. There are several possible reasons for gaps in adoption of energy efficiency in design and operation and maintenance practices of packhouses, which include lack of coordinated effort amongst different stakeholders, shortfalls in existing skill sets of operators and technicians, lack of awareness about energy efficiency and availability of financial resources for retrofitting facilities or replacing existing inefficient stock.

Table 35 highlights the challenges identified during the site visits, possible benefits of integrating energy efficiency, and corresponding recommendations for achieving compliance and adoption in new and existing packhouses. The recommendations in Table 35 are detailed in subsequent sections of this report.

Table 35: Matrix of site visit observations, opportunities and relevant recommendations

Challenges Observed	Opportunities for integration of energy efficiency	Relevant Recommendation
In some facilities, there is little or no emphasis on maintaining the recommended flow of produce and operations within a packhouse, leading to sub-optimal movement of people and produce, and consequently increased duration of high-temperature-exposure for the produce handled.	Operating the packhouse facility with careful attention to flow would ensure efficient conduct of packhouse functions by minimising movement of people and produce, hence reducing the produce's high-temperature-exposure-time. Reducing the -temperature-exposure-time not only extends shelf life but also reduces the pre-cooling refrigeration or cooling load.	***Recommendation 1: Establish guidelines for good practices in Operation and Maintenance (O&M) of packhouse facilities***
Owners of older facilities are not familiar with new and advanced energy efficient technologies.	Enhancing awareness to encourage adoption of the latest equipment through retrofitting, or regular maintenance of the dated pre-cooling and staging cold room refrigeration equipment could significantly reduce energy consumption for a given volume of produce handled.	
Most of the surveyed packhouses adopted in-house maintenance practices. Even when there's an Annual Maintenance Contract (AMC) in place, very limited or no emphasis on energy management was observed.	Regular maintenance abiding by reasonable energy performance targets would ensure a reduction in operational energy consumption and reduce wear and tear or frequent break-down of the equipment.	
Limited or no attention on refrigerant management in the operation of refrigeration plants for pre-cooling and staging cold rooms.	As part of maintenance practices, refrigerant quantity and quality checks should be scheduled, as this will also have a bearing on the overall operation and energy performance of the equipment. Good refrigerant management and servicing practices will help avoid refrigerant leakages and will also help in improving energy performance.	
The harvesting locations mainly drive packhouse site selection with limited emphasis on road connectivity and quality of power supply.	Site selection for packhouses can significantly impact the energy consumption by the facility, both through the cooling needs, and the energy required for transportation of the produce. If the packhouse doesn't have access to good quality and reliable power supply, this can impact the operation of cooling equipment. Significant variations in temperature can in turn lead to decomposition of the produce and higher consumption of energy for maintaining the optimum temperature. Locating a packhouse	***Recommendation 2: Establish guidelines for energy efficient packhouse design, equipment specifications and material selection***

Challenges Observed	Opportunities for integration of energy efficiency	Relevant Recommendation
	as close as possible to farms presents an opportunity for quick field heat removal, thus enhancing the shelf life of the produce, while on the other hand, power supply quality and reliability issues may be more prevalent in remote rural areas. It is important to recognize this trade-off while making siting decisions.	
In some cases, limited attention was focused on building orientation, which can sometimes result in solar heat gains in the building, which could have been avoided.	Thinking through the building orientation, identifying a setup that reduces solar heat gain and abiding by climate-responsive passive design strategies, responding to the microclimate of the site can reduce energy consumption for maintaining optimal indoor temperature.	
Majority of packhouses rely on artificial lighting as the building or window design doesn't allow utilizing natural daylight	Availability of adequate daylighting with properly designed windows, shading systems and glazing selection to allow visible light while minimising solar heat ingress within the packhouse building would reduce the artificial lighting energy demand and consumption.	
The material used for the construction of the walls and roof varies across different packhouses, and usually little emphasis on minimizing heat transfer across the building envelope.	Materials with good thermal performance would avoid heat gain from outside to inside of the packhouse and at the same time avoid cooling loss from inside to outside of the packhouse.	
Limited instances of designing an energy efficient pre-cooling and staging cold room system. Ceiling heights of pre-cooling and cold rooms in many cases were observed to be oversized, leading to energy waste.	Designing of pre-cooling and staging rooms proportionate to produce requirements and with energy efficiency considerations can deliver significant reduction in cooling load and resultant energy demand.	
The selection of refrigerants is primarily governed by upfront cost and availability rather than overall energy or environmental performance.	Selection of non-ozone depleting, lower-GWP refrigerant as appropriate for specific equipment over the currently prevalent refrigerants in the Indian market which are or will be controlled such as R-22, R134a and R404A can be a higher cost proposition in the short-term but still recommended for better environmental performance and longer-term savings in refrigerant servicing. Raising awareness on the trade-offs between energy performance, environmental implications and safety of refrigerants, and providing guidance to facility owners on reasonable choices for different use cases can enable better decision making.	

Challenges Observed	Opportunities for integration of energy efficiency	Relevant Recommendation
Lack of awareness of benefits of energy efficiency measures among facility owners, designers, operators and users is a significant barrier for the incorporation of energy performance considerations in design, construction and operation of packhouses.	Efforts to raise awareness and dissemination of knowledge on energy efficiency, which can be targeted at different stakeholder groups, can lead to greater uptake of energy efficiency measures and technologies among packhouses, and can influence the development of future building stock.	***Recommendation 3: Enhance awareness about energy efficiency in post-harvest management***
There are no standards or guidance on energy or environmental performance of pre-cooling and cold storage room equipment for packhouse owners and design consultants.	Gradual introduction of standards and labelling on most commonly used equipment in the packhouse segment can empower packhouse developers to make informed decisions about energy efficient and environment-friendly pre-cooling and staging cold room refrigeration equipment selection, and guide the evolution of the equipment designed specifically for packhouses handling different types of produce.	***Recommendation 4: Develop standards and labelling for pre-cooling and staging cold room refrigeration equipment***
There are no existing mechanisms to report or monitor energy use by packhouse owners. Furthermore, indicators for benchmarking and evaluating the energy performance of individual packhouses are not defined.	Establishing the practice and system of energy use reporting for packhouses will facilitate better understanding of energy performance status of packhouses in different segments. In the future, such as system can be useful for the development of energy performance baseline and benchmarks based on well-defined indicators.	***Recommendation 5: Introduce framework for energy use reporting and benchmarking***
Most of the packhouses visited are operated and maintained by semi-skilled technicians with limited understanding of refrigeration plant operation and packhouse processes. There is limited availability of skilled operators and technicians and existing operations and processes in handling, packaging, and palletisation are not carried out following standard operational protocol.	Building up the skills base for packhouse technicians and operators with an understanding of refrigeration plant and packhouse processes, operation and maintenance shall ensure compliance of standard operational protocol in handling, packaging, palletisation, etc. and in enhancing energy efficiency.	***Recommendation 6: Develop training and certification for energy efficient post-harvest management and packhouse operation***

3.3 Policy and Regulatory Recommendations

Based on the analyses, the following actions are recommended as foundational steps for incorporating energy efficiency practices into the design, development, operation and maintenance of packhouses and paving the way for the development of future policies, regulations and initiatives:

1. Establish guidelines for good practices in Operation and Maintenance (O&M) of packhouse facilities.
2. Establish guidelines for energy efficient packhouse design, equipment specifications and material selection.
3. Enhance awareness about energy efficiency in post-harvest management.
4. Develop standards and labelling for pre-cooling and staging cold room refrigeration equipment.
5. Introduce framework for energy use reporting and benchmarking.
6. Develop training and certification on energy efficient post-harvest management and packhouse operation.

All the recommendations are structured into three broad sub-sections:

1. **Present Scenario:** The first sub-section presents the background information about the proposed recommendation
2. **Key Elements:** The second sub-section presents the main substance of the recommendation for BEE and other line ministries
3. **Roll-out Strategies:** This sub-section presents the implementation or enforcement strategies for greater uptake of the respective recommendation, highlighting possible approaches for the operationalizing the recommendation. One discrete element of the roll-out strategy is "institutional mechanisms," which links the recommendation with existing practices and arrangements within different Government agencies and identifies opportunities for collaboration and coordination in implementation.

An overarching recommendation to the BEE, while advancing work on this important topic, is that the development of key guidelines, standards, or any other guidance, is carried out in a way that ensures broad participation from sector participants, including manufacturers, consultants, facility owners, users and academia, reflecting the multi-sector expertise needed.

3.3.1 Recommendation 1: Establish guidelines for good practices in operation and maintenance of packhouse facilities

3.3.1.1 Present Scenario

Good practice guidelines can have a direct bearing on operations and maintenance of, and hence energy use by, packhouses without requiring substantial investment. In addition to having the potential to deliver a reduction in operational and energy costs, effective O&M can ensure safety, reliability and consistent performance. Moreover, improvements to existing practices can often be accomplished quickly and at a relatively low cost compared to a major retrofit. An effective O&M mechanism can help individual equipment maintain performance closer to design parameters, last up to its economic life and in some case even exceed it; avoiding the investment required for replacement of equipment in the case of early equipment failure. In an exceptional case, the positive impact of good O&M practice on the overall performance of the packhouse was demonstrated by a newly built apple packhouse in the state of Himachal Pradesh. The site visit and subsequent stakeholder consultation revealed that the packhouse owners reaped benefits of adopting good O&M practices and investing in qualified and skilled O&M team, by not only keeping their energy bills in check but also running the facility well compared to their peers. Integrated O&M is a continuous function which requires coordinated action from facility management, operators and maintenance staff. Clear guidelines established for achieving energy efficiency in operation and maintenance, specifying the role of all the stakeholders, would be beneficial.

A thorough framework for ensuring efficient O&M requires the participation of the staff involved in operations, maintenance, engineering, training, and administration. In some cases, a given packhouse might not have all five of these separate entities and may have outsourced O&M to AMC providers and bundled some functions together. The proposed framework focuses on elements of O&M at the overall packhouse level and does not delve into the specifics of individual equipment maintenance requirements.

3.3.1.2 Key elements

The study revealed that there is significant scope for improvement in the essential operation of packhouse functions including sorting, grading, washing, packaging, etc. and the periodic maintenance of energy systems. The study recommends the development of guidelines for O&M of packhouses to enhance the operating life of the equipment and ensure their energy efficiency, possibly by BEE working closely with Ministry of Agriculture and Farmers Welfare and its institutes, and Ministry of Food Processing. The development of the proposed guidelines should be in consultation with the Ozone Cell in MoEF&CC for specifications regarding refrigeration, management of refrigerants and proper AC equipment installation and maintenance. The recommended framework for BEE to develop the O&M guidelines is described in the sections that follow.

3.3.1.3 Framework for the guidelines

The site visit observations on energy use and energy efficiency aspects were categorized based on overall building design, equipment and system installed, and operation and maintenance practices followed in the packhouses.

Operations: Suggested structure focusing on energy efficient operations are listed below.

- Operational procedures and protocols for produce specific packhouse functions such as sorting, grading, and packaging and palletisation could be adopted from the Food and Agriculture Organization (FAO) guidelines[46] and further adapted for Indian conditions. The operational guidelines can also recommend operations practices produce specific flow requirements, for efficient conduct of packhouse functions by minimising movement of people and produce, and reducing the produce's high temperature exposure time (straight-line and U-shaped flow of produce and operations are illustrated in Annex 4).
- Operational procedures and protocols for refrigeration plant (including refrigerant servicing) and other energy intensive systems.
- Energy management plan for energy use monitoring and reporting:

46 FAO RAP Publication. 2012/04. Good practice in the design, management and operation of a fresh produce packing-house. [online] Available at: < http://www.fao.org/3/i2678e/i2678e00.pdf>.

- Phase 1: gathering of total energy consumption data
- Phase 2: gathering of end-use segregated data
- Phase 3: formulation of a comprehensive energy management plan that outlines tasks, responsibilities and timelines, and an energy accounting system.

Maintenance: To cover the entire lifecycle of the equipment in a packhouse, the maintenance guidelines should include some key procedures involved in the maintenance of equipment, as listed below.

Prescriptive (and preventive) maintenance procedure

- Adherence to the user manuals in terms of operational procedures and warranty clauses of individual equipment as prescribed by the manufacturers.
- Periodic maintenance schedule (PMS) covering the following aspects:
  - Daily checks on refrigeration plant operating parameters, compressor motor current consumption, oil level, refrigerant level, pre-cooling and cold room temperature and relative humidity, air inlet and outlet temperature of the coil.
  - Monthly inspection checks covering operation of expansion valves, filters, cleanliness of the condenser, water quality, oil quality, defrost lines, vibration and noise levels, door gasket condition, integrity of insulation etc.
  - Periodic inspection on produce process flow adopted in the packing hall, water drainage, door opening in receiving and delivery areas.
  - Protocols on good practice for refrigerant handling and recharge to ensure energy efficient operation and avoid leakages.
  - Protocols for refrigerant reclamation, disposal or incineration at the end of life of refrigeration systems.

Reactive maintenance procedure

- Steps and actions to be taken in the scenario of a complete breakdown of the equipment.

Annual maintenance contract (AMC)

The contract document should specify the clauses related to energy performance monitoring, reporting and routine measures to maintain and improve efficiency built into the O&M guidelines.

Retrofitting of equipment

Procedures for retrofitting of equipment wherein ensuring energy efficient operations is beyond the scope of suggested O&M practices.

3.3.1.4 Roll-out Strategy

The dissemination mechanism is divided into three closely related parts: institutional mechanisms, awareness programmes (illustrated in Recommendation 3), and training and capacity building (illustrated in Recommendation 6).

Institutional mechanisms

The proposed guidelines for O&M should be incorporated into existing institutional mechanisms to the extent possible. It is recommended that BEE, in collaboration with line ministries and departments, could consider the following measures to accompany guidelines to ensure effective uptake by the respective stakeholders.

- Incorporation in existing MIDH, APEDA guidelines by including a separate chapter focussing on the energy efficient guidelines for packhouses.
- For retrofitting of packhouses BEE can coordinate with line ministries (MoA&FW, MoEF&CC, Ministry of Commerce and Industry, MoCI) to link the on-going incentives and subsidies for the replacement of existing equipment with energy efficient ones.

It can be worth exploring if BEE shall serve as the central nodal agency to coordinate the implementation, dissemination and upgradation of these guidelines with support of State Designated Agencies (SDAs) and other state level agencies from different line ministries.

3.3.2 Recommendation 2: Establish guidelines for energy efficient packhouse design, equipment specifications and material selection

3.3.2.1 Present Scenario

The site visits conducted as a part of the project, extensive stakeholder consultation and literature review revealed that the various aspects of packhouse infrastructure development, such as building design, equipment selection and operation and maintenance, are primarily driven by self-build (do-it-yourself) and self-selection of available technologies based upon the existing knowledge of owners and/or consultants, if engaged, without any specific consideration for energy efficiency. The processes involved in the development of packhouses are dependent on the awareness and economic capabilities of the individual/organisation. At present, there are no rigorous technical design guidelines available to guide the planning, design, siting, and maintenance of an energy efficient packhouse. In the absence of any codes or guidelines, the developers tend to overlook energy efficiency during planning and design of the buildings, as well as procurement of equipment. These choices lead to significant shortcomings and inefficiencies in the energy use performance of the systems and equipment, as was observed in various facilities during the team's site visits. Establishing guidelines on the main aspects of packhouses – building design, equipment selection and operation and maintenance – will be particularly beneficial to small packhouse developers who lack the technical knowledge and awareness about energy efficiency.

3.3.2.2 Overview of relevant policies and regulations

In the absence of a holistic framework for designing of packhouses, components from existing policies and codes (NBC, MBBL, ECBC) were analysed to identify portions applicable to various elements a packhouse – i.e. building design, construction, equipment and system design. On the one hand, regulatory instruments such as ECBC include provisions for active strategies like lighting and HVAC design and their controls and building management systems; on the other, the National Building Code (NBC) and Model Building Bye-Laws (MBBL) covers passive strategies like orientation, natural ventilation and other climate-responsive strategies in passive building design and selection of appropriate construction materials. It is recommended that the active[47] and passive[48] strategies for building

47 **Active design strategies** refer to the design and selection of energy efficient lighting and cooling systems and effective automation, controls and building management systems. A few examples of active strategies include LED lighting, daylight & occupancy lighting controls, and high COP cooling & refrigeration systems.

48 **Passive design strategies** include features innate to the form and design of a building that avail of available natural resources such as sun, wind, light and micro-climatic consideration to minimize the energy consumption for lighting and cooling while enhancing the occupant's visual and thermal comfort. Examples include daylight harnessing to reduce artificial lighting load and building orientation, shading, natural ventilation to reduce building cooling load.

design and construction covered in these regulatory documents are combined coherently to guide the development of holistic energy efficiency guidelines for packhouses.

3.3.2.3 Key elements

The packhouse design and equipment selection guidelines should include the following two broad aspects. (i) Packhouse building design and construction, and (ii) Packhouse equipment and system design. The main principles recommended for BEE to consider in the development of such guidelines are illustrated below.

Packhouse building design and construction principles

Site selection

The site selected for a packhouse impacts the time in transport both from the farm to the packhouse and from the packhouse to the market. The time required for transportation has an inverse relationship with the shelf life of the produce and the energy required in extending the shelf life of the produce. The site selection should be done keeping these factors in consideration. NCCD recommends that packhouses should be built on routes connecting markets to farms where travel time exceeds 48 hours, or where the distance exceeds 300 kms. While it may not be necessary for BEE to make any specific recommendations on where to site a packhouse, the proposed BEE guidelines can touch upon the following items in the context of site selection.

- **Power supply quality and reliability:** Packhouses located in very remote areas may not have access to adequate or reliable power supply. For locations where grid connectivity is absent or limited, or there are issues around the reliability of supply, the BEE Guidelines can guide the facility designers and owners in assessing the power supply situation in the site under consideration, and outline criteria for identifying suitable and practical options for backup or self-generation.

Table 36: Regulations relevant to energy efficiency in buildings at city level

Policy/Bye-laws	Department	Components
ECBC-2017	BEE, Ministry of Power (MoP)	1. Building envelope 2. Comfort systems and controls 3. Lighting and controls 4. Electrical and Renewable energy systems
NBC	BIS, Ministry of Housing and Urban Affairs (MoHUA)	NBC lays down provisions for functional aspects of a building: 1. Climate sensitive design 2. Ventilation 3. Thermal comfort
MBBL	MoHUA	MBBL outlines parameters for governing the design and planning of the building: 1. Site Selection 2. Site Planning 3. Building Characteristics

- **Role of Renewable Energy:** Where feasible, BEE can encourage facility designers and owners to consider the incorporation of renewable resources to meet the primary or residual energy needs of the packhouses, in ways consistent with the MNRE guidelines. This can be done both for building in RE into the design of new packhouses and also retrofitting existing packhouses, reducing grid dependency, or eliminating/ reducing reliance on inefficient diesel generators where feasible. To this end, the BEE design guidelines can draw on and refer to applicable MNRE guidelines, as well as state and local level building bye-laws and ECBC. There are a number of renewable and alternative energy technologies that have good potential for cold chain applications. In order to deliver on the potential of these technologies for a sustained period, they will need to be accompanied by strong engineering, and installation capabilities, quality components, and stringent commissioning and O&M services.

Site planning

- **Orientation:** Orientation of the building should take into account the site conditions and terrain, and any applicable local/micro-climatic conditions. As a general principle, efforts should be made to avoid exposing the longer facades of the building not be exposed to the sun for the majority of the year, to avoid heat gain.
- **Landscaping:** As far as possible, native trees should be planted to screen direct sun to reduce solar heat gain and decrease water requirements for landscaping.

Built structure

- **Ground Coverage:** To optimise natural ventilation and daylight inside the building, and to allow for smooth movement of traffic, ground coverage of the building can be regulated. As per the MBBL by Ministry of Housing and Urban Affairs (MoHUA) the ground coverage for warehouses is pegged at 30%, similar provisions could be made for Packhouses.
- **Floor Area Ratio (FAR):** To regulate the physical form of the building and determine the total built-up area, which influences energy consumption, FAR should be prescribed. As per the Model Building Bye-laws by MoHUA, FAR for warehouses is pegged at 1.2, similar provisions could be made for packhouses.
- **Natural Lighting:** Building design should use measures to integrate natural lighting to balance artificial lighting through a combination of passive and active measures, such as clerestory windows, transparent roof patches or appropriate window to wall ratio as specified in ECBC.
- **Window-to-Wall Ratio:** Adequate window to wall ratio should be provided. Providing windows for cross ventilation and turbo-ventilators on the roof will ensure adequate ventilation and help remove built-up heat in the sorting/grading or packing areas, thereby removing the accumulated built-up heat due to air-stagnation. Additionally, natural ventilation can also have positive impacts on the health and productivity of the packhouse staff.

Building layout

Considering the variations in packhouse functions observed during the site visits, suggested layouts and process design – specific to produce type – for various functions such as sorting, grading, packaging, and others can be included in the guidelines. The building layouts should be aligned with the suggested produce specific flow of produce and operations in a packhouse as outlined in Recommendation 1. In developing this guidance, it is recommended that BEE prioritizes produce that require the highest amount of energy for packhouses to handle, which, per the observations of this study, are grape, apple and mango, as recorded in Chapter 2. If this gradual approach is followed, mango packhouses would be a good first starting point, as it has a high connected load intensity and the highest process load share (out of total connected load) amongst the surveyed fruits and vegetables. Apple and grapes can follow mangoes, in view of the relative share of the process loads in their respective connected loads.

Building envelope and construction materials

It is recommended that, at minimum, compliance with Part 4 of the Energy Conservation Building Code (ECBC- latest version) which highlights the specifications of building envelope and construction materials is encouraged. Packhouses in the States which have notified their own ECBC can be required to comply with the state ECBC.

- Compliance with the ECBC-2017 standards for using construction materials with lower embodied energy and desired thermal performance should be ensured.

Packhouse equipment and system design principles

Low energy evaporative cooling system for temperature control in the packing hall

Installing low energy evaporative cooling system, utilizing the cooling effect of water evaporation, for areas such as packing halls can effectively provide favourable post-harvest environmental conditions required for fruits and vegetables. Evaporative cooling is more suitable for the hot and dry, and composite climatic conditions prevalent in major horticulture production zones in India growing banana, mangoes, grapes, kinnows, etc.

Refrigeration system design, equipment selection and controls

Since pre-cooling (one of the most critical packhouse functions) and staging cold rooms are the two most energy intensive systems in a packhouse, guidelines should be established on refrigeration system design and equipment for different fruits and vegetables. To begin with, guidelines for packhouses handling apples, grapes and mangoes, which require refrigeration and are more energy intensive, should be developed. The guidelines should provide calculations for sizing of pre-cooling and staging cold rooms and should include provisions for door sealing to prevent air infiltration. The guidelines can also include suggested measures for design of energy management controls and automation systems. Prescribed power quality parameters, such as acceptable voltage and harmonics, should also be specified to guide appropriate protective measures in case of power quality issues.

Selection of refrigerant meeting environmental and thermal performance requirements

For pre-cooling and staging cold room applications in fruits and vegetable packhouses, refrigerants with better environmental performance (lower GWP along with higher efficiency) should be considered.

Possible future action in this area

Subsequent to the development of design guidelines, BEE can consider the development of energy performance code for packhouses. One option for developing such a code could involve incorporation of packhouses in existing ECBC-2017 with a separate building category. Alternatively, BEE can develop a new energy code for packhouses depending upon the need and relevance.

3.3.2.4 Roll-out Strategy

The enforcement mechanism can be divided into three closely related parts: institutional mechanisms, awareness programmes (illustrated in Recommendation 3) and financing.

Institutional mechanisms

- **Option 1:** To promote investment in cold chain infrastructure, the central government currently offers incentives and demand-side subsidies through various channels (NCCD, MIDH, APEDA). The proposed guidelines for energy efficient packhouse design and equipment selection could be operationalized by introducing them as mandatory requirements for obtaining various incentives and subsidies offered by different agencies. BEE can work in close coordination with the line ministries and departments to pursue the incorporation of energy efficiency guidelines in the existing incentive and subsidy schemes.
- **Option 2:** As per the existing clearance framework, a builder needs to obtain permission from the local administration (Gram Panchayat or the ULB) for constructing a packhouse. In line with BEE's ECBC implementation strategy wherein it has been incorporated in the state and local building bye-laws for a few states, the proposed guidelines for energy efficient packhouse design and equipment selection can be adapted to eventually become part of the pre-requisites for obtaining the construction permit/clearance, first on a voluntary, and later mandatory basis, after an appropriate transition period.
- In collaboration with State level Horticulture Departments, State Designated Agencies can be involved in the effort to ensure compliance with the energy efficiency guidelines for packhouses.

Financing

- For ensuring the uptake of proposed design guidelines, it is recommended that BEE works closely with the line ministries (MoA&FW, MoFPI, MoCI) to facilitate access to financing for energy efficiency, building on existing subsidies and programmes for financing packhouses. In coordination with SDAs, State Horticulture Missions, state agricultural marketing boards and APMCs, the design and construction of energy efficient packhouses could be supported through existing incentive and subsidy channels for cold chain infrastructure development, and financing gaps could be better understood.
- System and equipment guidelines should also be applicable to existing packhouses. The possibility of extending ESCO models for retrofitting existing packhouses with energy efficient equipment may be explored in consultation with BEE, line ministries, state level departments and packhouse owners.

3.3.3 Recommendation 3: Enhance awareness about energy efficiency in post-harvest management

3.3.3.1 Present Scenario

As discussed earlier, good awareness of energy efficient practices will not only help reduce energy consumption but also lead to longer shelf-life, thereby contributing to better price realisation in the market. The site visits revealed that a lack of awareness on energy efficient practices and technologies among packhouse owners and design consultants were a primary barrier to the incorporation of energy efficiency aspects in the design, construction and operation of packhouses. The field visits also highlighted that, where energy efficiency considerations were observed, the facilities were also following good post-harvest practices, including for handling and preparation of produce for the onward cold chain journey. In addition to the awareness challenge, the site visits revealed an information constraint, as some packhouse developers reporting they had issues finding the right design consultants and equipment providers, because they didn't know how to find the good consultants, or what to look for while hiring design consultants or procuring equipment.

3.3.3.2 Key elements

The key actions recommended for overcoming the awareness and information barriers to advancing the adoption of energy efficient practices in post-harvest management are summarized below.

1. "Tip sheets" on the benefits of energy efficient practices in post-harvest management

The site visits revealed both good and bad practices currently being followed in post-harvest management[49], having a considerable impact on energy consumption and produce longevity. It is recommended that BEE considers developing brief (2-4 page) "tip sheets" for the adoption of best post-harvest practices. There could also be "tip-sheets" on good practice case studies in different post-harvest interventions at packhouses, such as shading in the receiving and despatch areas, air-curtains or fast roll-up doors for reducing air infiltration losses, proper packaging in boxes with sufficient holes for air movement, palletisation with appropriate box alignment and stacking for effective pre-cooling, the impact of refrigerant leakage on energy performance etc.

2. Product catalogue on building materials and packhouse equipment

The stakeholder consultations revealed that lack of reliable information on the range of energy efficient building materials and other equipment, nor applicable selection criteria to guide their selection, forced the packhouse developers to rely on either the knowledge of design consultants or on different vendors whose primary consideration is often just meeting (or even exceeding) the functional requirements, guided by the products they have in their portfolio, without necessarily optimizing for cost or energy efficiency.

It is recommended for BEE to support the development of a product catalogue to help address this information barrier faced by packhouse owners/developers in selecting the right equipment and materials without being restricted by the bias or preferences of consultants or vendors. The information on energy efficient building materials (insulation,

49 Post-harvest management is a system of handling, on-farm storage, market preparation (pre-cooling, sorting, grading, and packaging), transportation, storage, value addition/processing after harvest to preserve the quality and minimise loss or wastage of the agricultural produce.

air-sealants, etc.), refrigeration equipment (pre-cooling and staging cold rooms), sorting/grading and other packhouse process machinery collected during this study can be collated and built upon to put together a product catalogue. The product catalogue should include technical specifications gathered from manufacturers through referring product brochures, information on websites, directly reaching out to specific manufacturers and/or industry associations. The product specifications should include energy use considerations and cost ranges, apart from the functional details. The status of BEE Star Rating for appliances such as fans, motors, pumps, etc. and ECBC compliant construction materials, wherever applicable, should also be documented for different product categories. The energy consumption and cost ranges would facilitate a comparative cost-benefit assessment of the available technologies and solutions. The product catalogue will be particularly helpful for small packhouse developers in the decision-making process while selecting different packhouse equipment.

Down the line, the product catalogue will also facilitate the market research efforts for developing energy performance standards and labels as illustrated in Recommendation 4 on standards and labelling for pre-cooling and staging cold room refrigeration equipment.

3. Directory of design consultants

In the project stakeholder consultations, the packhouse owners and developers from different parts of the country shared their challenge finding the right experts to help them design and develop their facilities. To help address this information barrier, it is recommended that BEE in consultation with the industry associations should compile a list of currently active design consultants working in the packhouse segment. This recommended list can be published as a directory of design consultants by BEE, without necessarily implying BEE endorsement or certification. The BEE can also consider developing a guidance note, in collaboration with (MIDH, APEDA, etc.) to advise prospective packhouse owners in a set of standard questions and selection criteria that could assist them in the selection of design consultants. This directory of design consultants will serve as the target audience for the proposed training and empanelment of design consultants as per Recommendation 6 of this study.

4. Web-based platform

A web-based platform in the form of an online portal or tool should be developed wherein the “tip sheets”, product catalogue, list of design consultants, and selection criteria for design consultants could be posted. The online portal can be hosted on the BEE website, with links available on the NCCD, APEDA and other relevant websites of the Ministry of Agriculture and Farmers’ Welfare and active industry associations. The product catalogue can at a later stage be used as the basis for the development of an online calculation tool to help packhouse owners and investors in estimating the potential energy savings and carrying out a cost-benefit assessment of energy efficient products and solutions. Based upon the user feedback on the web-based platform, a mobile app could be developed by industry associations in close coordination with BEE and MoA&FW to create an alternate platform for packhouse owners and operators to access the above information. The mobile app could be regularly updated by industry associations and be potentially used by BEE and MoA&FW to quickly share any new relevant updates with the user base.

5. Demonstration projects

This study highlights that energy efficiency is currently not a priority or even a consideration on the radar of packhouse owners or operators. There is an evident need for making a case for integrating energy efficiency practices into packhouse design and operations. Hence, at a later stage BEE, in association with MoAF&W, could collaborate with sector participants to support demonstration projects to showcase the benefits of integrating energy efficiency in packhouse operations. The sample interventions and the approach to design an energy efficient packhouse presented in Chapter 2 can be considered for incorporation in the demonstration projects. The demonstration projects can highlight energy efficiency in the following areas: a) building Design; b) selection of building materials; c) layout of the Packhouse facility; d) packhouse process design; and e) refrigeration system design and equipment selection. BEE could collaborate with a suitable packhouse project under development and may consider covering any incremental cost for the energy efficiency interventions.

The demonstration projects can help achieve the following objectives:

- Showcase the technical practicalities in achieving energy efficiency in packhouses;
- Demonstrate energy saving, financial viability, as well as operational benefits of the different energy efficient design and technology choices;
- Provide evidence and confidence to designers, developers and financial institutions that incorporating energy efficiency will enhance the core operational function of a packhouse, and bring other co-benefits such as operational cost savings.

The lessons learned from demonstration projects can encourage greater adoption and significant shifts in awareness and future programs related to a capacity addition of energy efficient packhouses.

3.3.3.3 Roll-out Strategy

Subsequent to plugging the information gap, the following strategies are recommended for increasing awareness amongst packhouse developers and design consultants.

An awareness campaign can incorporate the following elements:

- It should focus on encouraging the application of energy efficiency in packhouse construction and operations through the uptake of guidelines for energy efficient packhouse design, equipment specifications and material selection, and good practices in O&M as detailed in Recommendations 1 and 2.
- It should aim to inform and influence present and future packhouse developers' thinking, through highlighting the short- and long-term benefits of energy efficient packhouses.
- The campaign should be launched in vernacular languages using mediums such as radio, television, mobile apps and newspapers.
- Introductory training and workshops for developers, technicians and service providers should also form a part of the campaign.
- The awareness campaigns should specifically target small packhouse owners as they are the most vulnerable section with regards to the lack of knowledge and resources required for energy efficient design and operation of packhouses.
- Opportunities to collaborate with industry associations shall be explored.

3.3.4 Recommendation 4: Develop standards and labelling for pre-cooling and staging cold room refrigeration equipment

3.3.4.1 Present Scenario

Currently, there are no standards or guidance on energy or environmental performance of pre-cooling and cold storage room equipment for packhouse owners and design consultants. The selection is based solely on the discretion of developers and/or design consultants. As per the analysis under this study, the refrigeration load of a pre-cooling and staging cold room constitutes up to 60-80% of the total packhouse energy consumption. The study findings reveal that energy savings of up to 20-25% could be realised through equipment level interventions within pre-cooling and staging cold room.

Developing and implementing S&L has been one of the major thrust areas for BEE. The current S&L program of BEE focusses on energy efficiency alone. Going forward, BEE may wish to consider broadening the coverage in the case of pre-cooling room equipment. In fact, ICAP recommends labelling of cooling appliances by considering the overall environmental footprint of cooling equipment, in terms of direct (refrigerant-related) and indirect (energy use-related) emissions. There are examples of cooling equipment technical standards and program requirements for combining energy efficiency and low-GWP refrigerant choice internationally and in India, which can have a significant impact. Therefore, considering the growth expected in the cold chain, BEE may consider developing a labelling program for cooling and refrigeration equipment used in pre-cooling and staging cold rooms, in a way that addresses both direct and indirect emissions from the cooling equipment, by targeting energy efficiency and refrigerant choice.

3.3.4.2 Key elements

To empower the packhouse developers to make informed decisions about equipment selection and advance the market uptake of energy efficient and environment-friendly pre-cooling and staging cold room equipment in packhouses, the following sequential approaches are suggested for BEE.

Voluntary comparative labels

It is recommended that in the short-term (1-2 years), BEE should focus on the development of Voluntary Comparative eco-labels by considering the following steps:

- Identification of the most energy efficient and environment-friendly models for pre-cooling and staging cold room refrigeration equipment and their market size.
- Drawing on its extensive experience with its standards and labelling program, which has involved extensive stakeholder engagement from the industry, reputed think tanks and academia, BEE can work to develop either a combined energy and refrigerant use metric or separate metrics for energy and refrigerant use. In this context, the relevant ICAP implementation thematic group under the aegis of MoEF&CC can also be helpful.
- Identification and analysis of Indian, ISO, or IEC test standards for pre-cooling and staging cold room refrigeration equipment. In the case of non-applicability of the existing standards, BEE can work with BIS and other stakeholders to develop new test procedures and standards.
- Assessment of existing test facilities in India and support for the development

of new testing infrastructure to address the capacity gaps, if any.

- Global or regional harmonisation by exploring synergies and opportunities with neighbouring countries and trade partners should be considered for steps 2 and 3.

Minimum energy performance standards

In the medium-term (3-5 years), BEE can develop Minimum Energy Performance Standards (MEPS) for the energy intensive pre-cooling and staging cold room refrigeration equipment considering the following steps:

- Evaluate the impact of the voluntary labelling programme launched and capture the relevant experiences.
- Assessment of the performance range of pre-cooling and staging cold room refrigeration equipment, market size and potential for improvement in terms of reduction in energy usage, peak demand and the GWP of the refrigerant.
- The same performance metrics to capture both energy and environmental performance, as alluded under Voluntary Comparative Labels should be referred for MEPS as well.
- Evaluation of test methods and capacity of test labs considering the total volume of equipment that could potentially be tested.
- Cost-benefit analysis to rank and identify target pre-cooling and staging cold room refrigeration equipment.
- Use a combination of market analysis (eliminate the worst 20%) and engineering analysis (least life cycle cost) to arrive at the MEPS.

Depending upon the market growth of pre-cooling and staging cold room refrigeration equipment segment, the uptake of voluntary comparative labels in the short-term (1-2 years) and the implementation of MEPS in the medium term (3-5 years), BEE can take a call whether to bring the labels in the mandatory regime with MEPS being the lowest rank of the comparative label.

It is strongly recommended that while developing the labels and standards, BEE replicates its own good practice and continues to ensure broad participation from industry, users and academia, reflecting the cross-sectoral expertise required. While developing standards for cooling, or any equipment, it is crucial that BEE's good practice of focusing on equipment performance and setting requirements in a way that doesn't create an advantage for any specific manufacturers is continued and replicated in other technical requirements.

Enforcement of S&L

BEE's existing enforcement framework for the S&L scheme should include the labelled pre-cooling and staging cold room refrigeration equipment as well. BEE, in coordination with SDAs and other stakeholders, already performs certain enforcement related tasks to encourage voluntary compliance and deter non-compliance, namely market surveillance, check testing with the support of third-party labs, and publish check testing results and imposing financial penalties, where warranted.

3.3.4.3 Roll-out Strategy

The various strategies for advancing the market uptake of energy efficient and environment-friendly equipment through the S&L scheme are mentioned below:

- **Linking financial incentives/ subsidies with S&L requirements.** For enhancing the demand for labelled pre-cooling and staging cold room equipment BEE in collaboration with other line ministries should encourage the inclusion of S&L mandatory requirements in MIDH/APEDA/other schemes for packhouse development. The inclusion of better energy performance in the requirements of existing incentive schemes would facilitate the adoption of 3-star or higher labelled pre-cooling and staging cold room refrigeration equipment and other appliances.

- **Incorporation of labels in procurement guidelines for public sector packhouses:** In line with the recommendation of ICAP, all relevant government agencies at the central and state level should issue guidelines for procurement of eco-labelled refrigeration equipment for packhouse development by the public sector.
- **Tax relief:** BEE could consider exploring with the Ministry of Finance the feasibility and desirability of any incentives or tax rebates, such as the Goods and Services Tax (GST), wherever applicable and feasible for the procurement of labelled equipment in packhouses.
- **Demand aggregation model:** To further create and sustain the market for labelled equipment, a demand aggregation model can be explored by BEE in close coordination with EESL. EESL could aggregate the number of packhouses by collaborating with State Horticulture Missions, existing and new cooperatives for packhouses development and operation, agricultural marketing boards and APMCs for retrofitting of existing packhouses and construction of new packhouses.

Buy-back or replacement of existing equipment with labelled ones

Working with the DISCOMs or through an online portal (existing or new), BEE with support of MoEF&CC, EESL or other ESCOs can roll-out a buyback program for the replacement of old inefficient packhouse refrigeration equipment with efficient labelled ones at discounted prices.

3.3.5 Recommendation 5: Introduce framework for energy use reporting and benchmarking

3.3.5.1 Present Scenario

At present, there are no established energy performance indicators or benchmarks for evaluating the energy performance of packhouses, which makes it difficult to assess the energy performance at both the design and operational levels. This study's preliminary assessment based upon design data of 21 packhouses handling different produce shows that the connected load intensity varies from 1 kW/MT to 10 kW/MT, while the energy use intensity varies from 10 kWh/MT to 80 kWh/MT due to the functions performed for handling the various types of produce-types (grapes, mango, apple, banana and vegetable). The study also highlights that of the various packhouses handling different types of produce, grape packhouses have the highest energy use intensity (60-100 kWh/MT) followed by apple and mango, both varying from 40 kWh/MT to 80 kWh/MT.

The development of energy performance indicators and benchmarks for the most energy intensive packhouses can help achieve several helpful outcomes. Use of these indicators can:

- Create awareness about energy use in processing different agricultural produce by tracking and reporting of energy data across different packhouses,

- Facilitate evaluation of the energy performance of these packhouses,
- Create a framework to track the energy performance of packhouses,
- Encourage peer to peer competition amongst the packhouse owners, and
- Help provide inputs to ongoing national energy data management efforts in the country.

3.3.5.2 Key elements

Considering the energy use intensity data collated in this study, packhouses handling three produce categories – grape, apple and mango – are recommended as the target segment for developing energy performance benchmarks, as they were observed to have the highest energy use intensity as illustrated in Chapter 2. BEE should take up the following recommended actions to develop framework for energy data reporting and energy performance benchmarking.

Defining energy performance indicators

Based on the analysis in this study, two separate indicators depicting the energy intensity at both the design and operation level can be considered.

(i) Connected load intensity (kW/MT), and

(ii) Energy use intensity (kWh/MT/day)

Development of energy performance benchmarks

Based upon the data collected in this study, substantiated with supplemental information related to ancillary services or functions carried out at different packhouses, BEE can develop energy performance benchmarks for packhouses handling grape, apple, and mango.

Incentivising energy use data disclosure

The various applicable subsidy schemes of MIDH, APEDA should be linked with a requirement of energy use data submission by the packhouse owners.

Star Rating for packhouses

BEE has already developed a star rating program for the existing commercial buildings (Offices, Hotels, BPOs) which has led to increased awareness about energy efficiency practices amongst the commercial building owners and operators. A more detailed energy efficiency label for the residential buildings has also been launched by BEE.

On similar lines, BEE could further consider the development of a Star Rating program for packhouses. The Star Rating for packhouses will potentially help advance the market uptake of energy efficiency measures in the design, construction and operation of packhouses through enhanced awareness about energy efficiency solutions amongst packhouse owners and operators.

3.3.5.3 Roll-out Strategy

BEE should collect the information on energy use data reported as per Recommendation, as and when available. The SDAs should initiate the collection of energy use data in coordination with State Government departments, especially with the state horticulture boards. The energy use data could be further collated to develop energy performance benchmarks for specific categories of packhouses. BEE may consider developing an online tool (which could eventually progress to a mobile app) for calculating and assessing the energy performance metrics at both design and operation levels. This tool should be integrated with the web-based platform illustrated in Recommendation 3.

3.3.6 Recommendation 6: Develop training and certification on energy efficient post-harvest management and packhouse operation

3.3.6.1 Present Scenario

The study revealed that there is substantial scope for training the farmers on better management of produce both pre-harvest and post-harvest. Right from the choice of timing of harvesting to harvesting techniques, on-farm handling, packaging (if any), loading/ unloading, and transportation to the packhouse have a significant impact on the quality of produce and governs the applicability of cold chain in enhancing its life cycle. In addition to the general lack of effective operation to meet the desired conditions for different produce, energy efficiency has not been considered in the overall scheme of things and has led to inefficiency right from the design, and commissioning to the operation of packhouse. The impact of refrigerants on energy performance is currently often neglected by the packhouse operators. Hence, increased awareness regarding management of refrigerant (which can be flammable and toxic) management, especially if cost-effective solutions are made available, will not only avoid usage of poor performing refrigerant, and high GWP substances[50] but also help India achieve its environmental obligations under the Montreal Protocol by reducing demand for new substances.

Additionally, as noted earlier, some packhouses visited during this study were found to be operated by unskilled or semi-skilled technicians with limited understanding of refrigeration plant operation and packhouse processes. According to the assessment of the relatively small sample reviewed under this study, and discussions that took place during the stakeholder consultation workshops, there appears to be limited availability of skilled packhouse operators and technicians throughout India and the existing packhouse operations and processes adopted in handling, packaging, palletisation is not carried out following standard operational protocol.

MoA&FW's Indian Council of Agricultural Research (ICAR) is an autonomous body responsible for co-ordinating agricultural education and research through its vast network of 101 affiliated institutes and 71 agricultural universities spread across the length and breadth of the country. The National Institute of Food Technology Entrepreneurship and Management (NIFTEM) conceived by the MoFPI is another notable national institute active in teaching, research, consultancy, skill development, business incubation and enterprise development. These institutes (Central Institute of Post-Harvest Engineering and Technology under ICAR being a notable one), agricultural universities and other private institutes in the country, already have some training programs/courses on post-harvest management with a focus on the packaging of fresh fruits and vegetables to reduce post-harvest losses and increase the shelf life, thus improving viability, sustainability and profitability for the farmers. These agricultural centres and institutes in association with various civil society organisations also should be tapped to conduct a variety of on-field training programs for farmers.

3.3.6.2 Key elements

The following targeted training programs and certification schemes are recommended for farmers, packhouse operators, O&M personnel, and design consultants.

50 High GWP refrigerants are not flammable and generally non-toxic – these desirable traits, in fact come with higher GWP values (from F-gases).

Training programs for farmers and packhouse operators on post-harvest management

It is recommended for BEE to collaborate work with ICAR and NIFTEM to first incorporate the energy efficiency aspects into their existing on-field training programs based upon the learnings from this study and further inputs from NCCD, MIDH, APEDA, equipment manufacturers and industry associations. Subsequently, ICAR and NIFTEM should lead the development of demand specific training modules of different durations, wherein BEE can support the integration of energy efficiency aspects based upon the findings of this study and the proposed design and O&M guidelines. ICAR and NIFTEM, with the support of BEE, can then organize "Training of Trainers" workshops for existing institutes and centres, offering post-harvest management courses. The existing institutes, in turn, can then conduct these training programs across different regions of the country.

Training and certification program for packhouse O&M personnel

To address the current skill gaps of O&M personnel, it is recommended to develop training and certification programs for O&M professionals, operators, and technicians. BEE, in collaboration with industry associations such as Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) and Global Cold Chain Alliance (GCCA), etc. should develop training modules in line with the proposed Recommendation 1 of the report outlining O&M guidelines covering both energy efficient and sound refrigerant management practices. BEE in consultation with MOA&FW, MoEFCC, and MOFPI can identify and provide training to affiliate state level institutes or associations to conduct these training programs across different regions of their state.

Integrating cold chain energy efficiency in BEE's Energy Manager and Energy Auditor certification examination

The current study focussing on packhouses has revealed the energy efficiency opportunities in this important segment of the cold chain industry. However, considering the interlinkages of packhouses with the other cold chain links, to address the sector holistically, BEE should integrate cold chain energy efficiency aspects in its national certification examination for Energy Managers (EM) and Energy Auditors (EA). Working with experts from the cold chain industry, BEE should lead the development of relevant study material for the same which could be incorporated in the existing guidebooks for EM/EA. The EM/EA study material on cold chain energy efficiency should be developed in sync with the other training (and/or certification) programs for farmers, packhouse operators, O&M personnel, and design consultants, recommended in this study, wherever feasible.

Training and empanelment of design consultants

In line with its successful national certification program for Energy Managers and Energy Auditors, the BEE, in collaboration with NCCD (or MoA&FW) and support from ISHRAE should carry out training and empanelment of the Agri-design consultants on energy efficiency and environmental management in their design practices. The list of empanelled design consultants should be posted on BEE's website along with the directory of design consultants (as suggested in Recommendation 3 to address the information barrier on finding the right experts), with its link available on the websites of all relevant departments of MoA&FW and MoFPI, among others. This will enhance the credibility of these BEE-empanelled design consultants amongst the packhouse owners and farmers.

3.3.6.3 Roll-out Strategy

For better uptake of the training and certification programs, the existing government support schemes for energy efficient packhouse development, including MIDH and APEDA amongst others, should be linked with a mandatory requirement for certified O&M personnel and design consultants on lines of the O&M guidelines formulated under Recommendation 1.

3.4 Summary of the recommendations

In the preceding sections, the report outlined a series of recommendations required for enhancing the uptake of energy efficiency measures in packhouses. It has illustrated the present landscape for energy efficiency in packhouses in India by identifying the policies, existing guidelines, codes and standards where the suggested measures could be incorporated facilitating the uptake of energy efficiency measures in packhouses in India. Building on research carried out and stakeholder consultations, the report highlights challenges observed on the ground and the improvements possible in the energy performance of packhouses with incorporation of energy efficiency measures.

Each of the recommendations is followed by its specific dissemination and implementation mechanisms. However, the initiation process of implementing the recommendations is dependent on the liaising of BEE with other line ministries and departments like MoA&FW, MoCI, MoFPI and other state level stakeholders.

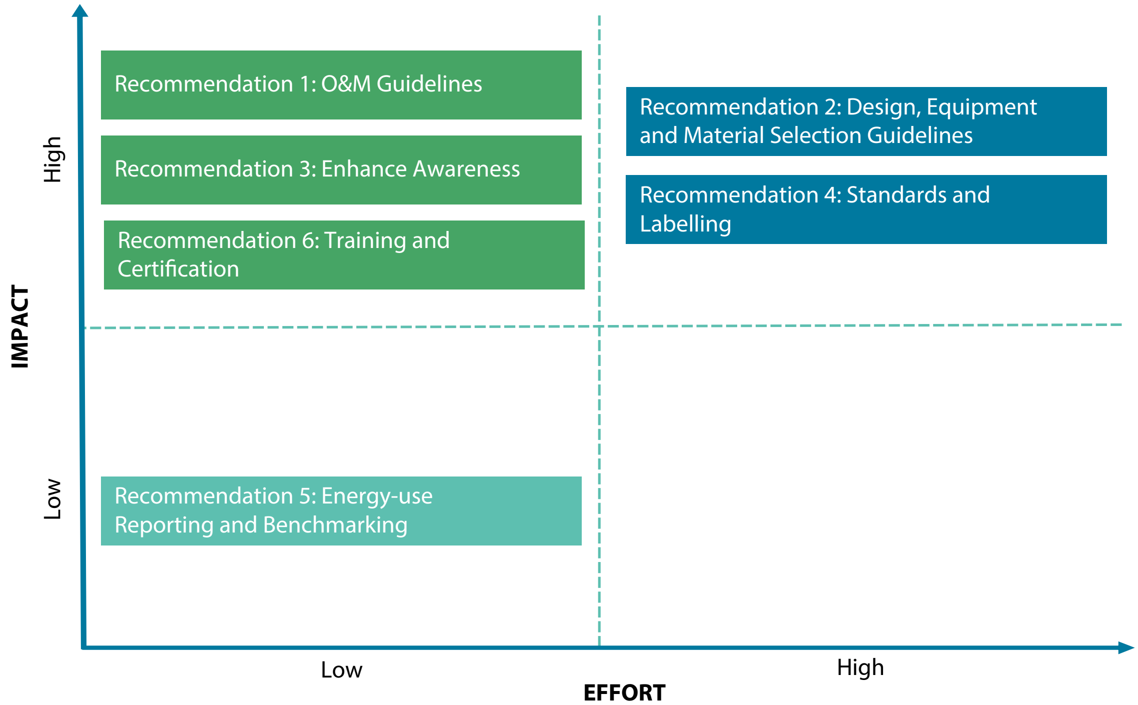
The bundle of recommendations that emerged from the analyses in the preceding sections of the report, make a compelling case for recommendations which are diving deep in the technical aspects of parts or whole of packhouses, like design and equipment selection guidelines for packhouses, good O&M practices, S&L, reporting of energy use and key performance indicators. At the same time, the recommendations bring forward the need for establishing capacity building and training mechanisms for design and O&M of packhouses. The recommendations also highlight the pressing need of spreading awareness among various groups of stakeholders including the farmers, developers, packhouse owners, manufacturers and consultants about the benefits of taking up energy efficiency measures in existing and new packhouses. The recommendations have been designed in similar way and the dissemination and implementation mechanisms have been envisaged considering the cross-sectoral nature of recommendations on capacity building and awareness.

3.5 Strategic prioritisation of the proposed recommendations

The impact-effort matrix (Figure 24) represents the relative ease of implementation and the expected impact of the above recommendations. The matrix shown will be useful for BEE to decide which recommendation to pursue based on the level of effort (from low to high), and the impact of implementation (from low to high). The matrix is meant for illustration purpose only and is developed to provide an indicative comparison of effort and impact for different actions.

While all the recommendations together form a conducive environment for the mainstreaming of energy efficiency measures in packhouses, Figure 24 classifies the recommendations in the four quadrants (low effort-low impact, low effort-high impact, high effort-low impact and high effort-high impact). As stated earlier, the matrix is not based on a systematic or quantitative assessment, but rather a qualitative categorization based on the experience and

Figure 24: Impact-Effort Matrix for Strategic Prioritization of Recommendations



insights under this study. However, these classifications are also significantly dependent on the priorities, enabling environment and institutional capacity available for BEE to initiate the process of dissemination and implementation.

3.6 Way Forward

The implementation of the study recommendations will hinge upon multi-sector coordination wherein constant engagement with multiple ministries, departments, industry and farmers will be of paramount importance. It is strongly recommended that BEE plays a catalytic role in stimulating multi-agency collaboration for development of an implementation roadmap for the recommendations and enable coordination between relevant stakeholders.

It is essential for BEE to work in collaboration with the MoA&FW and MoEF&CC, in particular for aligning the ongoing inter-ministerial efforts to achieve good outcomes. The inter-ministerial committee on Doubling Farmers' Income already recognizes the importance of a robust cold chain infrastructure to provide essential market linkage and reduce food loss and ensure food security. In this context, upfront thinking on energy efficiency has a critical role to play, to make sure the scale-up can happen in a sustainable manner. It is recommended that BEE leverages the ongoing platforms, including the cold chain thematic group for the implementation of ICAP, to operationalize study recommendations.

Building on the impact-effort matrix, Table 37 illustrates the time frame for the development and implementation of recommendations of the study. The table also highlights the relevant line ministries and departments expected to be involved in developing and rolling out each of the policy and regulatory recommendations. The table spreads the mechanisms across short (0 to 2 years), medium (3 to 5 years), and long (above five years) terms.

It is worth noting that while the energy efficiency recommendations proposed in this study are restricted to packhouses alone, the packhouse infrastructure creation cannot happen in isolation but should instead be viewed in the context of demand dynamics from the agricultural market and with proper linkage to the rest of the integrated cold chain, particularly reefer vehicles. The future evolution of the value chain, energy consumption by the cold chain, and business models that could help create and sustain the market for energy efficient packhouses will all depend on how agricultural markets evolve to the demand from end consumers. Overall, a holistic phase-wise implementation of this study's recommendations can ensure that the growth of packhouse infrastructure follows a sustainable trajectory.

In conclusion, it is worth noting that, the methodology adopted for this study and the suggested tools and recommendations has a significant replication potential across other cold chain components (cold storages, ripening chambers, reefer transport) and immunization supply cold chain as well. For instance, the suggested framework for the development of operation and maintenance protocols, guidelines on energy efficient design and equipment selection, standards and labelling and energy use reporting & benchmarking could possibly be utilised for cold storages and ripening chambers for different perishables, or walk-in freezers/coolers, ice lined refrigerators employed in the vaccine cold chains. Further, the recommendations on enhanced awareness and training & certification for packhouse owners, operators, design consultants, etc. about energy efficiency in post-harvest management would work best when integrated with other cold chain components including reefer vehicles, cold storages and ripening chambers encompassing the entire value chain of post-harvest interventions to reduce food loss and meet the nutritional requirements of end consumers.

3.7 Stakeholder Feedback and Important Considerations for Future Work

During the stakeholder consultations carried out on the draft final report of this study (November 2020 – January 2021), very useful feedback and inputs were provided by key stakeholders. Based on the comments received, further revisions were made to the report, where feasible, while the rest of the comments were taken note of by BEE for future work on this subject. The full set of comments, along with BEE responses, are provided in Annex 10.

One of the main comments received from stakeholders, including NITI Aayog and Ministry of Food Processing Industries, was on the importance of having a detailed cost-benefit analysis on the different energy efficient equipment for informing packhouse owner or developer decisions. BEE agrees with the importance of cost benefit analysis in guiding well-informed and rational decisions on energy performance improvement in current and future packhouses. As this study was the first of its kind study on energy efficiency improvement potential of the agricultural cold chain, it was exploratory in nature, and a detailed cost analysis was not its preliminary focus. If and when BEE proceeds with preparation of guidelines and labelling of packhouses and other cold chain infrastructure elements, BEE would undertake a thorough assessment of prevailing and emerging technologies appropriate for the Indian market, along with their costs and benefits. Such an analysis would directly inform the corresponding BEE guidelines and schemes.

Table 37: Summary of Recommendations, Implementation time frame and relevant stakeholders

Recommendation	Indicative Implementation Time Frame						Relevant Stakeholders for collaboration
	Short term (0-2 yrs)		Medium term (3-5 yrs)			Long term (>5 yrs)	
	0-12 months	12-24 months	24-36 months	36-48 months	48-60 months	60 months and beyond	
Recommendation 1: Establish guidelines for good practices in Operation and Maintenance (O&M) of packhouse facilities							
Development of guidelines							MoEF&CC, MoFPI, MoCI, MoSDE, State Horticulture Departments, industry and farmer associations
Dissemination and implementation of guidelines through incorporation in existing standards/guidelines of MIDH, APEDA, etc.							
Recommendation 2: Establish guidelines for energy efficient packhouse design, equipment specifications and material selection							
Development of guidelines							MoHUA, MoRD, MNRE, MoA&FW, State Horticulture Departments, ULB, Gram Panchayat, Industry Associations
Implementation through incorporation in construction approval, existing subsidy schemes, etc.							
Recommendation 3: Enhance awareness about energy efficiency in post-harvest management.							
"Tip sheets" on the benefits of energy efficient practices							MoA&FW, MoFPI, MoCI, MoEF&CC, NCCD, APEDA, ICAR, CIPHET, NIFTEM, industry and farmer associations
Product catalogue on building materials and packhouse equipment							
Directory of design consultants							
Web-based platform							
Demonstration projects							
Dissemination through awareness campaigns							
Recommendation 4: Develop standards and labelling for pre-cooling and staging cold room refrigeration equipment							
Voluntary Comparative Labels							MoEF&CC, MoA&FW, MoFPI, MoCI, MoF, Industry Associations
Minimum Energy Performance Standards							
Enforcement of S&L							

Recommendation	Indicative Implementation Time Frame						Relevant Stakeholders for collaboration
	Short term (0-2 yrs)		Medium term (3-5 yrs)			Long term (>5 yrs)	
	0-12 months	12-24 months	24-36 months	36-48 months	48-60 months	60 months and beyond	
Advancing market uptake of S&L through linking with financial incentives and incorporation in procurement guidelines		■	■	■	■	■	
Recommendation 5: Introduce framework for energy use reporting and benchmarking							
Defining energy performance indicators	■	■					MOP, MoA&FW, MoFPI, MoCI, State Horticulture Departments
Development of energy performance benchmarks		■	■				
Incentivising energy use data disclosure		■	■	■			
Implementation through enegy-use data collection and online tool development		■	■	■			
Star rating for packhouses			■	■			
Recommendation 6: Develop training and certification on energy efficient post-harvest management and packhouse operation							
Training programs for farmers and packhouse operators on post-harvest management			■	■	■	■	MoEF&CC, MoSDE, NCCD, APEDA, ICAR, CIPHET, NIFTEM, NPC, Industry Associations
Training and certification program for packhouse O&M personnel			■	■	■	■	
Integrating cold chain energy efficiency in BEE's Energy Manager & Energy Auditor certification examination			■	■	■	■	
Training and empanelment of design consultants				■	■	■	
Rolling out training and certification programs through linking with existing subsidy/incentive schemes			■	■	■	■	

ANNEXES

Annex 1: Energy saving measures included in NCCD Guidelines

The energy efficiency aspects covered in NCCD's "Guidelines and minimum system standards for implementation in cold chain components" are summarized in this annex.

Energy saving Equipment & Measures	
Details of Energy Saving devices	**Brief Description and Savings**
Light Fixtures	Type of light fixtures-CFL/LED
Natural Lighting for general areas	Specify the provision for natural lighting is included
VFD/Electronic Technology for fans/ compressors	Control of fan motors speed using variable frequency drives or by electronic technology in 2 steps fan for evaporators
Refrigerant Controls and Automation	Automation controls used to save energy for optimizing the performance of the refrigeration system
Air Purger	List the type and operation of air purger
Power Factor Controller	Measure of efficient use of electrical power in the connected system
Energy Recovery	Provide use of energy recovery for ventilation system
PLC Control & Data Acquisition	Automation for monitoring and control of the parameters and Refrigeration plant
Any other Components	Describe the monitoring and control used such as CO_2 scrubbers, odor control, ozonisers, ethylene scrubber etc.

Under the guidelines for cold store chamber sizing and capacity, following section has been added on energy saving equipment and measures, reproduced from the Guidelines themselves:

- For automation in cold chain facilities, the guidelines have mentioned the importance of program logic controller (PLC) for monitoring of the operating conditions through sensors and the PLC processor serving as the decision-making unit.
- The concept behind introducing this component is to incentivize the automation bring energy efficiency in existing and upcoming cold storage facilities as a policy direction. This incentive option could greatly benefit existing cold stores through one-time

modernization and automation that effectively optimizes the operating times and parameters of their cooling equipment.

- The subsidy is intended to incentivise the use of PLC equipment in cold chain and actual chargeable costs can vary depending on design. As an approximate rule of thumb, cost per chamber be in the region of INR 25,000-40,000.
- Under the modernization of refrigeration in existing cold storage, guidelines have described how up-gradation of refrigeration system can achieve substantial and measurable reduction in carbon footprint of the facility and reduction in the recurring cost of the power consumed. Around 5% energy can be saved through efficient compressor in the existing refrigeration system of the cold storage
- Under the modernization of insultation, guidelines have mentioned about the insulation used in peripheral and intermediary wall, roof and floor of cold chain facilities.
- Foam insulation used should be CFC, HCFC and preferably HFC free where possible recognizing that spray foam currently has limited options.
  (NB: It is worth noting that there are other alternatives, primarily c-pentane, that can be easily used, per industry standard in most countries.)

Annex 2: Details of Relevant Government Schemes

Table A2.1: Cost Norms for NHM and HMNEH (Integrated Post Harvest Management)

NHM and HMNEH: Integrated Post Harvest Management		
Component	**Typical Cost norm**	**Assistance details**
Packhouse	INR 4.00 lakh/unit cost. with the size of 9m x 6m	50% of capital cost
Integrated packhouse with facilities for conveyer belt, sorting, grading units, washing, drying and weighing	INR 50.00 lakh per unit with a size of 9m x 18m	Credit-linked back-ended subsidy @ 35% of the cost of the project in general areas and 50% of the cost in Hilly and Scheduled areas
Pre-cooling unit	INR 25.00 lakh/unit with a capacity of 6MT	Credit-linked back-ended subsidy @ 35% of the cost of the project in general areas and 50% of the cost in Hilly and Scheduled areas
Cold room (staging)	INR 15.00 lakh/unit of 30 MT capacity	Credit-linked back-ended subsidy @ 35% of the cost of the project in general areas and 50% of the cost in Hilly and Scheduled areas
Cost Norms for NHB: Integrated Post Harvest Management		
Component	**Typical Cost norm**	**Assistance details**
Integrated Post Harvest Management Projects e.g. packhouse, Ripening Chamber, Refer Van, Retail Outlets, Pre-cooling units, primary processing, etc.	INR 145.00 lakh per project. The add-on components of pre-cooling, packhouse, grading, packing, and the cold room can be taken up as individual components.	Credit-linked back-ended subsidy @ 35% of cost limited to INR 50.75 lakh per project in general areas and @ 50% of project cost limited to INR 72.50 lakh per project in the North-East, Hilly and Scheduled Areas, ensuring backward and forward linkages.

Subsidies are also available for technology induction and modernization in cold chain under the MIDH scheme, as shown in Table 4.

Table A2.2: Technology induction and modernization in cold chain under the MIDH

Item	Description	Admissible Cost
Controlled Atmosphere (CA) Generator	Inclusive of sensors, pressure equalising equipment, controls	**INR 125.00 lakh per unit, maximum of 2 generators**
Specialized CA Doors	Add-on specialisation to storage doors for positive pressure chambers	**INR 2.50 lakh per door, maximum of 20 doors**
CA Tents	Low-cost enclosure of polyethylene PVC, mylar or other impermeable body for existing or new cold stores	**As per original invoice, maximum 5 enclosures**
Programmed Logic Controller (PLC) equipment	Electronic and electrical logic controls for machinery and equipment for existing or new cold stores	**50% of the cost as per original invoice, maximum INR 10 lakh**

Item	Description	Admissible Cost
Dock Leveller system	In existing or new storages	**Max INR 7 lakh per unit, max 5 units**
Warehouse Development and Regulatory Authority (WDRA)/Negotiable Warehouse Receipt (NWR) system, equipment	Computers, printers and software for use with NWR of WDRA	**100% of the cost as per original invoice, maximum INR 2 lakhs**
Specialised Packaging	Automated packaging lines for fruits & vegetables with farm code labelling, with packaging material	**100% of the cost as per invoice, maximum INR 15 lakh per project**
High Reach Material Handling Equipment (MHE)	Specialised Material Handling Equipment	**INR 17 lakh per unit, for max 2 units**
Modernisation of refrigeration	For upgrading of evaporator system, compressor system	**50% of the cost as per the original invoice, maximum INR 100 lakhs @ INR 2500/MT**
Modernisation of insulation	For repair or modernising of cold chamber insulation	**50% of the cost as per original invoice, maximum INR 100 lakh @ INR 1500/MT**
Reefer Container	Reefer container for use on existing chassis trailers	**Max INR 6 lakhs per 9MT (20-foot container)**
Advanced Grader	Computerised, Optical Grading Lines, with packaging material	**100% of the cost as per the original invoice, max INR 75 lakh per line**
Stacking system	Racking system bins and pallets for existing or new cold stores	**100% of invoice cost, max INR 2000/MT**
Retail Shelf/equipment	Temperature controlled retail cabinets or merchandising equipment	**Maximum INR 10 lakhs per establishment**
Alternate Technology	Vapour Absorption, Phase change material, Solar PV panels or Solar Thermal system	**100% of the cost as per invoice, maximum INR 35 lakhs per project**

Annex 3: International Examples

The Philippines Cold Chain Project (PCCP)

A structured multi-year program with dedicated funding and implementation entity, PCCP is a five-year project (Sep. 2013 to Dec. 2018) funded by the United States Department of Agriculture (USDA) 'food for the progress' program and implemented by Winrock International along with its partners in CARAGA Region of Philippines.[51] The material presented in this section is based on information provided on Winrock International's website.

PCCP primarily focuses on providing benefits at the producer level to improve production, inputs, technology and practices at the farm level. PCCP's objectives include increasing agricultural productivity of select high-value commodities, such as high-value vegetables, bananas, livestock and fisheries; and, to expand trade of agricultural products by ensuring production of high-quality products to maintain competitive market prices as well as meet all food safety standards in order for the producers to be competitive in outside markets.

PCCP worked with businesses, producers, government, and non-governmental entities to facilitate participation through project-related assistance, training, and intervention. The major activities involved included:

- Creating new agricultural producer groups and strengthening existing ones;
- Creating new, and strengthening existing, trade associations;
- Developing agro-dealers and other input suppliers;
- Training sanitary and phytosanitary issues;
- Providing financial services to producer association members;
- Providing grants for equipment and inputs;
- Developing new and strengthening existing buyer-seller relationships;
- Facilitating PPP;
- Developing and promoting a media and technology use plan;
- Training improved agricultural techniques;
- Training post-harvest handling and storage;
- Training post-harvest processing.

PCCP project achievements included helping create or strengthen 258 producer groups, and training of 923 agricultural producers on improved agricultural techniques.

Thailand: ThaiGAP – public-private standard development

Thailand is among the world's largest exporters of several agricultural products, and the agricultural sector plays an important role in the country's economy in terms of its GDP distribution and export earnings. Following the establishment of EUREPGAP (now GlobalGAP), a private standard for retailer and suppliers in the European market to prevent unsafe fresh products from farm to shelf, the requirements in the regulations affected growers supplying these target markets. In direct response to

51 Winrock.org. n.d. Winrock International - Market Fresh: How Refrigeration Increases Small Farmer Incomes In The Philippines. [online] Available at: <https://www.winrock.org/project/pccp/> [Accessed 1 May 2019].

the requirements, in 2003, a Cluster Group was formed in Nakorn Pathom province, comprising of private entities (exporters), academia, government agencies, and suppliers and growers.[52] Thai agricultural commodity standards were announced to facilitate trade and Good Agricultural Practice (GAP) was established as a standard for producers ever since.[53] In 2003, the Thai government also announced the national food safety policy under two authorizations: Ministry of Agriculture and Cooperatives, and the Ministry of Public Health. Ministry of Public health controls food for domestic consumption while Ministry of Agriculture takes responsibility for trade and export of agricultural products.

The Cluster assisted the government with selected policy and institutional reform and worked with media and academia to shift mindsets and spread awareness about good agricultural practices. The Cluster also organized training programs pertaining to Western GAP that modified the control points of the EUREPGAP standard in the beginning. The training programs have broadened to cover capacity building for farmers and exporters who seek GlobalGAP certification.

There are approximately 1 million small farms farming in fresh fruit and vegetable (FFV) sector for the Thailand agribusiness. To keep FFV sectors sustainable in the world market, steps were taken to ensure that the smallholder farmers are enabled to comply with the GAP requirements. This project was illustrative the importance of establishing links between farmer and exporter, and clarifying roles and responsibilities in meeting the GAP requirements. Investment in infrastructure, and training and certification costs were a major burden to smallholder farmers. In most cases, exporters paid for certification cost and provided farm advisors to implement and train farmers. Another learning was that collectors and suppliers along the supply chain should play a participatory role as the quality assurance to farm practice when they buy produce directly from the farm.

In 2007, Western GAP requirement changed its name to ThaiGAP, and by 2010 the benchmarking process of ThaiGAP with GLOBALGAP was completed. After completion of benchmarking for export to the global market, THAIGAP standard was revised to be more practical for the domestic market. In 2014, ThaiGAP standard for domestic was prepared in collaboration with a group of suppliers and Certification bodies. In order to promote local producers using the standard as a tool to access retailers and hypermarkets, the Thai Chamber of Commerce (standard owner), plays an active role to expand the implementation and adoption of THAIGAP standard for the domestic market.

Thailand currently has a pyramid system for GAP development of smallholder farmers to step up to achieve higher standards. At the basic level is 'platform food safety' for FFV that is enabled through awareness; the next level up is the ThaiGAP domestic standard monitored through 3rd party certification, and the final level is the ThaiGAP benchmarked to GlobalGAP which requires 3rd party certification as well as accreditation.

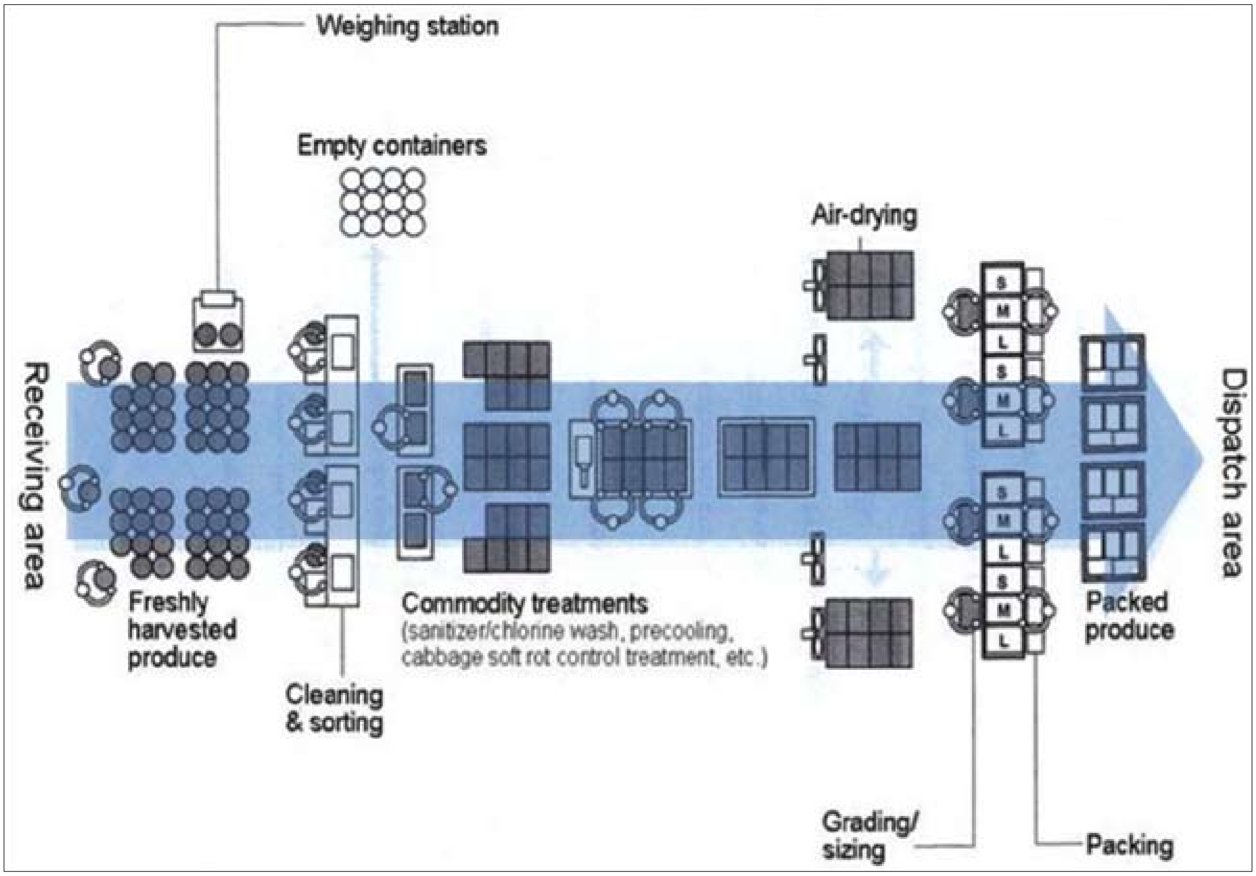
52 Taenkam, P., 2016. Development And Implementation Of Thaigap In Thailand. [ebook] Available at: <https://gapcambodia.files.wordpress.com/2016/12/mr-pathom-taenkam-development-implementation-of-thaigap-7-dec-16-lahore-pakistan.pdf> [Accessed 1 May 2019].

53 Korpraditskul, R. and Ratanakreetakul, C., 2015. THAI Good Agricultural Practice. [online] Available at: <http://ap.fftc.agnet.org/files/ap_policy/558/558_1.pdf> [Accessed 1 May 2019].

Annex 4: Sample schematics for flow of produce and operations

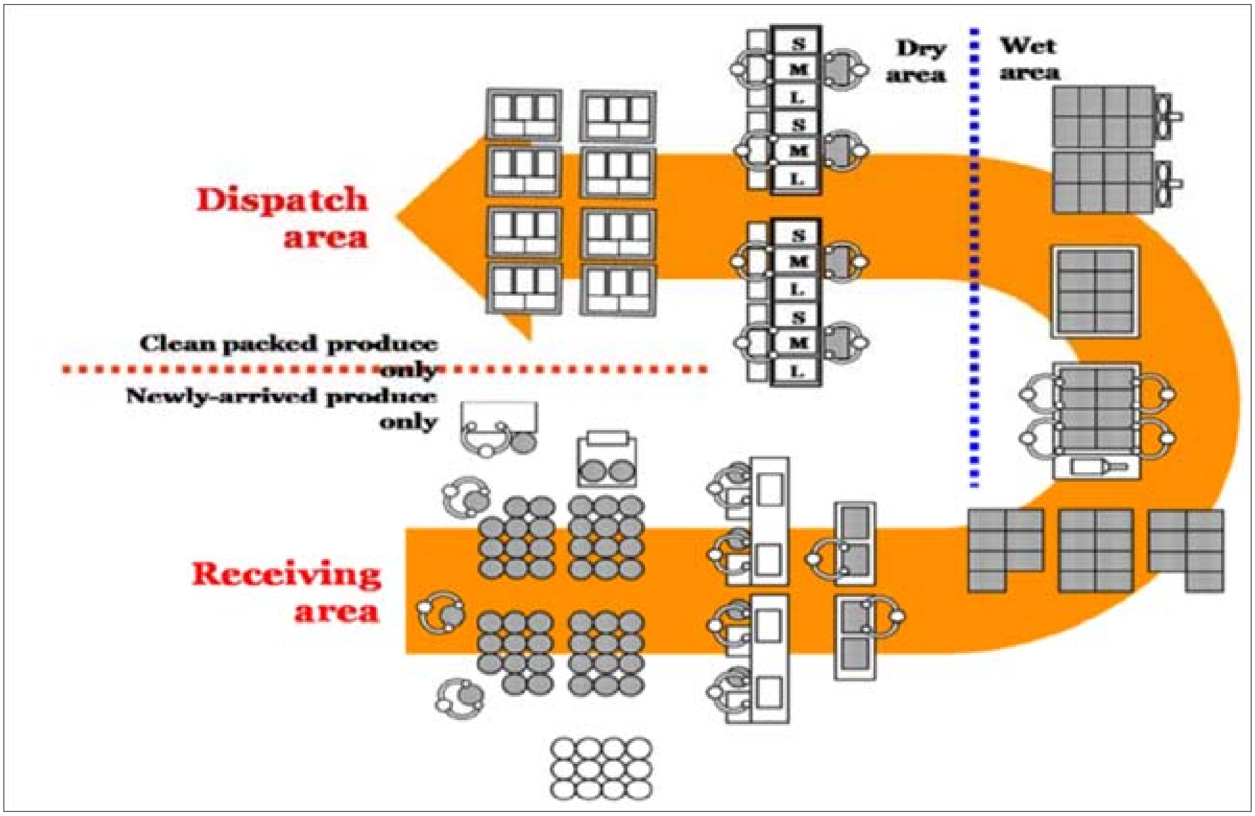
The figures below depict two typical types of flow of produce and operations (sorting, grading, cleaning, packaging, pre-cooling, etc.) in a packhouse considering the movement of personnel and contamination of the produce by separating the receiving area from the dispatch area. (AVRDC training manual[54])

Figure A4.1: Straight-line flow of produce and operations in a packhouse



54 Acedo AL Jr, Rahman MA, Buntong B, Gautam DM. 2016. Establishing and managing smallholder vegetable packhouses to link farms and markets. Publication No. 16-801. AVRDC – The World Vegetable Center, Taiwan. 46 p.

Figure A4.2: U-shaped flow of produce and operations in a packhouse



Annex 5: Indicative cost figures for sample integrated packhouse

Table A5.1: Cost break-down of sample integrated packhouse

Cost of sample integrated packhouse (lakh INR)					
	Grapes	**Apple**	**Banana**	**Mango**	**Vegetable**
Built up area (m^2)	640	640	640	640	640
Pre-cooling room construction cost	6	6	6	6	6
Pre-cooling equipment cost	14	14	12	14	12
Staging cold room Panel cost	12	12	12	12	12
Staging cold room equipment cost	8	8	6	8	6
Sorting and grading- building cost	20	20	20	20	20
Sorting and grading- equipment cost	40	100	20	40	20
Lighting	0.68	0.68	0.68	0.68	0.68
Forklift	8	8	0	0	0
Civil cost (12000 INR/m^2)	88.32	88.32	88.32	88.32	88.32
Total cost	**197**	**257**	**165**	**189**	**165**

Annex 6: Sample payback calculations

This annex provides illustrative are energy savings calculation for various measures explored in this study. These calculations were developed by the consultants as indicative values, based on information collected in packhouses sampled as part of the study, and observation-based assumptions about incremental costs of the measures. The monetary saving is calculated based on industrial tariffs, taken as INR 8/kWh for this analysis.

These calculations are for illustration purposes only, and are by no means intended to be definitive values for a whole range of packhouses for specific produce. It should be emphasized that the applicability of measures, incremental cost of the measures, corresponding energy savings, and the related cost-benefit analysis will vary from facility to facility, and will be greatly influenced by real operational parameters and tariffs.

Table A6.1: Sample Grape packhouse: Cost-benefit Analysis

S.No.	EEMs - Packhouse building design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Natural lighting, proper orientation and shading for minimizing solar heat gains	1824	14594	NA
2	Wall and Roof insulation	1911	15291	5.0
3	Cool roof treatment	478	3823	0.6
4	Provision for natural ventilation- ceiling-mounted turbo ventilators	0	0	NA
5	Optimized size of pre-cooling and cold rooms	6466	51731	NA
6	Airtight doors for pre-cooling and cold rooms	1293	10346	2.6
7	Fast roll-up doors to prevent hot/moist air infiltration	2587	20692	7.2
8	Pre-cooling and staging cold room insulation with optimum thermal performance (PUF/PIR panels)	2587	20692	4.3

S.No.	EEMs - Equipment and System Design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Low energy evaporative cooling system for temperature control in the packing hall	3033	24261	0.1
2A	Selection of refrigerant meeting environmental and thermal performance requirements - Air cooled	6466	51731	7.0
2B	Selection of refrigerant meeting environmental and thermal performance requirements - Water cooled	4526	36212	9.9

S.No.	EEMs - Equipment and System Design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
3A	Selection of energy efficient equipment - Semi hermetic reciprocating or scroll compressors in a rack system	10993	87943	4.1
3B	Selection of energy efficient equipment - Water cooled heat rejection system or adiabatic condensers	8406	67251	5.4
4	Sub-metering individual energy loads, including pre-cooling, staging cold rooms, process machinery, etc.	NA	NA	NA
5	Electronic expansion and subcooling	12933	103462	1.4
6	Energy Management Systems to effectively manage refrigeration plant and indoor environmental parameters	9557	76457	3.3

Table A6.2: Sample Apple packhouse: EEM Analysis

S.No.	EEMs - Packhouse building design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Natural lighting, proper orientation and shading for minimizing solar heat gains	3130	25044	NA
2	Wall and Roof insulation	2504	20035	3.8
3	Cool roof treatment	626	5009	0.4
4	Provision for natural ventilation- ceiling-mounted turbo ventilators	0	0	NA
5	Optimized size of pre-cooling and cold rooms	8948	71583	NA
6	Airtight doors for pre-cooling and cold rooms	1790	14317	1.9
7	Fast roll-up doors to prevent hot/moist air infiltration	3579	28633	5.2
8	Pre-cooling and staging cold room insulation with optimum thermal performance (PUF/PIR panels)	3579	28633	3.1

S.No.	EEMs - Equipment and System Design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Low energy evaporative cooling system for temperature control in the packing hall	3033	24261	0.1
2A	Selection of refrigerant meeting environmental and thermal performance requirements - Air cooled	8948	71583	5.0
2B	Selection of refrigerant meeting environmental and thermal performance requirements - Water cooled	6264	50108	7.2
3A	Selection of energy efficient equipment - Semi hermetic reciprocating or scroll compressors in a rack system	15211	121691	3.0
3B	Selection of energy efficient equipment - Water cooled heat rejection system or adiabatic condensers	11632	93058	3.9
4	Sub-metering individual energy loads, including pre-cooling, staging cold rooms, process machinery, etc.	NA	NA	NA
5	Electronic expansion and subcooling	17896	143166	1.0
6	Energy Management Systems to effectively manage refrigeration plant and indoor environmental parameters	12522	100176	2.5

Table A6.3: Sample Banana packhouse: Cost-benefit Analysis

S.No.	EEMs - Packhouse building design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Natural lighting, proper orientation and shading for minimizing solar heat gains	1448	11581	NA
2	Wall and Roof insulation	1158	9265	8.3
3	Cool roof treatment	290	2316	1.0
4	Provision for natural ventilation- ceiling-mounted turbo ventilators	0	0	NA
5	Optimized size of pre-cooling and cold rooms	4790	38321	NA
6	Airtight doors for pre-cooling and cold rooms	958	7664	3.5
7	Fast roll-up doors to prevent hot/moist air infiltration	1916	15328	9.8
8	Pre-cooling and staging cold room insulation with optimum thermal performance (PUF/PIR panels)	1916	15328	4.7

S.No.	EEMs - Equipment and System Design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Low energy evaporative cooling system for temperature control in the packing hall	2654	21228	0.1
2A	Selection of refrigerant meeting environmental and thermal performance requirements - Air cooled	4790	38321	9.4
2B	Selection of refrigerant meeting environmental and thermal performance requirements - Water cooled	3353	26824	13.4
3A	Selection of energy efficient equipment - Semi hermetic reciprocating or scroll compressors in a rack system	8143	65145	5.5
3B	Selection of energy efficient equipment - Water cooled heat rejection system or adiabatic condensers	6227	49817	7.2
4	Sub-metering individual energy loads, including pre-cooling, staging cold rooms, process machinery, etc.	NA	NA	NA
5	Electronic expansion and subcooling	9580	76641	1.8
6	Energy Management Systems to effectively manage refrigeration plant and indoor environmental parameters	5791	46324	5.4

Table A6.4: Sample Mango packhouse: Cost-benefit Analysis

S.No.	EEMs - Packhouse building design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Natural lighting, proper orientation and shading for minimizing solar heat gains	1826	14609	NA
2	Wall and Roof insulation	1461	11687	6.6
3	Cool roof treatment	365	2922	0.8
4	Provision for natural ventilation- ceiling-mounted turbo ventilators	0	0	NA
5	Optimized size of pre-cooling and cold rooms	4599	36791	NA
6	Airtight doors for pre-cooling and cold rooms	920	7358	3.7
7	Fast roll-up doors to prevent hot/moist air infiltration	1840	14716	10.2
8	Pre-cooling and staging cold room insulation with optimum thermal performance (PUF/PIR panels)	1840	14716	6.0

S.No.	EEMs - Equipment and System Design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Low energy evaporative cooling system for temperature control in the packing hall	3033	24261	0.1
2A	Selection of refrigerant meeting environmental and thermal performance requirements - Air cooled	4599	36791	9.8
2B	Selection of refrigerant meeting environmental and thermal performance requirements - Water cooled	3219	25754	14.0
3A	Selection of energy efficient equipment - Semi hermetic reciprocating or scroll compressors in a rack system	7818	62545	5.8
3B	Selection of energy efficient equipment - Water cooled heat rejection system or adiabatic condensers	5979	47828	7.5
4	Sub-metering individual energy loads, including pre-cooling, staging cold rooms, process machinery, etc.	NA	NA	NA
5	Electronic expansion and subcooling	9198	73582	1.9
6	Energy Management Systems to effectively manage refrigeration plant and indoor environmental parameters	7305	58436	4.3

Table A6.5: Sample Vegetable packhouse: Cost-benefit Analysis

S.No.	EEMs - Packhouse building design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Natural lighting, proper orientation and shading for minimizing solar heat gains	2117	16935	NA
2	Wall and Roof insulation	1694	13548	5.7
3	Cool roof treatment	423	3387	0.7
4	Provision for natural ventilation- ceiling-mounted turbo ventilators	0	0	NA
5	Optimized size of pre-cooling and cold rooms	6772	54178	NA
6	Airtight doors for pre-cooling and cold rooms	1354	10836	2.5
7	Fast roll-up doors to prevent hot/moist air infiltration	2709	21671	6.9
8	Pre-cooling and staging cold room insulation with optimum thermal performance (PUF/PIR panels)	2709	21671	3.3

S.No.	EEMs - Equipment and System Design	Energy Saving (kWh)	Monetary Saving (@ INR 8/kWh)	Payback Period (Years)
1	Low energy evaporative cooling system for temperature control in the packing hall	2654	21228	0.1
2A	Selection of refrigerant meeting environmental and thermal performance requirements - Air cooled	6772	54178	6.6
2B	Selection of refrigerant meeting environmental and thermal performance requirements - Water cooled	4741	37925	9.5
3A	Selection of energy efficient equipment - Semi hermetic reciprocating or scroll compressors in a rack system	11513	92103	3.9
3B	Selection of energy efficient equipment - Water cooled heat rejection system or adiabatic condensers	8804	70431	5.1
4	Sub-metering individual energy loads, including pre-cooling, staging cold rooms, process machinery, etc.	NA	NA	NA
5	Electronic expansion and subcooling	13544	108356	1.3
6	Energy Management Systems to effectively manage refrigeration plant and indoor environmental parameters	8468	67742	3.7

Annex 7: Stakeholder consultation workshop agendas and participant list

WORKSHOP 1: NEW DELHI, OCTOBER 4, 2019

AGENDA

Time	Events
09:30 - 10:00	**Registration, Tea & Networking**
10:00 - 10:45	**Keynote Session:** ▪ *Welcome address* by Amol Gupta, Energy Specialist, World Bank ▪ *Setting the context* by Dr Satish Kumar, President and Executive Director, Alliance for an Energy Efficient Economy (AEEE) ▪ *Theme Address* by Prof. Pawanexh Kohli, Chief Executive Officer and Advisor, National Centre for cold Chain Development (NCCD) ▪ *Keynote address* by Shri Abhay Bakre, Director General, Bureau of Energy Efficiency (BEE) ▪ *Special Address* by Ms Geeta Menon, Joint Secretary, Ministry of Environment Forest & Climate Change (MoEF&CC) ▪ *Vote of thanks* by Shri Arijit Sengupta, Director, BEE
10:45 - 11:00	**Introductory address** by Prof. Pawanexh Kohli, NCCD
11:00 - 11:45	**Study findings - Discussion on key observations** **Description:** The objective of the session is to discuss the: ▪ Key observations from site visits ▪ An integrated approach to design a packhouse ▪ International best practices **Theme setting and Moderation:** ▪ Mr Arijit Sengupta, Director, BEE **Panellist:** ▪ Mr Rajagopal Sivakumar, AEEE ▪ Mr Tarun Garg, AEEE **Moderated Question and answer (Q&A) session for 15 mins**
11:45 - 12:00	**Tea/Coffee**
12:00 - 13:15	**Energy Efficiency status in the design and operation of packhouses** **Description**: The objective of the session is to discuss the: ▪ Challenges faced by packhouse owners and operators to implement EE ▪ Key considerations for ensuring EE in packhouse infrastructure planning ▪ Defining key energy performance indicators for packhouse design (TR/MT or kW/MT) and operation (kWh/MT) ▪ Govt. support offered for skill development of packhouse operators ▪ Role of civil society in making coldchain more energy efficient

<table>
<tr><th>Time</th><th>Events</th></tr>
<tr><td></td><td>Theme setting and Moderation:
▪ Dr Satish Kumar, President and Executive Director, AEEE
Panellist:
▪ Ms Seema Gulati, Elle Farms
▪ Mr Arvind Jhamb, World Bank
▪ Mr Harshal Surange, ACR Project Consultants Pvt. Ltd.
▪ Mr Keku Bomi Gazder, AAI Cargo Logistics and Allied Services Company Limited (AAICLAS)
▪ Mr Shubhashis Dey, Shakti Sustainable Energy Foundation
Moderated Question and answer (Q&A) session for 15 mins</td></tr>
<tr><td>13:15 - 14:00</td><td>Lunch break</td></tr>
<tr><td>14:00 - 15:15</td><td>Role of low energy and energy efficient technologies in overall energy efficiency of the packhouse
Description:
The objective of the session is to discuss the:
▪ Existing technologies and solutions adopted in packhouses
▪ Adoption of innovative low energy solutions for packhouses
▪ Energy efficiency potential of various technological options
▪ Challenges and gaps for the market uptake of energy efficient technologies
Theme setting and Moderation:
▪ Mr Rajagopal Sivakumar, AEEE
Panellist:
▪ Mr Sunil Kurade, Danfoss Industries
▪ Mr Satinder Singh Sindhu, Star Coolers & Condensers Pvt. Ltd.
▪ Mr Nirdosh Sharma, Rinac India Ltd.
▪ Mr Vishnu Sasidharan, Pluss Advanced Technologies Pvt. Ltd.
▪ Mr Ravindra Dolare, Ecozen Solutions Pvt. Ltd.
▪ Capt. Ramanujam, Logistics Skill Council
Moderated Question and answer (Q&A) session for 15 mins</td></tr>
<tr><td>15:15 - 15:45</td><td>Closing remarks and way forward by WB, BEE and AEEE</td></tr>
</table>

LIST OF PARTICIPANTS

S.No.	First Name	Last Name	Company Name	Designation
1	Abhay	Bakre	BEE	DG
2	Amol	Gupta	World Bank Group	Energy Specialist
3	Pawanexh	Kohli	NCCD	CEO
5	Geeta	Menon	MoEFCC	Joint Secretary
6	Arijit	Sengupta	BEE	Director
7	Ms. Seema	Gulati	Elle Farms	
8	Arvind	Jhamb	World Bank	Agriculture expert
9	Harshal	Surange	HVAC consultant	Director & CEO
10	Keku Bomi	Gazder	AAI Cargo Logistics and Allied Services Company Limited (AAICLAS)	CEO
11	Shubhashis	Dey	Shakti Sustainable Energy Foundation	Program Manager, Energy Efficiency
12	Sunil	Kurade	Danfoss	Head - Applications & Training
13	Satinder Singh	Sindhu	Star collers and condensers Pvt. Ltd.	Assistant manager - Sales & Marketing
14	Nirdosh	Sharma	Rinac India Ltd.	Vice President - Business Development
15	Vishnu	Sasidharan	PLUSS technologies	Vice President - Products
16	Capt. T.S.	Ramanujam	LSC (Logistics Skill Council)	CEO
17	Ravindra	Dolare	Ecozen Solutions	
18	Kr. Vijay	Singh	Rinac India Ltd.	Deputy General Manager - Business Development
19	Shailja		BEE	Media Advisor
20	Pawan	Kumar	SFACH	Chief Project Coordinator
21	Pramod	Prabhakar	Tabreed India	PM
22	Pradeep	Deswal	IREDA	Manager
23	Parmeet	Gupta	Tabreed India	Associate
24	Sandra Soares	da Silva	KFW	Head of Energy Cell
25	Ekta	Mehra	KFW	Senior Sector Specialist - Financial Sector
26	Ritika	Jain	Shakti Sustainable Energy Foundation	Associate (Energy)
27	Sumit	Mudgal	BEE	Project Engineer
28	Mr. Siddarth	Dhar	BEE	Project Engineer
29	Pankaj	Kumar	SFACH	Chief Project Coordinator

S.No.	First Name	Last Name	Company Name	Designation
30	Sunil	Kurade	Danfoss	Head - Applications & Training
31	Mr. T.P.	Ashwin	BEE	Project Engineer
32	Mr. Sameer	Pandita	BEE	Director
33	Mr. Rajeev	Kashyap	BEE	Project Engineer
34	Asheesh	Fotedar	SSEC	
36	Chetan	Methul	Siemens	
37	Dr.	Saini	HSAMB	Director General, Horticulture
38	Govind	Gore	Desai Fruits & Vegetables Pvt. Ltd.	Sr. Manager
39	Kapil	Singhal	BP RefCool	Managing Director
40	Markus	Wypior	GIZ	Director
41	Nitin	Kumar	inficold	CMO
42	Santosh	Paragond	Desai Fruits & Vegetables Pvt. Ltd.	AGM - Supply Chain Management
43	Sunil	Rawat	Blue Star and RAMA	Manager - Installation (Product Sales Group)
44	Ashutosh		SEETECH Solutions	
47	Narendra	Dadhich	Star Collers and Condensers Pvt. Ltd.	Sr. Business Development Manager
48	Srinivasu	Moturi	Voltas	Sr. General Manager (R&D)
49	Madhuri		Honeywell Internation (I) Pvt. Ltd.	Government Relations Specialist
50	Arvinder Singh	Pental	Voltas	Vice President - CR
53	Mr. Saravjeet	Singh	Freshpro Agri Solutions Pvt. Ltd.	Director
54	Nitin	Kumar	Inficold	CMO
55	Kishan	Dhameliya	Ecozen Solutions	Manager - Special Projects

WORKSHOP 2: NEW DELHI, NOVEMBER 14, 2019

AGENDA

<table>
<tr><th>Time</th><th>Events</th></tr>
<tr><td>09:30 - 10:00</td><td>Registration, Tea/Coffee & Networking</td></tr>
<tr><td>10:00 - 10:10</td><td>Welcome Address and Project Overview
Ms Defne Gencer, World Bank Group
Shri Abhay Bakre, Director General, BEE
Prof. Pawanexh Kohli, NCCD
Mr K B Subramanium, Director, MoFPI
Dr Amit Love, Joint Director, MoEF&CC
Keynote address by Mr P K Swain, Joint Secretary, Marketing, Ministry of Agriculture</td></tr>
<tr><td>10:10 - 10:40</td><td>Study findings- Policy and regulatory options for improving EE in packhouses
Dr Satish Kumar, AEEE
Description:
The objective of the session is to discuss:
Key observations from the study
Recommended policy and regulatory options for improving the energy efficiency in packhouses</td></tr>
<tr><td>10:40 - 13:00 (Tea Break at 11:30 AM)</td><td>Roundtable discussion on the proposed policy and regulatory recommendations
Moderator: Shri Arijit Sengupta, Director, BEE
Packhouse owner, state officials, think-tanks, institutions, industry associations and alliances, technology providers
Description:
The objective of the session is to discuss:
Guidelines on energy-efficient design and operation of packhouses
Need for development of baseline and benchmark for energy performance evaluation of packhouses
Institution building and skill development
Synergies with ICAP implementation</td></tr>
<tr><td>13:00 - 13:30</td><td>Closing remarks and way forward by WB, BEE and AEEE</td></tr>
<tr><td>13:30 - 14:30</td><td>Lunch</td></tr>
</table>

LIST OF PARTICIPANTS

S.No.	Name	Organisation
1	Abhay Bakre	BEE
2	Akbar Sher Khan	IMPARGO
3	Amit Love	MoEF&CC
4	Anu Raswant	AEEE
5	Archana Bhardwaj	International Solar Alliance
6	Arijit Sengupta	BEE
7	Ashwini Mehra	ISHRAE
8	Darshi Dhaliwal	TORO WATT
9	Defne Gencer	World Bank Group
10	Gerry George	AEEE
11	Ishan Jain	AEEE
12	K. Narsaiah	ICAR - CIPHET
13	Kr. Vijay Singh	Rinac India Ltd
14	Lt. Col. Subhash Deswal (Retd.)	Sushine Vegetables, Sikandrabad
15	Milind Chittawar	SEE-Tech Solutions
16	Mohd. Ali Rehman	MSME
17	Mrigendra Pratap Singh	Amar Bharti
18	P.K. Swain	Ministry of Agriculture & Farmers' Welfare
19	Pawanexh Kohli	NCCD
20	P.K. Goel	Eurovent Certita
21	Rajagopal Sivakumar	Agrivaluechain
22	Ravipal Singh	Department of Horticulture - Punjab Govt.
23	Ritika Jain	Shakti Sustainable Energy Foundation
24	Ronnie Khanna	KFW
25	Rukmini Parthasarathy	KFW
26	Sandeep Kachhawa	AEEE
27	Santosh Paragond	Desai Fruits & Vegetables Pvt. Ltd.
28	Satinder Singh Sidhu	Star coolers and condensers Pvt. Ltd.
29	Satish Kumar	AEEE
30	Shivam Sharma	NITI Aayog
31	Subhashish Dey	Shakti Sustainable Energy Foundation
32	Sumit Mudgal	BEE
33	Sunil Kurade	Danfoss Industries
34	Sunil Rawat	Blue Star
35	Tarun Garg	AEEE
36	Tiger Aster	TORO WATT
37	Vijay Singh	Rinac India Ltd.
38	Vimal Dixit	Star coolers and condensers Pvt. Ltd.
39	V.K. Arora	NIFTEM
40	Zeeshann Haider	Blue Star
41	Zerin Osho	International Solar Alliance

Annex 8: List of stakeholders consulted in focussed interviews

Name	Designation	Organization
C.P. Gandhi	Deputy Director	National Horticulture Board (NHB)
Pawan Kumar	Horticulture Officer	
S.K. Kaul	Assistant Commissioner	The Mission for Integrated Development of Horticulture (MIDH)
Tarun Bajaj	General manager	Agricultural & Processed Food Products Export Development Authority (APEDA)
Gurmeet Singh	Member of CII Taskforce on Cold chain	Confederation of Indian Industry (CII) - Task Force
Ashish Fotedar	Founder	System Solution Engineering Consultants
Nagahari Krishna Lokanadham	Director	Danfoss
Arijit Sengupta	Director	Bureau of Energy Efficiency (BEE)
Rahul Singh, Prashant Kamboj	Deputy General Manager	Mahindra Farms (Delhi)
Rajbir Singh, Ajit Otari	Associate Manager	INI Farms (Baramati)
Mr. Fritz	Founder	Fritz Popma

Annex 9: Data collection questionnaire used for packhouse site visits

General Information	
Name of the packhouse	
Contact details of the facility owner	
Date/Year of construction	
Date/Year of commencement of operation	
Received financial assistance from which govt scheme, if any	MIDH/APEDA/MoFPI/RKVY/other
Date of receiving financial assistance	
Amount of financial assistance received if any	
Type of Ownership	Central Govt/State Govt/Private Ltd/FPO/Other
Ownership model	Lease/Captive/any other
Operational Information	
No. of Produce Handled	
Primary Produce Handled	
Other major produce handled	
Functions performed	Sorting/Grading/Treating/De-sapping/Washing/Drying/Cleaning/Waxing/Packing/Pre-cooling/Staging (Cold Room)
Avg. Daily Operating Hours	Sorting/Grading
	Pre-cooling

	Staging (Cold Room)
Produce-wise operational schedule	Seasonal vs year-round
If Seasonal - months of operation	
Schedule of maintenance practices	Periodic Maintenance Schedule (Number of days/month)
	Annual Maintenance Schedule
	Any other
Packaging Process	Punnet/Crates/Pallet/Bags/other
Facility maintenance	AMC/Self-maintenance
Name of Firm in case of AMC	
Qualification of facility manager in case of self-maintenance	Diploma/any other
Details of energy audits conducted during the last 3 years, if any	
Produce Throughput	
Packhouse handling capacity (MT/day)	Crop 1 - ____________, Crop 2 - __________________, ____________
Produce handled annually (MT/year)	Crop 1 - ____________, Crop 2 - __________________, ____________
Design Capacity of Sorting & Grading Lines	No. of Lines
	Capacity (MT/hour) of each line

Design Capacity of Pre-cooling	No. of Pre-coolers						
	No. of batches per day per pre-cooler						
	Running hour per batch						
	Capacity MT/batch						
Design Capacity of Staging (Cold Room)	No. of Cold Rooms						
	Holding Capacity per Cold Room (MT)						
	Total Capacity (MT)						
Structural Details							
Roof Details	Type of Insulation						
	Total roof area in m^2						
Wall details	Type of Insulation						
	Total wall area in m^2						
Window details	Total Window area in m^2						
	Type of Window (Single or double glazed)						
	Any shading provided on the windows						
	Shading projection in mm						
The total footprint of the packhouse facility	Specify the total plinth area of the facility in m^2						
Parking	Covered/Uncovered						
Dimensions (Length *Width *Height)	**Parking**	**Receiving area**	**Holding area**	**Sorting and grading area**	**Pre-cooling**	**Staging cold room**	
Dock Leveller	Yes/No						
Dock Shelter	Yes/No						
Strip Curtain	Yes/No						
Air Curtain	Yes/No						
Layout Drawing	Provide layout drawings of the complete packhouse including pre-cooler and staging cold room.						

Energy Consumption Trends							
Provide monthly electricity bills for the last years							
DG set consumption (litres/ month)							
Electricity tariff	Electricity tariff						
Alternate beside Grid and DG	Biomass/Solar thermal/Solar PV/Storage/Wind						
Feedback from Packhouse Owner	Scope of Energy Efficiency? How much does it affect your bottom-line?						
Equipment Details							
Power generating unit	Sanctioned load (kW/kVa)						
	No. of transformers						
	Rating of transformers						
	No. of DG sets						
	Rating of DG sets						
Lighting	Type of lighting used (CFL/LED/Normal – total numbers and wattage).						
	Total Lighting load (kW)						
Motor rating		**Number of motors**	**Make/ Model**	**Capacity in kW**	**Efficiency**		
	Sorting line						
	Grading line						
	Washing line						
	Drying line						
	Waxing line						
Hot water treatment	**No. of electric heater**		**Capacity of each electric heater (kW)**		**Number of pumps**	**Rating of pump motors (kW)**	

Cooling Unit Details		Receiving area	Holding area	Sorting and grading area	Pre-cooling area	Staging cold room	Despatch area
Cooling System used	Air-cooled or water-cooled				(Forced air cooling, hydro, icing, vacuum, room cooling)		
Design Temperature and RH levels.	°C/%						
Refrigeration System Load	Refrigeration TR						
	Input power (kW)						
Evaporator Details	Make						
	Model						
	No. of units (working/standby)						
Condenser Details	Make						
	Model						
	No. of units (working/standby)						
Controls Used	Specify the electronic controller for room temperature and relative humidity monitoring & control.						
Refrigerant used	R-134a/R404A/R507/R22/other						
Insulating material used	Type of insulating material,						
	Thickness (mm)						
Power Rating of ancillary equipment	Dock leveller - ________, Air curtain, _______________, Fork lift__________						
Type of Fans							
No. of Fans							
The power rating of each fan							

Annex 10: Matrix of key stakeholder comments and responses

S.No.	Ministry	Comment	Comments/Actions
1	DEA	Disclaimer: This study does not necessarily reflect the views of the Government of India and the findings of the study are not binding on the Government of India	Disclaimer added in the report on page 2 (inside cover of the report)
2	APEDA	APEDA would be happy to implement the recommendations of World Bank study and capacity building of existing pack houses as well as forth coming projects under its infrastructure development component. It has made the following observations, a) under the emergent agricultural reforms period, substantial changes are required at the basic processing levels. The point raised in World Bank Study for creation of Rural Horticulture handling units is essentially the first step towards completing the cold chain, b) The energy efficient cold chain will be beneficial for rural sector as the investment by Farmers or FPO's will be limited. The Scheme of credit linkage to FPO'S should be utilized for implementation of energy efficient cold storage and primary processing facilities. Financial Assistance under any of the scheme of the government or through World Bank for Creation of Cold Chain infrastructure near farm would be a boon for the Horticulture Sector, and c) APEDA would also recommend issuance of guidelines & good practices in operation and maintenance of Pack Houses. Use of energy efficient methods in designing and running of Pack Houses will be useful to disseminate to exporters.	The comments are very helpful, and have been incorporated in the main report where feasible, and will be taken into account in future BEE work. BEE also agrees on the importance of maintaining an integrated cold chain that can meet the needs of the target markets and enable farmers to offer their produce to end market.
3	MoEF&CC	The World Bank study should also address the following: 1) The adoption of the latest monitoring, control mechanisms and automation in data capturing will be very useful tool as cold chain sector has a long way to go. The key to transforming this aspect is to localize the technologies to suit the scale of industry and by creating flexibility in the system to accommodate and modify the elements of complex supply chains on a need basis. There are a number of renewable and alternate energy technologies that are promising or cold chain application. In order to deliver on their potential for a sustained period of time, these technologies will require excellent	The comments are very helpful, and have been incorporated in the main report where feasible, and will be taken into account in future BEE work. BEE also agrees on the importance of maintaining an integrated cold chain that can meet the needs of the target markets and enable farmers to offer their produce to end market. The comments on the organization of the sector (in point #2), connecting the farmers to markets, and increasing the value captured by the farmers along the value chain, while beyond the

S.No.	Ministry	Comment	Comments/Actions
		engineering and installation' high quality components, and stringent commissioning and O&M services. 2) 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. Without facilitation of cold chain, the average farmer 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. The intermediary, disengages the value created by the farmer, and may further connect to nearby markets or may utilize the produce to create a new product. This in effect, disconnects farmers from scope of increased value realization directly from consumers of fresh produce. 3) Cold chain is to be perceived as a logistics conduit, linking producing points with consumption Centres. Refrigeration is a key component of cold chain infrastructure. Cooling Action Plans provide a tool for bringing in sustainability paradigm to a largely logistics issue, in terms to technologies, energy efficiency, maintenance to end-to-end cold through real time monitoring technologies resulting reduced food loss. and 4) Regional collaborations in terms of data gathering, market development and technology transfer could be worked out appropriately in a mutually beneficial manner. Solar Cooling initiative of ISA is one such example.	immediate scope of the present study, are pertinent points. As such, the BEE will be sharing those comments with MoA&FW for further consideration during next phase of implementation. Point number 6 in Section 2.6.3 (EEMs - equipment and system design) of the report highlights the Energy Management Systems (with control and automation) to effectively manage refrigeration plant and indoor environmental parameters. The suggestions by MoEF&CC on the same is also incorporated in that section. In section 3.3.2.3 (Key elements) which is part of Recommendation 2: Establish guidelines for energy efficient packhouse design, equipment specifications and material selection of the report - aspects related to the role of Renewable Energy has been added. In section 1.2.1.1 (Cold chain and its importance), the suggestions on socio-economic impact have been added. In section 1.2.3 (Treatment of cold chain under ICAP), introductory para added related to cooling action plan.
4	MoFPI	Overall, it is noted that no new technology or design with any cost breakdown has been assessed/shared in the report. Further, the main objective is to establish good practices for operation of packhouses, establish guidelines for energy efficient pack house design and specifications, create awareness, develop standards, introduce framework for energy use reporting and benchmarking and develop training and certification on energy efficient post-harvest management and pack house operation. In order to identify some concrete next step w.r.t enhancing awareness, standards/labelling & incentives and energy performance bench-marking further discussion is required for which they look forward to BEE.	BEE agrees on the importance of having detailed cost-benefit analysis on the different energy efficient technologies and equipment to packhouse owner/developer decisions and energy performance improvement in current and future packhouses. If and when BEE proceeds with preparation of guidelines and labelling of packhouses and other cold chain infrastructure elements, at that time, BEE would undertake a thorough assessment of prevailing and emerging technologies appropriate for the Indian market, along with their costs and benefits. Such an analysis would directly inform the design of the corresponding BEE guidelines and schemes.

<table>
<tr><th>S.No.</th><th>Ministry</th><th>Comment</th><th>Comments/Actions</th></tr>
<tr><td>5</td><td>NITI Aayog</td><td>An illustrative example of energy efficiency through differential cost-structures could be added in the study for better understanding in financial terms as well as savings towards the sustainability and the scope of incremental benefit. It will help in better planning as well as development of total value chain.</td><td rowspan="3">In Section 2.3 (Energy efficiency measures) the cost-benefit analysis of various identified EEMs was carried out against a representative theoretical integrated packhouse for each produce studied. The TOR of the study was focused on assessing the baseline energy performance and suggesting suitable energy efficient technologies and design.

These detailed insights are helpful. Indeed, the report highlight the Agriculture and processed foods export promotion scheme of APEDA in Section 1.2.1.8 which covers the complete cold chain.

The report findings also highlights that most of the grape packhouses are equipped with all facilities, here are some observations from the report - Considering the fragility of grapes, cooling systems are installed in the receiving area, sorting and grading area and despatch area (in addition to the pre-cooling and staging cold rooms) to avoid deterioration in quality from exposure to high temperatures. This also distributes some of the load from pre-coolers to other packhouse areas where the produce is being prepared before it is pre-cooling.

Only in grape export packhouses, fast rollup doors are installed in the receiving and delivery areas.

Only in grape packhouses, the sorting and grading areas are air-conditioned.

These grape packhouses also had skilled and qualified technicians/ operators compared to the majority of the remaining packhouses operating in the domestic market.

In Section 3.1.1 of the report - there is a dedicated recommendation to develop training and certification on energy efficient post-harvest management and packhouse operation.</td></tr>
<tr><td>6</td><td>NITI Aayog</td><td>The approach of considering energy intensity is well accepted. The aspect of entire value chain has been covered and recommendations cover SOP, Standards Labelling, post-harvesting measures of energy efficiency, etc. along with timelines. However, the analysis includes 30% efficiency improvements in the future; it would be also advisable to have cost estimates for the same. It would provide clarity to the investors and the govt. for long term planning.</td></tr>
<tr><td>7</td><td>APEDA</td><td>From APEDA's point of view the scheme of infrastructure implemented by APEDA covers the complete cold chain from Farm to Pack House and then to Exports, Most of the Grape Exporters, Pack Houses are equipped with all facilities. While we certainly feel that similar facilities for handling other fruits like Bananas, Mangoes, Citrus, Apples and Vegetables of consumer packs should be installed for preserving product quality and enhancing shelf life.

Process Fruit and Vegetable Exporters also highlighted the need for having freezer with capacity of storing Fruits and Vegetables at -18 degree for use in making finish products as and when the demand arise.

There is no doubt that there is a lack of skills for managing pre-cooling and staging of labelling and packing in the pack houses. It is recommended that the creation of energy efficient infrastructure along with development of skills in postharvest management would be required.</td></tr>
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8	MoEF&CC	Ministry has developed India Cooling Action Plan. The plan would inter-alia integrate the phase out of ODSs/phase down of HFCS while maximizing energy efficiency of air-conditioning equipment. This Plan proposes to synergize actions for addressing cooling demand across all areas: technology, manufacturing, energy efficiency and the environment, while reemphasizing the principles enshrined in the Country Programme of India for phase out of ODS i.e. to have minimum economic dislocation and obsolescence cost and maximize indigenous production to twin environment and economic gains. The India Cooling Action Plan provides recommendations on the Cold Chain Sector which inter-alia include: ▪ Encourage development of cold chain infrastructure with use of low-GWP refrigerant based energy efficient cooling systems. ▪ Development of safety standards for flammable and toxic refrigerants for cold storage and other segments of the cold chain. ▪ Develop programme for retrofitting of existing cold storage to reduce cooling, refrigerant demand and energy consumption. ▪ Standardize all design, construction and associated specifications for small, medium and large cold chain infrastructure components. ▪ Link the incentives being provided for development of cold chain infrastructure with adoption of energy-efficient design, construction and maintenance practices and low GWP refrigerant and renewable technologies. ▪ Provide specialized training facilities for cold chain professionals and technicians to promote proper utilization and operation of technology, as well as energy efficiency. ▪ The ICAP factors in future use of cutting edge non-refrigerant based technologies for cooling, real-time monitoring systems for cold chains inter alia using internet of things (IOT) use of renewable and alternate energy technologies. ▪ The cooling action plan integrates sustainable development goals and environment benefits and provides way to connect and synergize with the development of agri-logistics.	These insights are highly appreciated. The ICAP recommendation has been added in Section 1.2.3 (Treatment of cold chain under ICAP) of the report.

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9	MoP	It is stated that since the report has been prepared in consultation with Bureau of Energy Efficiency, a statutory body under the aegis of Ministry of Power, they have no specific comments to offer and have no objection to the report.	BEE appreciates this endorsement.
10	EDO	The report has been prepared in collaboration with BEE and contains recommendations on how to improve energy efficiency in pack houses, especially in the backdrop of the expectation that this segment of food processing will expand greatly in the next decade. EDO supports the recommendations in the report.	BEE appreciates this feedback.
11	MoAgri	For ICAP implementation, cold chain thematic group has been formed. The findings and recommendations emerging from this study can be presented to the thematic group for an actionable set of activities for MoEF&CC, MoA&FW and BEE under the ICAP platform. Since the report has been prepared on the basis of pack houses visited by the team setup after 2014 which are as per "Guidelines & minimum System Standards for Implementation in Cold chain Components", this Division may incorporate the actionable set of activities for MoA&FW from cold chain thematic group in the operational guidelines of MIDH, as and when the same are made available to DAC&FW.	The comments are very helpful. The findings and recommendations emerging from the study will be shared with the thematic group.

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