File No.: 223/4/2024-Solar R and D
Government of India
Ministry of New and Renewable Energy (MNRE)

Atal Akshay Urja Bhawan,
Lodhi Road, New Delhi - 110003
Dated: 29th February, 2024

Subject: Inviting Comments from Public/Stakeholders on Draft Design Specifications for Solar Cold Storage (SCS) – regarding

The Draft Design Specifications for Solar Cold Storage (SCS) framed by the Ministry of New and Renewable Energy (MNRE), Government of India, are being put up on the website of the MNRE for comments/views.

The comments/views of the Public/Stakeholders are invited on the Specifications mentioned above on the email ID: <*akchoudhary.mnre@gov.in*>, within 15 days from the date of publication on the website.

Arun Kumar Choudhary
Digitally signed by Arun Kumar Choudhary
Date: 2024.02.29 13:08:31 +05'30'

(Arun K Choudhary)
Scientist-B
Email: akchoudhary.mnre@gov.in

Encl: as above

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Specification for Cold Storages

(Draft for Approval)

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Contents

1. Scope

This document contains basic design specifications and performance guidelines for Solar Cold Storage (SCS) with an appropriate capacity Thermal Energy Storage (TES) as a backup. The storage capacity of 2MT to 10MT is taken to be powered entirely by Solar PV as Distributed Renewable Energy Source (DRE). The SCS parameters are decided in such a manner that it can be installed on a site anywhere in India. The guidelines and specifications are primarily documented keeping in mind to provide storage and preservative facility for storage of suitable produce within the temperature of 4°C to 15° C. The proposed specifications are applicable to perishable and non-perishable commodities like Fruits, vegetables, etc. All individual components of the SCS system should be certified as per the relevant standards.

- SCS shell meet all Critical Storage Conditions (CSC) and cooling requirements specified in National Horticulture Board (NHB) standards.
- The Operational Life of the SCS system should be at least 10 years from the date of Commissioning.
- The document provides minimum specifications to be followed under the New Scheme for Farmers to be launched by the Government of India.

2. Terminologies

2.1. Solar Cold Storage:

A thermally insulated environmental chamber of suitable capacity with appropriate control electronics used for long-term storing agriculture produces.

2.2. Thermal Energy Storage (TES):

Contains energy storage material, absorbs cool from refrigeration systems, and release the cool as and when required. TES has sufficient cool to support the system for 96 Hours (4 days including autonomy) based on requirement.

2.3. Critical Storage Conditions:

Environmental conditions such as Loading rate, Temperature, Humidity, Air Flowrate, etc., are defined as critical for the long-term storage of the farmer produced commodities. Number of days of autonomous operation for a prescribed radiation is important factor.

2.4. Refrigeration System:

Attached to Cold room and absorbs electrical power from controller and generates required cooling, and supply it to cold chamber and charging TES

2.5. Loading Rate:

The percentage of total storage capacity of the commodity filled in a day by during the loading of the cold storage.

2.6. Temperature & Humidity Controller:

An electronics controller used to set and control temperature and humidity conditions inside cold chamber.

2.7. Maximum Power Point Tracker (MPPT):

MPPT is an algorithm that is included in the chamber power controller electronics used for extracting maximum available power from SPV array under a given radiation and temperature conditions. The voltage at which SPV array can produce maximum power is called 'maximum power point' voltage (or peak power voltage).

2.8. Cold Room:

Temperature controlled enclosure where the agriculture produce is stored.

2.9. SPV Module Array (SPVMA):

Consists of suitable number of same type/ identical, model and almost equal capacity PV Modules connected in series and parallel to generates the required DC electrical energy

2.10. Universal Solar Controller:

Converts the DC Power from SPVMA into Variable Frequency AC power

2.11. Axillary Battery bank:

This battery bank of suitable capacity supply power to Auxiliary Loads Evaporator Fans, RMS, Lights, other loads of the SCS. The battery bank is charged through same SPV array which supplies power to refrigeration unit. The capacity should be designed as per load requirements, this is also have autonomy up to three day is also operates all the time as per the TES operation.

Major References Documents

The following are main reference documents consulted during the preparation of this document:

1.	NBH Technical Standards for Cold Storages NHB-CS-Type 01-2010, NHB-CS-Type 02-2010, NHB-CS-Type 03-2010, NHB-CS-Type 04-2010 and NHB-CS-Type 05-2010.
2.	MNRE Circular No. F. No. 41/3/2018-SPV Division dated 22.02.2023 for PM-KUSUM programme guidelines for PV Modules, Universal Solar Pump Controller (USPC) Specifications for Stand-alone applications
3.	MNRE OM No. 32/5/2021-SPV Division, dated 27.09.2021 on SPV Controller requirements
4.	IS 661:2000, Thermal Insulation of Cold Storage- Code of Practice
5.	IS 9303:2001 Guide for Cold Storage of Grapes, Technical Specifications for Solar Cold Storage Systems of Kerala state Tender: SCS 2018A
6.	Technical Specifications of the Indian Solar Cold Storage manufacturers.
7.	ALL INDIA COLD STORAGE CAPACITY AND TECHNOLOGY - BASELINE STUDY: Report by Hansa Research Group Pvt. Ltd., June 2014
8.	MIDH Operational Guidelines Horticulture Division, Department of Agriculture and Co-operation, Ministry of Agriculture, Krishi Bhavan, New Delhi, April 2014

3. Major Assumptions

1.	1MT require 120 Cf_3 of volume
2.	1TR is equal to 12000BTU/Hour OR 3.517KJ/Sec=3.517KWe =4.713Hp
3.	Small Capacity Single Chamber SCS system only
4.	Product to be stored: Fruits (perishable) and Non-perishable Fruits and Vegetables listed in NHB standard: NHB-CS-Type 02-2010, March 2010 are referred.
5.	Loading Rate : Fruits (perishable) 20% 2MT Capacity, and Non-perishable Fruits and Vegetables 10% per day for higher capacities of 5MT and 10MT.
6.	The SCS is uses Thermal Energy Storage (TES) a main back up storage
7.	Average global solar irradiance on horizontal plane is 5.0kWh/m^2 for High radiation sites and it is 4.0kWh/ m2 low radiation sites per day in the country
8.	The SCS system are decentralized systems, the availability Grid is taken as an emergency backup. The system is mainly designed for Stand-alone operation.
9.	Ambient atmospheric conditions of operations at 40^{o}C
10.	Minimum number for days for which the cold room should be able to precool every day and maintain temperature should be greater than 300 days in a year.

4. Critical Storage Conditions

- Most types fresh fruits and vegetables and other horticulture products which require pre-cooling or rapid room cooling to “seven-eighth-cooling”. The 7/8 cooling time is the time needed for the product temperature to drop to “seven-eighths” of the difference between the initial product temperature at the time of loading and the temperature of the cooling air circulating in the cold rooms.
- NHB Guidelines divide Most of the commodities in to 7 groups. The temperature ranges required by different groups are:
  - Group 1 to 3 temperature range of 0°C to 2 °C (Group1: RH 90% to 95%, Group2: RH 95% 100% and Group3 RH 65% to 70%)
  - Group 4 temperature of 4.5 °C (RH 90% to 95%)
  - Group 5 temperature of 10 °C (RH 85% to 90%)
  - Group 6 temperature of 13 °C to 15 °C (RH 85% to 90%)
  - Group 7 temperature of 18°C to 21°C (RH 85% to 90%)
    (refer NHB-CS-Type 02-2010 standard of NHB)
- Pre-cooling Time- 4-6 hours for pre-cooling to 7/8th cooling time is recommended for majority of fresh fruits and vegetables. However, in case of fresh produce like carrots, apples etc. meant for long/medium term storage, which are directly cooled and stored in the cold rooms, the cooling period, can be up-to 20 hours per day and should meet the requirements specified in the commodity storage manuals.
- High rate cooling for perishable commodities (like Strawberries, Cherries, Flowers, etc.) 4 to 6 Hours from ambient 35 °C to 4°C as per NHB Guidelines. followed by pull down rate of 0.5°C per day till holding temperature of 0°C to 2°C ±1°.
- Non-Perishable commodities such as Onions and Garlic without pre-cooling requirement 20 hours cooling to 13°C to 15°C ±1°C and temperature maintained for long period of storage up to months

1.	**Humidity range:**	90 to 95% or 60%to 85% +/- 2.0% RH depending on stored commodity refer to NHB standards.
2.	**CO_2 Level:**	Only in case of selective fruits <4000 ppm during loading and >2000 ppm during holding.
3.	**Loading Rate:**	Generally, 10% should be the loading rate for most commodities, however, in case of specific fruit varieties and low capacity chambers (2MT) 20% loading rates are considered.
4.	**Pull-down time:**	4 to 6 Hours for perishable fruits for 2MT -10MT capacity and 12 hours for pull down to 4°C further pulled down to holding temperature of 2°C ±1°C at rate 0.5°C/day .
5.	**Air Circulation:**	**400** CMH/ MT during the loading and pull-down period, fan speed reduced to almost 70% and thereafter maintain temperature variation within chamber at less than ± 1°C throughout the storage period.
6.	**Lighting Condition:**	Dark

5. Constructional Features

5.1. General:

SCS System uses the solar PV Modules Array to convert irradiance into DC electrical energy to power the refrigeration unit. The PV array produces DC power, which is utilized to drive a refrigeration system generating cooling to cool the products stored inside a Cold Chamber.

5.2. A Cold Chamber:

Chamber Volume	Min. 240 Cf^3 to 1200 Cf^3 depending on capacity 2MT to 10MT
Cold room insulation walls, ceiling, and flooring	Poly Urethane Foam, 100 mm, 40+/- 2 kg/m3 or equivalent. Follow the standard National Horticulture Board Technical Standards for Cold Storages: NHB-CS-Type 01-2010, NHB-CS-Type 02-2010, NHB-CS-Type 03-2010, NHB-CS-Type 04-2010 and NHB-CS-Type 05-2010
Cold room body	Pre-painted galvanized iron/ SS
Room door	Insulation: PUF or equivalent; Thickness: Min. 100 mm
Door Opening	10 Times in a day as per Indian industry standards

5.2.1. Refrigeration System:

Refrigeration system consisting of a condensing and an evaporating unit working on the Vapor Compression Cycle principle. The condensing unit generates cooling energy which can be used for providing cooling to the cold storage and to charge the TES system. The capacity and power requirement of the refrigeration unit depends on the design and capacity of the SCS system. In the present SCS system, the TR capacity of refrigeration unit varied from 1TR, 2.5TR & 4 TR depending on the stored commodity capacity of 2MT, 5MT & 10MT respectively.

5.2.2. Specifications of Controller for SCS Systems:

A Maximum Power Point Tracker (MPPT) shall be included to optimally use the power available from the SPV array and maximize the power input to the refrigeration unit as well as battery charging. The controller must have protection or shall be housed in a cabinet having at least IP-65 protection. Adequate protections shall be provided in the controller to protect the Solar Cold Storage against the following:

- Open circuit
- Accidental output short circuit
- Under voltage
- Reverse polarity
- SPD to arrest high current surge
- Lightening arrestor
- Safety Certification: As per IS 16221 (Part-2) & IP 65 environment

- Maximum Power Point Tracker (MPPT) efficiency: > 95%
- Operational Voltage Range: 80V to 600V or 800V based on Array capacity
- Electrical Capacity of Compressor Controller: 6KW to 12KW
- A DC switch as per IS/IEC 60947-1 suitable for switching dc power ON and OFF shall be provided in the Compressor Controller.
- All cables used shall be as per IS 694 or IS 9968(Part 1).
- Suitable size of the cable shall be used in sufficient length for interconnection between the SPV array to Compressor Controller and the Compressor Controller to the refrigeration system. Selection of the cable shall be as per IS 14536.
- Controller shall be integrated with GSM/GPRS Gateway with Geotagging

1.	**Controller Power Capacity to drive the Chamber**	► Controller Power Capacity should match to Solar Panels Power Capacity, not Compressor Capacity.
2.	**Power Point Tracking (MMPT)**	► Should track power only and not Voltage at Maximum power point. The minimum MPPT efficiency should be 95%
3.	**Enclosure**	► The Controller must have IP54 protection or must be housed in a cabinet having at least IP65 protection.
4.	**Isolator Switch**	► Should be between Solar panels and controller
5.	**GSM/GPRS**	► Controller shall be integrated with GSM/GPRS gateway with Geo-tagging ► GSM/ GPRS Charges are to be included in the Costing till the end of the Warranty period of the Pump set

5.2.3. Electric Battery Bank for Auxiliary Components

The auxiliary power system consists of the following equipment – Displays, Controls, Fans, Sensors, RMU, Protection circuits, Alarms, etc. A set battery banks are available in the system. These are meant to provide electricity for auxiliary electrical loads such as fans of the evaporator unit, TES control panel, temperature controller unit, lighting, and data monitoring system. **The battery bank is designed for 2 additional days of Autonomy.**

5.3. Solar Photovoltaic (SPV) Array:

SPV arrays contain a specified number of the same capacity, type, model and specification modules connected in series or parallel to obtain the required voltage or current output. The SCS system should be operated with a PV array capacity in the range of 4KWp to 12KWp, measured under Standard Test Conditions (STC).

- A sufficient number of modules in series and parallel could be used to obtain the required voltage or current and power output.

- For the details on individual PV modules used in the PV array, all specifications and relevant qualification standards of MNRE issued under KUSUM Programme vide OM :41/03/2018-SPV Division, dated 22.02.2023, Annexure-A, Section 3.3 to be followed.

5.4. Module Mounting Structures and Tracking System:

- The PV modules should be mounted on metallic structures of adequate strength and appropriate design, which can withstand load of modules and high wind velocities up to 150 km per hour. The raw material used and process for manufacturing of module mounting structure including welding of joints should conform to applicable IS 822. The module mounting structure should be hot dip galvanized according to IS 4759. Alternatively, one can use MS Painted structures for non-costal/non-corrosive area.
- To enhance the performance of SPV array SCS systems *optional* arrangement for seasonal tilt angle adjustment three times in a year may be provided.
- The general hardware for structure fitment should be either SS 304 or 8.8 grade. Modules should be locked with antitheft bolts of SS 304 Grade. In case the PV Modules are mounted on the roof of SCS, fixed tilt structures with seasonal adjustment at least two or three times a year or preferred.
- In case modules are ground mounted, the foundation should be as per the site condition, based on the properties of Soil. Foundation can be done either with the help of 'J Bolt' (refer IS 5624 for foundation hardware) or direct pilling, it should be decided as per the site and relevant IS i.e. IS 6403 / 456 / 4091 / 875 should be referred for foundation design. Details of Module Mounting Structure for ground mounting for capacities of SCS systems are attached at Annexure-I.
- These are indicative of minimum standards and a manufacturer/ Implementing Agency may use better designs for higher standards

5.5. Earthing Arrangement:

- Earthing of the Chamber compartment, refrigeration unit, compressor, and condenser, shall be done as per IS 9283 in accordance with the relevant provisions of IS 3043. Separate earthing shall be provided for Controller, Refrigeration unit, and SPV array.
- For safety purpose, it shall be ensured during installation that the earthing is capable of taking care of leakage current.
- A lightening arrestor shall be provided with every Solar Cold Storage System.
- For the safety purpose, separate earthing may be provided for AC Side (compressor/AC supply), DC Side (structure/controllers/modules), Lightning Arrestor.
- The value of earth resistance should be less than 5 Ω.

6. PERFORMANCE REQUIREMENTS

Under the “Average Daily Solar Irradiance” condition of 4.0 kWh /m^2 (low irradiance) sites and 5.0 kWh /m^2 (Normal Irradiance) sites on the Global Horizontal plane. The PV Systems are designed considering the low radiation conditions i.e., 4.0 kWh/m^2. The PV array capacity is slightly overdesigned. The minimum cooling generated by different capacity models of SCS are specified below:

- 2MT SCS with storage volume of Min. 240 Cf^3 (6.8cuM) and 4KWp to 5.5 KWp PV array producing 60-77MJ of cooling energy is required to fast cool 20% 2MT of Perishable Fruits from 35°C to 5 °C in 4 to 6 hours or 20Hours direct cooling period. TES capacity for 2day autonomy will be 153MJ. Then Fruits will be stored in the SCS at the required storage temperature for a required period without damaging the product.
- 5MT SCS with storage volume of Min. 600 Cf^3 (17cuM) and 6KWp to 7KWp PV array 88- 113MJ of cooling energy required to cool 10% of 5MT of Commodities (Fruits, Vegetable, etc.) requiring pre-cooling from 35°C to 5 °C in 6 hours or 20Hours direct cooling period. Subsequently pulling down to required storage temperature at a rate of 0.5°C/day. TES capacity for 2day autonomy will be 237MJ. Further, the commodities will be stored for a required period from a few weeks to months depending on the application.
- 10MT SCS with storage volume of Min. 1200 Cf^3 (34cuM) and 10.5KWp to 12KWp PV array 165-206MJ of cooling energy requiring pre-cooling to cool 10% of 10MT of Fruits & Vegetables from 35°C to 5°C in 6 Hours or 20Hours direct cooling. Then the cold room temperature is pull down to required storage temperature at a rate of 0.5°C/day. TES capacity for 2day autonomy will be 481MJ. Further, the commodities will be stored for a required period from few weeks to months depending on the application

7. Guarantee of Performance

- The SCS shall be guaranteed for their performance of the nominal cooling rate Under the “Average Daily Solar Irradiance” condition of 4.0 kWh /m^2 (low irradiance) sites on the Global Horizontal plane by using the electrical energy generated by SPV array of PV Modules.
- The actual amount of cooling energy generated duration on a particular day could vary depending on the solar intensity, location, Array Tilt, season, etc.
- SCS Systems shall be guaranteed by the manufacturer against the defects in material and workmanship under normal use and service for a period of at least 10 years, from the date of commissioning. In case of PV modules, the warranty shall be for a period of 25 Years.
- Manufacturers should provide a list of spares for trouble free operation during the warranty period.

8. Marking and Parameters to be declared by the Manufacturer

The Solar Cold Storage used shall be securely marked with the following parameters declared by the manufacturer:

8.1. Refrigeration Unit

- Manufacturer's name, logo, or trademark
- Model, size, and SI No of pump set if used (To be engraved/laser marked on the motor frame)
- Compressor & Condenser Rating (TR/ HP/KW)
- Total storage Capacity (CM/Cf)
- Operating Temperature Range
- Type: Refrigeration Unit
- Photo Voltaic (PV) Array Rating in Watts peak (Wp)
- Country of origin

8.2. Controller

- Manufacturer's name, logo or trademark.
- Model Number.
- Serial Number.
- Voltage Range.
- Power Range in kW for Controller; and
- Current rating (A)
- Country of origin
- Maximum DC Current (A)
- DC Voltage Range (V) and

9. Operation and Maintenance Manual

An Operation and Maintenance Manual, in English and the local language, should be provided with the Solar Cold Storage system. The Manual should have information about:

- Solar energy, photovoltaic, modules
- DC/AC Compressors & condensation
- Refrigeration units
- Tracking system
- Mounting structures, electronics, and switches.

It should also have clear instructions about:

- Mounting of PV module, DO's and DONT's and on regular maintenance and Trouble Shooting of the system
- Helpline number and Name and address of the Service Centre and contact number of authorized representatives to be contacted in case of failure or complaint should also be provided.
- A warranty card for the modules and should also be provided to the beneficiary.

9.1. Comprehensive Operation and Maintenance.

The Contractor should provide 5 years comprehensive maintenance of the Solar Cold Storage system.

10. Procedure for Testing and Inspection of Solar Cold Storage Systems

Only NABL accredited laboratories should take up the testing of Solar Cold Storages.

11. Parameters, Symbols & Units

Following parameters and symbols are referred during testing of Solar Cold Storage system:

Parameter	Symbol	Unit
Array voltage (DC)	V_a	V
Array current (DC)	I_a	A
Solar PV Array peak power capacity	P_{max}	W_p or KW_p
Daily Solar Radiation	E_{GH}	kWh/m2/day
Volumetric Storage Capacity of SCS	Q_{SCS}	MT/m^3
Thermal Energy Storage (TES) Capacity	Q_{TES}	MJ
Heater Energy (E_{HE})	E_{HE}	kWh
Storage Temperature	T_s	ºC
Backup duration	q	hours
Radiation	E_e	W/m2
Ambient Temperature	T_a	ºC
Energy Requirement for Auxiliary Loads	E_{AE}	kWh
Initial Grid Energy	(IGE)	kWh
Auxiliary Battery capacity	C	Ah
Total/ Grid Energy meter	(E_{GE})	kWh

The critical constructional and delivery aspects of Solar Cold Storage with TES should include the following:

- The installed Solar PV Array peak power capacity (in kilowatt peak or kWp)
- The Thermal Energy Storage capacity (in Mega-Joules or MJ)
- The Auxiliary electrochemical Battery capacity (in Volt- Ampere hours or VAh)
- The Loading rate or precooling capacity (in metric-tons or MT or % of total capacity)
- The Volumetric Storage Capacity SCS (in metric tons or MT)
- The Backup duration or holdover capacity (in hours)
- Storage temperature range (in °C)
- Insulation type and thickness (in mm)

12. Test Setup/ Equipment

12.1. Cold storage Temperature Measurement

The cold storage temperature needs to be recorded during the test by using multiple temperature sensors with repeatability of ±0.1^{0}C and accuracy of ±0.5°C. The sensors should be placed at the suction of evaporator fans to measure the return air temperature inside cold storage, and at least three different places to check the homogeneity over its volume. No sensor should be in contact of any surface which can cause error in room temperature measurement.

12.2. Electric Air Heater with Energy Meter

An electric air heater shall be placed inside the cold room which will be treated as heat load to measure the TES system capacity. A 1 kW capacity electric heater shall be used whose operating switch should be located outside the cold room, such that the heater can be switched ON/OFF from outside without disturbing the inside temperature of cold room (the 1kW heating rate of electric heater is meant for 5MT cold storage capacity), and will be appropriately scaled for larger capacities (10MT & 20MT). To measure energy consumption of the electric heater, an energy meter, with accuracy class of 0.5% as per IEC/AS Standard 62053-11, shall be used separately and the heater should be connected to electric supply through energy meter. This energy meter is termed as Heater Energy (E_{HE}) meter and energy consumption should be measured in kWh. This heater energy consumption will be used to analyze the TES system storage capacity as explained in Test-1 and Test-2 of this procedure.

Recommended rating of electric Heater capacity for different capacity of cold storage system are:

S. No	Cold Storage Capacity (MT)	Recommended Heater Rating (kW) for testing purpose
1	2MT	0.4KW
2	5MT	1.0KW
3	10MT	2.0KW

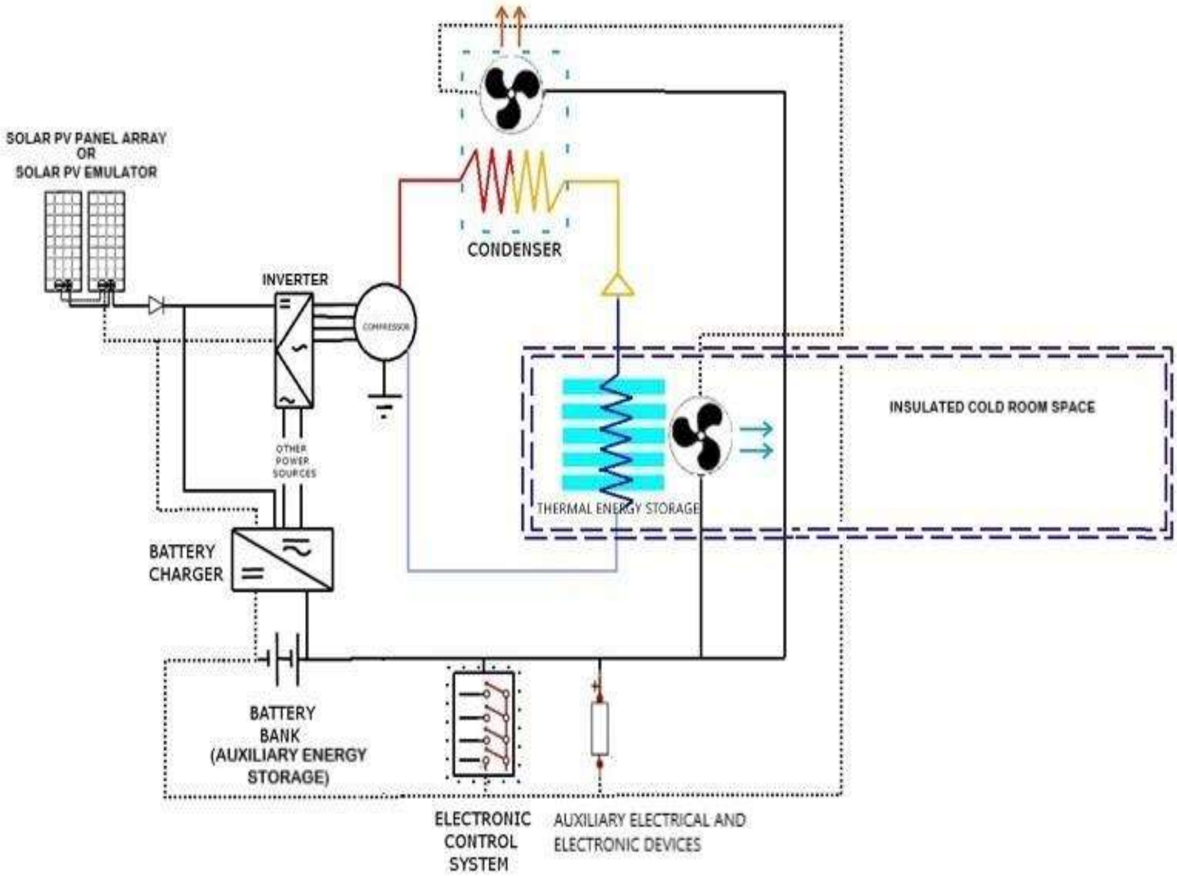
12.3. Total Energy Meter on system

TES charging performance shall be monitored by providing electrical energy through grid connection for data repeatability. An energy meter, with accuracy class of 0.5% will be installed as prescribed in IEC/AS Standard 62053-11, to monitor the total energy consumption by the complete system. It will correlate to the energy consumed by system during charging of TES system as explained in Test-1. Therefore, this energy meter is termed as Grid Energy (E_{GE}) meter and the energy consumption shall be measured in kWh.

12.4. Energy Meter for Auxiliary load

Auxiliary load in a solar cold storage system includes electro-mechanical components other than compressor and condensing fan, which are necessary to operate the system as per design. The auxiliary load will be powered through a Charge controller/ Solar Inverter / or their combination (to be done as per system wiring diagram provided by the manufacturer). Energy requirement for auxiliary load shall be measured as explained in Test-2. An energy meter (E_{AE}) is used separately to measure energy consumption by auxiliary load (E_{AE}). To measure the energy consumption of auxiliary load, another energy meter is connected on the output of chemical batteries during the discharge tests.

FIGURE 1: BLOCK DIAGRAM FOR SOLAR COLD STORAGE SYSTEM ROOM WITH THERMAL ENERGY STORAGE



13. Test Precautions:

Before conducting the test of Solar Cold Storage system with Thermal Energy Storage (TES), following precautions must be followed:

- The cold storage door should always be kept close during the test except when required by the test procedure.
- All sensor devices should be calibrated to avoid error in recording of test/ measured parameters/ data with an accuracy of ±0.1^{0}C.
- Connections to sensor devices to monitor and recording test data should be proper.
- An ambient temperature sensor should be placed near the cold storage away from any surface
- All electrical connections shall be proper to avoid any sparking due to lose connection or wire breakage.
- Earthing of system points wherever specified should be adhered for system protection and human safety.

- Before initiating testing, check cold storage system is working in all modes as per design such as automatic operation of evaporator fans to circulate air inside cold storage, TES discharging to provide cooling to cold storage working as per cold storage set temperature automatically. Refer to System manual supplied by the customer.
- Electrical continuity shall be verified to ensure connections are made as per electrical diagram to be supplied by the customer.
- TES capacity indication shall be monitored during the test. TES capacity indication will be provided by the manufacturer as per manufacturer's design. This is a numerical value in percentage.
- All temperatures are monitored once in 5 seconds.

14. Test Procedure for Performance Evaluation

14.1. Test 1: Minimum Temperature Achievable Test, system cooling rates and Thermal Energy Storage (TES) system cooling delivery capacity Test

With the goal being to determine actual performance parameters of the TES the ultimate goal is the start and end at the same point (i.e. one complete cycle) and then cycle the system more than once. In battery systems it is common to start at 100% charged, then discharge to a known amount (i.e. based on system capabilities) and then charge back up to 100% this would be one cycle. An average of 3 cycles should be done to achieve a more accurate measure of nominal performance.
First, test is to ascertain minimum temperature achievable in cold room when cooling through thermal storage system and the cooling delivery capacity of Thermal Energy Storage (TES). Below is the stepwise procedure for carrying out the test:

14.1.1. A. Identify 0% level of TES system

- The system should indicate the 0% level inside of determining via external factors only.
- The system should be identifying its 0% (i.e. fully discharged) and 100% (i.e. fully charged) levels.
- Charge should occur before discharge
- Switch OFF grid/solar supply to refrigeration condensing unit.
- Switch ON grid supply to air heater placed inside the cold storage.
- Switch ON grid supply to auxiliary power system equipment.
- Change cold storage set point temperature to 10°C and switch ON cooling.
- This automatically starts the discharging of TES. Continue the discharging to an extent that cold storage temperature is already above 15°C or reaches above 15°C after some time and TES is not able to pull down the temperature to below 15°C.
- Switch ON grid supply to refrigeration condensing unit.
- This starts the charging process of TES while discharging is still kept ON, and system trying to achieve set point temperature of 10°C inside the cold storage.
- After cold storage temperature attains set point value of 10°C, TES is assumed to be 0% charged at this energy level.
- Switch OFF grid supply to air heater placed inside the cold storage.
- Switch OFF the cooling equipment of cold storage from set point controller.

Note: Record the Grid energy meter reading as Initial Grid Energy (IGE).

14.1.2. B. Charging Thermal Energy Storage (TES) system to 100%

- The test should start with the system being charged first.
- Monitor and note down the reading of Grid Energy meter (EGE), ambient temperature (Ta), TES capacity indication and cold storage temperature (TC) at the start and at fixed repeated intervals (say 10Sec) all through the test. Note Ta at the same fixed repeated intervals, this is to estimate the average Ta during the test.
- Charge the TES to 100% through continuously supplying power to Refrigeration Condensing system. When TES is completely charged (100% capacity, as displayed by capacity meter), the operation of condensing unit should automatically turn OFF.
- □Note down the grid energy meter reading - Final Grid Energy (FGE).
- □Note the Ta during test. Estimate the average ambient temperature ($T_{avarage}$) during the test, from Ta.
- □The difference between FGE and IGE will be total electrical energy consumption (EGE) by TES for100% charging of TES system.
- Switch OFF grid supply to refrigeration condensing unit.

14.1.3. C. Discharging of Thermal Energy Storage (TES) system to characterize system cooling rates and minimum achievable temperature inside the cold storage

- It is advised to break the cooling rate and minimum achievable temperature into two separate evaluation steps
- This procedure starts after procedure B, When TES is 100% Charged. Minimum time difference required to start the discharging test (Step C) from the completion of charging test (Step B) is 1 hours.
- Switch OFF grid/solar supply to refrigeration condensing unit.
- The heater should be placed inside the unit beforehand and be switched on or off electronically based on the test step. A heater rating as per Table 1 is placed inside the cold room. Turn ON the heater and note down the heater energy meter reading and it will be termed as Initial Heater Energy (IHE) in kWh. Initial temperature of the cold storage shall be recorded
- Change cold storage set point temperature to 0° C.
- Monitor the cold storage room temperatures to test the lowest achievable temperature. If the rate of decrease in room temperature is less than 0.1° C in 10 minutes, it is assumed that the cold room has achieved the minimum achievable temperature.
- Note the cold storage room temperature reading as minimum temperature achievable - T_{min}
- Change the set temperature to 7° C once the minimum temperature is achieved.
- Continue the cooling until cold storage room temperature achieves a value higher than 10°C. This indicates TES is fully discharged and at this state TES can be assumed to have reached the condition at 0% TES charge level.

- Switch OFF the electric air heater and note down heater energy meter reading. It will be termed as Final Heater Energy (FHE) in kWh.
- The difference between FHE and IHE will be total electrical energy consumption (EHE) by the air heater.
- Cooling delivery capacity of TES will be the sum of total energy consumed by air heater and external heat influx energy. For the measurement of Heat influx use the formula of adding kAdT over time for the duration of this step. For that ambient sensor should be placed

14.1.4. D. Placement of water balls inside the cold storage for further testing

TES should be 100% charged by repeating Step "B". Now, place 500kg of water balls in the following configuration. The amount of water balls should be sized proportionately based on system size

- Crate size: 400 mm X 325 mm X 250 mm
- □Each crate's maximum water ball handling capacity – approx. 25 kg water ball
- □Crates should be placed, uniformly distributed inside the cold storage all its Floor area
- □Continuously monitor temperature of 5 samples (water balls) kept on the top crate (sample size should be of 1-inch diameter with +/- 5% error)
- Initial core temperature of water balls has to be in the temperature range of 25°C. It should be at a maximum +/-0.5°C. i.e. 25°C with tolerance of +/- 0.5°C

14.2. Test 2: Thermal Energy Storage (TES) System Cooling Delivery Capacity, Performance and Reliability Test

This test is to ascertain the cooling delivery capacity of Thermal Energy Storage (TES), when cooling through thermal storage system and efficiency of thermal storage system. Below is the stepwise procedure for carrying out the test:

14.2.1. Identify 0% level of Thermal Energy Storage (TES) system as per procedure A of 15.1 test 1.

14.2.2. Charging Thermal Energy Storage (TES) system to 100% as per procedure B of 15.1 test 1

14.2.3. Placement of Load inside the cold storage

- Once TES Level is 100% charged, place standard 250 ml packaged drinking water bottles of mass equivalent to 10 % of cold storage capacity (500 kg for 5 MT system) inside the cold room.
- Water Bottles should be placed in standard crates (Make: Supreme, Model: PC-304) and distributed uniformly inside the cold storage across all its floor area. To maintain the consistency of testing, the crates need to be placed side by side with no spacing left between them and balance crates need to be stacked on the top of bottom crates in the similar manner. As walking space is required, 1.5 to 2 feet spacing need to be provided on all the four sides of the floor area for easier movement. Initial core temperature of water bottles including the cold storage has to be in the temperature range of 30°C ±2°C.
- Continuous monitor temperature of 8 samples (4 near corners and 3 in center) of water bottles.

14.2.4. D. Discharging of TES system to test cooling delivery capacity, Performance and Reliability of TES System

- The minimum time difference required to start the discharging test (Step D) from the completion of charging test (Step B) is 1 hour. This is required to place the load (water bottles) inside the cold room
- Switch OFF grid/solar supply to refrigeration condensing unit and to auxiliary power system.
- Change cold storage set point temperature to 7°C. The allowable minimum air temperature in the room is 6°C to reduce the possibility of chilling injury. The chilling injury is based on the produce being stored. Since that is not taken into account then an allowable minimum should be 0 to 2° C. Temperature Stability should be within ±1°C.
- During discharging process, monitor temperature of 8 samples (4 near corners and 3 in center) in fixed repeated intervals.
- Determine the cooling rate as following:
    - Once the average temperature of water bottles has achieved 20°C, note down the time as start of cooling rate test – Ti
    - Monitor the temperature of water bottles sample till temperature has achieved as 7/8th precooling, which means, if starting temperature was 30 C, set temperature was 7 C - the

temperature that should reach should be 30 - (30-7)/7*8 =9.875 C 7° C. Note the time as finish of cooling rate test - Tf

  - The difference between Tf and Ti will be total time taken for water temperature to attain 7° C from starting temperature of 20°C.
  - Calculate external heat influx energy as an integration of conducted heat kA (delta T) where delta T is the difference between the room temperature and the cold room's outer body temperature.
  - Tc (=Tf - Ti) and external heat influx energy characterizes the cooling rate performance of the system.

- Continue the test for 24 hours or until cold storage temperature achieves a value higher than 10° C
- If cold storage temperature is less than 10° C even after 24 hours of test, switch ON heater and note down the heater energy meter reading and it will be termed as Initial Heater Energy (IHE) in kWh.
- Continue the test until cold storage temperature achieves a value higher than 10° C. Supply power to auxiliary system if required. This indicates TES is fully discharged and at this state TES can be assumed to have reached the condition at 0% TES charge level.
- Switch OFF the electric air heater and note down heater energy meter reading. It will be termed as Final Heater Energy (FHE) in kWh.
- The difference between FHE and IHE will be total electrical energy consumption (EHE) by the air heater.
- Cooling delivery capacity of TES will be assumed to be the sum total of energy used to cool water bottles, the energy consumed by air heater and external heat influx energy.
- Plot graph between TES capacity indication, ambient temperature and cold storage temperature along with time.
- Efficiency of TES can be estimated here (there has to be a scaling parameter for correct ambient temperature and reported at 40°C): efficiency is defined as cooling stored / electricity consumed while charging. Heat Losses of cold room are already accounted in the TES capacity.
- The following parameters need to be collected and should be reported in the test report:
  - Charging Test
    - • Total Charging Duration of TES
    - • Total Energy Consumption during Charging Test
  - Discharging Test
    - • Minimum Temperature of Air achieved inside the cold room
    - • Cooling Rates
    - • Energy Consumption by Auxiliary Load during Discharging Test (Load on Electrical Batteries)
    - • Number of hours of power backup of auxiliary load via fully charged Electrical battery
    - • Total Heat Load met Through TES
    - • Estimated Backup Duration from Thermal Energy Storage and

- • Estimated Precooling Capacity in 6 hour

Note:

1. *In regard to the measurement of Storage Capacity of thermal storage system the temperature of the outer surface is monitored, a lookup table will be made to account for the heat influx. The heat influx energy can be calculated as an integration of conducted heat kA (delta T) where delta T is the difference between the room temperature and the cold room's outer body temperature. The conductivity of the room shall be fixed at 0.027 W/m2K irrespective of the insulation used. Conductivity of insulation is typically not a fixed number and can be temperature dependent. The surface area of the room would be the sum total of all surfaces of the cold room exposed to the ambient environment. This is being proposed to bring repeatability and an improvement on accuracy of the test. To account for the floor surface area, it is recommended to measure the ground temperature throughout the test.*
2. *Correction factor in COP with respect to ambient temperature shall applied based on compressor data sheet as provided by the original equipment manufacturer*

14.3. Test 3: Solar Performance Testing of cold storage - Simulator Method

This test is carried at the end of test procedure 1. Switch OFF the cooling for the entire duration of this test. This test is to ascertain the performance of solar system including SPV system and solar controller. This test is carried out by using a SPV simulator.

Simulation methods are the easiest and fastest way of estimating SPV performance. However, in these methods actual PV array is not used, instead a PV array simulator is used. Here, a Programmable SPV array simulator capable of generating power output equal to actual SPV array under the given radiation and temperature conditions for given SPV array configuration (i.e. the number of modules, the type and the series / parallel combination) will be used.

For the purpose of testing, one conditions of hot summer day conditions (hot profile) shall be used. Starting the system at the 100% charged state then going to 0% discharge and back to 100% charged should be 1 cycle. 3 cycles should be performed and an average taken. Before starting the test, it is required to discharge the TES to 0 % Level as per the test 8.1 (A). Also, the electric batteries are discharged. After the 0 % level is achieved for TES and batteries, charging of TES shall be started using the simulator for hot day profile. After the profile is completed, the discharging of TES should be done after 2 hours as per procedure D of Test 2 to verify the Pre-cooling of 10% of system capacity within 6hours and backup of 4 Days without any additional power being fed into the system with respiration load equivalent to system commodity MT capacity.

Although any radiation & temperature can be created, for the purpose of testing, one conditions of hot summer day conditions (hot profile) shall be used. A typical hot day profiles is shown Figure 1. The profile of full day solar irradiance and temperature shall be loaded in PV array simulator, sequentially one after the other. The simulator output is connected to the system through the controller and the profiles are run on 1X speed. The following performance parameters are collected for the entire duration of run time (per profile) – Irradiation (kWh/m2), Electricity generated by panels (kWh).

- Available Power from Solar Array, P_{Solar}
- Input Power from Solar Array (measured in wire), P_{Wire}
- DC Input Power to VFD, In-P_{vfd}
- DC Input power to PV charge controller for auxiliary system, In-P_{cc}

- Output power from VFD, Out-P_{vfd}
- Output power from PV charge controller, Out-Pcc
- Power to Auxiliary Load, P_{aux}
- Energy from PV array
- Energy Consumed by refrigeration system
- Energy consumed by auxiliary load
- Threshold wattage for starting and shutdown for refrigeration system
- Threshold wattage for starting and shutdown for Charge controller.
- TES charge % reached
- Cooling Energy delivered from TES

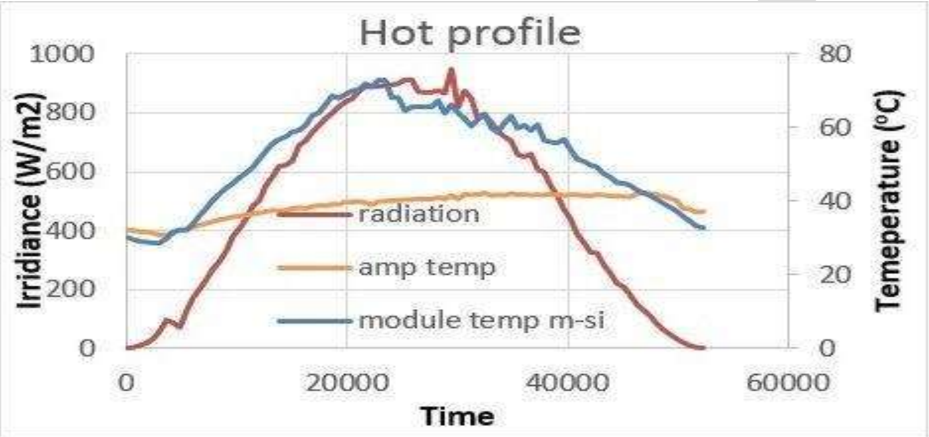


Figure 2 – Typical Solar Radiation Hot Profile

14.4. Test 4 Power Source Switching Operation Testing - Grid to Solar and Solar to Grid (Automatic)

The system would be tested for switching from solar operation to grid operation and via versa automatically when solar power becomes unavailable and cooling is not sufficient and should switch back to solar in presence of solar power. This can be done by connecting both the power sources (solar simulator and a three phase grid supply).

1. First switch on solar power. Let the system run.
2. Switch on grid supply.
3. Turn off solar supply. The refrigeration system should start running on grid power.
4. Switch on solar power. The system should switch back on solar power.

15. Measurements and Apparatus

15.1. Measurement of Temperature:

Cold storage temperature needs to be monitor at the suction of air circulation fans mounted on evaporator inside the cold storage. Ambient temperature of core of water ball at least 5 samples at different locations.

15.2. Measurement of Electrical Loads:

Electrical energy (load) should be measured by using an electric meter at following loads:

- A 0.4/1.0/2.0 kW capacity Electric Heater (non-radiator based as per SCS capacity) used in testing
- Refrigeration Unit load includes (Compressor, Condenser fan and evaporator fans)
- Auxiliary loads of system Lights, fans, RMS, etc.

15.3. Observations:

Following parameters should be monitored and all readings are taken throughout the test duration and should be present in the test record sheet.

- Temperature (OC) Reading of cold storage
- Temperature (OC) Reading of ambient
- Time taken to cool water ball – tc
- Minimum cold storage temperature achieved - Tmin
- Power Output (Generation) and Irradiation readings from solar simulator
- Electric Air Heater energy (EHE)
- Grid Energy consumption for condensing unit (EGE)
- Auxiliary load energy (EAE)

15.4. Calibration of Equipment:

All measuring instruments i.e. temperature sensors, electric meters etc. are to be calibrated periodically as per requirement.

16. Computation of system performance parameters:

There are 6 parameters to be computed from the measured test data. They are:

1. Storage Capacity of thermal storage system in KJ or kWh
    a. Storage Capacity of TES will be the sum total of cooling load of water balls and the electrical energy consumed by air heater (EHE).
    b. Change in temperature of water ball, dT = Initial core temperature of water ball – 7 ^{O}C
    c. Storage Capacity in kWh = (mass of water balls ∗ Specific heat of water ball ∗ dT) + EHE
2. Minimum temperature attainable inside cold room = Tmin
3. Efficiency of the thermal storage system
    a. Efficiency of TSS = (Storage Capacity of TES) / EGE
    b. The charging efficiency can be scaled for standard ambient temperature of 30 OC. This can be done by finding out the % change in cooling efficiency (COP) of the compressor with the ambient/condensing temperature, as per the manufacturer datasheet.
4. Power requirement of auxiliary load = PAE

    Number of hours of power backup for auxiliary load via fully charged chemical battery= (Capacity of chemical battery (Volt Ah))/ (PAE ∗ 3600)
5. Efficiency of Solar Charge controller

    (Energy Supplied by Controller to Refrigeration unit) / Energy (V X I) Fed by the PV Array Simulator)
6. Cooling rate in OC per minute

Annexure-1

Table 1: Provides Critical Parameter Range Specified by NHB for different types of commodities application

Reference: National Horticulture Board Technical Standards for Cold Storages: NHB-CS-Type 01-2010

Table-1: Draft Performance Specifications of Solar Cold Storage

S. No.	Nominal / Indicative Storage Capacity	Internal Storage Volume (Cubic Feet/CuM)	% of Loadin Capacity/ Day	Total cool Energy Required (kWh/day) or(MJ/Day)	Commodit Temperatu e pulldown (°C)	System Temperatur e Rang (°C)	Compress r Capacit (TR)	Range of PV Array Wattage (kWp)	Minimum TES capacity for 2 days of autonomy on solar (in MJ)	Commodity to be stored
1	2MT	240/7	20%	9/76	35 to 5 C	4 to 15 C as set by user	1.75	4 to 5	153	Fruits/ Vegies
2	5MT	600/17	10%	16/113	35 to 5 C	4 to 15 C as set by user	2.5	6 to 7	237	Fruits/ Vegies .
3.	10MT	1200/34	10%	25/180	35 to 5 C	4 to 15 C as set by user	3.75	10.5 to 12	481	Fruits/ Vegies

Table-2: Sizing of the Solar PV Array with Specifications

S. No.	Nominal Storage Capacity	PV Array Wattage (kWp)	Controller Specifications
1	2MT	5	6KW, Power Tracking MPPT
2	5 MT	7	7KW, Power Tracking MPPT
3	10MT	12	12KW, Power tracking MPPT

Table-3: Sizing of the Axillary Battery Bank for 2day Autonomy:

S. No.	Nominal Storage Capacity	Capacity of batteries	Approximate battery bank Capacity in Ah	Aux battery charge Controller Specifications
1	2MT	6 kWh	48V/ 80AH	1 KW controller,
2	5MT	9.4 kWh	120V/100Ah	2 KW controller,
3	10MT	9.6 kWh	120V/100Ah	3 KW Controller ,

Note: For battery charging use the same solar string used for compressor with appropriate DC-DC Converter to reduce the voltage to charge the battery bank.

All the above specifications are indicative, customers can verify and can use better design specifications.

Annexure-2

Group 1: Fruits and vegetables, 0 to 2°C (32 to 36°F), 90-95% relative humidity. Many products in this group produce ethylene.

apples	grapes (without Sulphur dioxide)	parsnips
apricots	horseradish	peaches
Asian pears	kohlrabi	pears
Barbados cherry	leeks	persimmons
beets, topped	longan	plums
berries (except cranberries)	loquat	pomegranates
cashew apple	lychee	prunes
cherries	mushrooms	quinces
coconuts	nectarines	radishes
figs (not with apples)	oranges*	rutabagas turnips

*Citrus treated with biphenyl may give odors to other products

Group 2: Fruits and vegetables, 0 to 2°C (32 to 36°F), 95-100% relative humidity. Many products in this group are sensitive to ethylene.

Amaranth*	cherries	parsley*
anise	daikon*	parsnips*
artichokes*	endive*	peas*
asparagus	escarole*	pomegranate
bean sprouts	grapes (without sulfur dioxide)	raddichio
beets*	horseradish	radishes*
Belgian endive	Jerusalem artichoke	rhubarb
berries (except cranberries)	kiwifruit	rutabagas*
bok choy	kohlrabi*	salsify
broccoli*	leafy greens	scorzonera
brussels sprouts*	leeks' (not with figs or grapes)	snow peas
cabbage*	lettuce	spinach*
carrots*	lo bok	Sweet corn*
cauliflower	mushrooms	turnips*
celeriac*	onions, green*	water chestnut
celery*		watercress*

*these products can be top-iced

Group 3: Fruits and vegetables, 0 to 2°C (32 to 36°F), 65-75% relative humidity. Moisture will damage these products:

Garlic	Onions

Group 4: Fruits and vegetables, 4.5°C (40°F), 90-95% relative humidity.

cactus leaves	lemons*	tamarillo
cactus pears	lychees	tangelos*
caimito	kumquat	tangerines*
cantaloupes**	mandarin*	ugli fruit*
clementine	oranges (Calif. and Arizona)	yucca root
cranberries	pepino	

* citrus treated with biphenyl may give odors to other products.
** can be top-iced.

Following are the Assumptions and Conversion formulas:

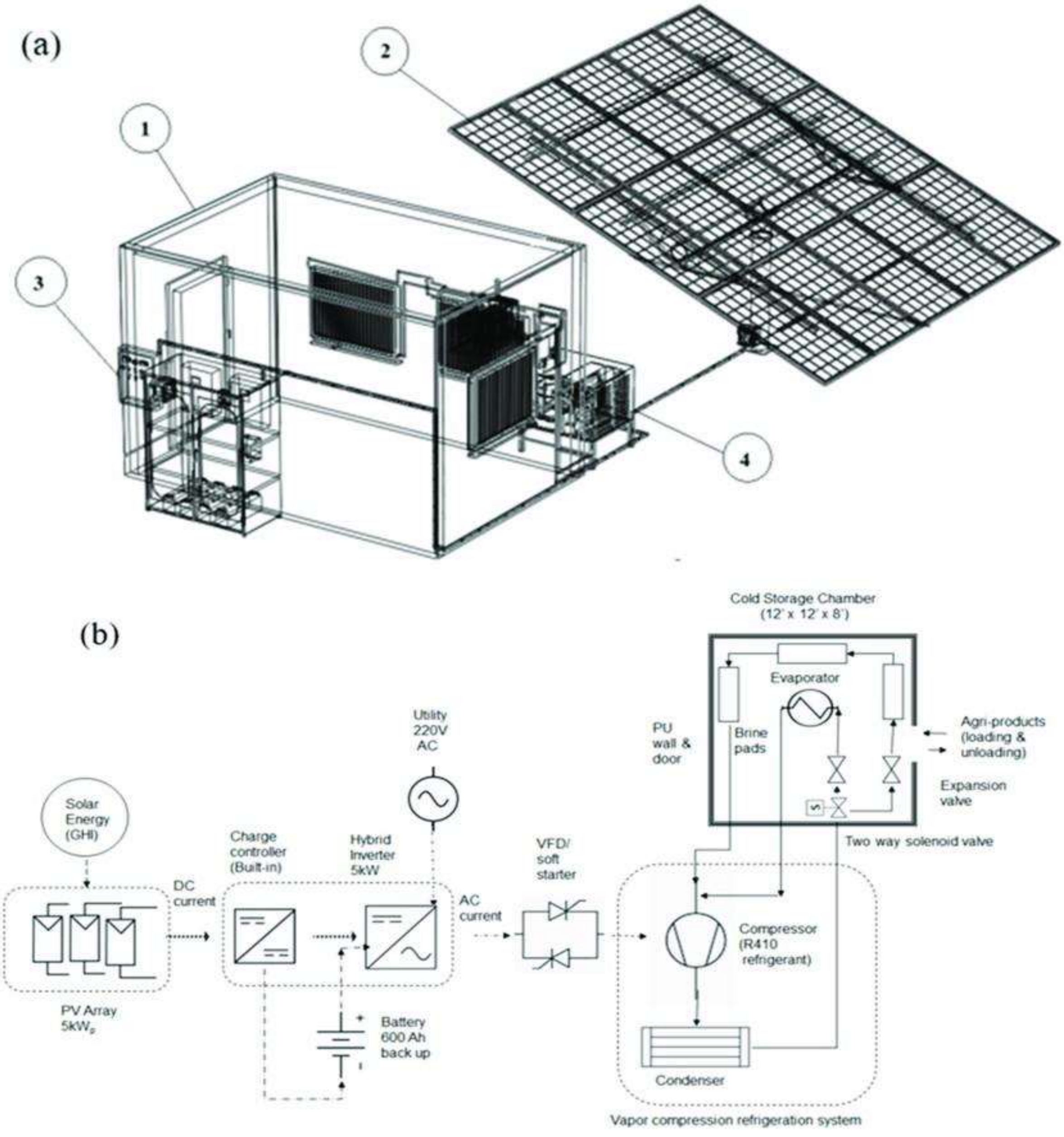
- 1MT require 120ft^3 or 3.4Cum Volume (Ref: MIDH Guidelines April 2014, page: 21)
- 1TR= 4.716Hp = 3.5KWe require 4.68kWp PV array (Approximately 1.3 times load 3.6KWe);
- 1MJ=0.27777kWh;
  1MJ= 239.01Kcal;
  1kCal=0.0011622kWh; OR 1kWh= 860.43kCal;

1TR=1200BTU/ Hour OR 3024kCal/Hour OR 12.65MJ/Hour

- Respiration Rate: 0.04W/Kg
- Thermal Heat Losses (k= 0.24 W/m^2 K) PUF at 100mm Thickness (page:50 of NHB-CS-tye01-2010)
- Specific Heat of Fruits/ Vegetables = 0.83kcal/ Kg/°C (Above Freezing)
- The cycle operation of the Compressor system is about 7Hours/ day

Annexure-3

Diagram of a Solar Cold Storage with Utility Grid and Auxiliary Battery:
(a). Sketch
(b). Block diagram



Annexure-4

Complementing a Solar Water Pump

A solar cold storage system could also be used as a complimentary system with a solar water pumping system especially for a rural agricultural application.

- Solar water pumping system would provide water for irrigation, which is essential for crop production. In rural areas, where there is often no access to electricity, a solar water pumping system can be a reliable and cost-effective way to irrigate crops.
- Solar cold storage system would provide cold storage for crops, which can help to extend their shelf life and prevent spoilage. In rural areas, where there is often no access to refrigeration, a solar cold storage system can be a valuable way to preserve food.

The two systems would complement each other by providing the water and cold storage needed to grow and store crops. This would help to improve crop yields and food security in rural areas. Most of the times, during sowing, the primary need is for the solar water pumps for irrigation of the lands. At this time, there is little energy needed for the cold storage system as the system has already maintained the storage temperature. During harvesting, there is little to no need of solar pumping system. This is the time when most energy is needed for the solar cold storage system to cool the harvest at storage temperature.

In a remote village, a solar water pump and solar cold storage system can provide clean drinking water and food storage for the villagers. This can improve the health and well-being of the villagers, and it can also help to reduce poverty. In addition to the above, here are some other benefits of using solar water pumping and solar cold storage systems in rural agricultural applications:

- **Cost savings:** Since the same solar modules are used for both systems, there is no need to purchase separate solar panels. This can save a significant amount of money, especially in areas with high electricity costs.
- **Efficiency:** By using the same solar modules for both systems, the overall efficiency of the system can be improved. This is because the solar modules can be sized to meet the combined demand of the water pump and cold storage system.
- **Reduced complexity:** By using a single system, the overall complexity of the installation is reduced. This makes it easier to install, maintain, and troubleshoot the system.
- **Environmental benefits:** Solar energy is a clean and renewable source of energy. By using solar modules for both systems, the environmental impact of the system is reduced.
- **Reduced dependence on grid electricity:** Solar energy is a clean and renewable source of energy, so using solar water pumping and solar cold storage systems can reduce dependence on grid electricity
- **Improved water efficiency:** Solar water pumping systems can be more efficient than traditional water pumping systems, which can help to conserve water resources.
- **Increased crop yields:** By providing reliable access to water and cold storage, solar water pumping and solar cold storage systems can help to increase crop yields. This can lead to improved food security and economic development in rural areas.

Annexure-5

NOTE: Innovation

The specifications in this document are a broad guideline for the Solar Cold Storage System. Any improvements and innovations that can be made to the product without compromising its safety or functionality could be considered by the designated authority.

The designated authority will review any proposed improvements or innovations and decide on whether to approve them. The designated authority may require that the improvement or innovation be tested and evaluated before it is approved.
The decision may be based on the following factors:

- The safety and functionality of the product
- The cost of implementing the improvement or innovation
- The benefits of the improvement or innovation
- If the designated authority approves the improvement or innovation, the product will be updated to reflect the changes.

The product standardization shall allow for improvements and innovations, while still ensuring that the product is safe and functional. It also provides a clear process for how proposed improvements and innovations will be reviewed and approved.

One such innovation that is being implemented is to custom build the cold room underground with access from the roof. This reduces the heat loss from the walls as well as during door opening, therefore reducing the compressor capacity as well as the PV module size.

Annexure-6

LIST OF REFERRED INDIAN STANDARDS

List of BIS standards applicable for components of Solar PV Applications

Standard Number	Title of Indian Standard
3043:1987	Code of Practice for Earthing
NHB-CS-Type 01-2010	National Horticulture Board Cold Storage Technical Standard 01:2010
NHB-CS-Type 02-2010	National Horticulture Board Cold Storage Technical Standard 02:2010
NHB-CS-Type 03-2010	National Horticulture Board Cold Storage Technical Standard 03:2010
NHB-CS-Type 04-2011	National Horticulture Board Cold Storage Technical Standard 04:2011
NHB-CS-Type 05-2011	National Horticulture Board Cold Storage Technical Standard 05:2011
IS6221 (Part 1)	Safety of Power Converters for use in Photovoltaic Power Systems Part1 – General Requirements
IS6221 (Part 2)	Safety of Power Converters for use in Photovoltaic Power Systems Part2 – Particular Requirements for Inverters
IS 14286	Crystalline Silicon Terrestrial Photovoltaic (PV) modules – Design Qualification and Type Approval
IS/ IEC 61730 (Part 1)	Photovoltaic (PV) Module Safety Qualification Part 1 Requirements for Construction
IS/ IEC 61730 (Part 1)	Photovoltaic (PV) Module Safety Qualification Part 2 Requirements for Testing
IS 16270	Secondary Cellsand Batteries for Solar Photovoltaic Application General- Requirements and Methods of Test.
4091:1979	Code of practice for design and construction of foundations for transmission line towers and poles (First Revision)
4759:1996	Hot - Dip zinc coatings on structural steel and other allied products - Specification (Third Revision)
5120:1977	Technical requirements for roto-dynamic special purpose pumps (First revision)
5624:1993	Foundation bolts - Specification (First Revision)
6745:1972	Methods for determination of mass of zinc coating on zinc coated iron and steel articles
8034:2018	Submersible pump sets - Specification (third revision)
9968 (Part 1):1988	Specification for elastomer insulated cables: Part 1 for working voltages up to and including 1100 volts (First Revision)
IS/IEC 61701 : 2011	Salt mist corrosion testing of photovoltaic (PV) modules First Revision
IS 17210 (Part 1) : 2019 IEC TS 62804-1 : 2015	Photovoltaic (PV) Modules — Test Methods for the Detection of Potential-Induced Degradation Part 1 Crystalline Silicon
IS/IEC 61683:1999	Photovoltaic System-Power Conditioners — Procedure for Measuring Efficiency
IS 14286: 2016 /IEC 61215:2019	Crystalline Silicon Terrestrial Photovoltaic (Photo Voltaic (PV)) modules - Design Qualification And Type Approval (First Revision)
IS/IEC 61730-1 : 2011	Photovoltaic (Photo Voltaic (PV)) Module Safety Qualification Part 1 Requirements for Construction
IS/IEC 61730-2 : 2011	Photovoltaic (Photo Voltaic (PV)) Module Safety Qualification Part 2 Requirements for Testing
IEC 60068-2-6:2007	Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)
IEC 60068-2-30:2005	Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 + 12h cycle)

IS/IEC 60947 : PART 1 : 2007	Low - Voltage switchgear and control-gear: Part 1 general rules (First Revision)
IS xxxxxx (Doc No MED/20/13071)	Solar Photovoltaic Water Pumping Systems — Testing Procedure Guidelines
3043 : 1987	Code of Practice for Earthling
IEC 60068-2-6 : 2007	Environmental testing – Part 2-6 Tests – Test Fc: Vibration (sinusoidal)
IEC 60068-2-30 : 2005	Environmental testing – Part 2-30 Tests – Test Db: Damp heat, cyclic (12 + 12h cycle)
IEC 60146-1-1 : 2009	Semiconductor converters - General requirements and line commutated converters Part 1-1 Specification of basic requirements
IEC 60364-4-41 : 2005	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock
IEC 60364-7-712: 2017	Low voltage electrical installations - Part 7-712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems
IEC 60529 : 1989	Degrees of protection provided by enclosures (IP Code)
IEC 60947-1 : 2007	Low-voltage switchgear and control gear - Part 1: General rules
IEC 61000-6-2 : 2016	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments
IEC 61000-6-3:2006	Electromagnetic compatibility (EMC) - Part 6-3: Generic standards -Emission standard for residential, commercial and light-industrial environments
IS/IEC 61683 :1999	Photovoltaic Systems — Power Conditioners — Procedure for Measuring Efficiency
IEC 62109-1:2010	Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
IEC 62305-3:2010	Protection against lightning - Part 3: Physical damage to structures and life hazard
IEC 62458:2010	Sound system equipment – Electro-acoustical transducers - Measurement of large signal parameters
IEC 60068-2-6 : 2007	Environmental testing – Part 2-6 Tests – Test Fc: Vibration (sinusoidal)
IEC 60068-2-30 : 2005	Environmental testing – Part 2-30 Tests – Test Db: Damp heat, cyclic (12 + 12h cycle)
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IEC 61000-6-3:2006	Electromagnetic compatibility (EMC) - Part 6-3: Generic standards -Emission standard for residential, commercial and light-industrial environments
IS/IEC 61683 :1999	Photovoltaic Systems — Power Conditioners — Procedure for Measuring Efficiency

Annexure-7

Abbreviations/ Acronym Used in the document

CSC	: Critical Storage Conditions
DRES	: Distributed Renewable Energy Sources
EHE	: Electrical Air Heater Energy
FHE	: Final Heater Energy
IHE	: Initial Heater Energy
kWh	: kilo-watt-hour
MT	: Metric Ton
MJ	: Mega Joules
MPPT	: Maximum Power Point Tracker
MIDH	: Mission for Integrated Development of Horticulture
MNRE	: Ministry of New and Renewable Energy
NHB	: National Horticulture Board
PM-KUSUM	: Pradhan Mantri Urja Suraksha evam Utthaan Mahabhiyaan
RMS	: Remote Monitoring System
SCS	: Solar Cold Storages
SPV	: Solar Photovoltaic
SPVMA	: Solar Photovoltaic Module Array
TES	: Thermal Energy Storage
DC	:Direct Current
AC	: Alternating Current
USPC	: Universal Solar Photovoltaic Controller
VDF	: Variable Frequency Drive