F. No. 223/4/2024-Solar R and D
Government of India
Ministry of New and Renewable Energy
(R&D Div.)
*****

Atal Akshay Urja Bhawan,
Lodhi Road, New Delhi-110003
Dated: 11th February, 2025

OFFICE MEMORENDUM

Subject: Guidelines on "Design Specifications, Performance Guidelines, and Testing Procedure for Solar Cold Storage with Thermal Energy Storage Backup"

The Ministry of New and Renewable Energy (MNRE) has prepared a "Guidelines on Design Specifications, Performance Guidelines, and Testing Procedure for Solar Cold Storage with Thermal Energy Storage Backup" after extensive and due consultation with all stakeholders. These guidelines are herewith notified (attached) by MNRE.

2. These guidelines shall come in force with immediate effect and will serve as the standard reference for all concerned stakeholders. All Central and State Government departments, authorities, agencies, and stakeholders are directed to strictly adhere to the guidelines in the implementation and operation of "solar-powered cold storage systems" in the country.

This issues with the approval of the Hon'ble Minister, NRE.

(Dr. Anil Kumar)
Scientist-E

Copy to:

1. Chief Secretary of all states/UTs
2. Secretary, Ministry of Agriculture and Farmers Welfare along with National Horticulture Board
3. Secretary, Ministry of Power
4. All State Government Departments of Agriculture, Energy & Horticulture
5. All concerned industries/manufacturers
6. COO, NCCD with request to include these guidelines in their guidelines
7. DGs of NISE, NIWE, NIBE, MD of SECI & CMD of IREDA
8. All SNAs
9. Chairperson, NABL
10. DG of BIS

Internal Distribution:

1. PS to Hon'ble Minister of New and Renewable Energy
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नवीन एवं
नवीकरणीय ऊर्जा मंत्रालय
MINISTRY OF
NEW AND
RENEWABLE ENERGY

सत्यमेव जयते

GUIDELINES

DESIGN SPECIFICATIONS, PERFORMANCE GUIDELINES AND TESTING PROCEDURE FOR SOLAR COLD STORAGE WITH THERMAL ENERGY STORAGE BACKUP

FEBRUARY 2025

Contents of Guidelines

Executive Summary

This document provides comprehensive guidelines on the design, performance, and testing standards for Solar Cold Storage systems equipped with Thermal Energy Storage (TES) backup. These systems operate primarily on solar photovoltaic (PV) energy, offering a sustainable solution for preserving agricultural, fish, dairy, and pharmaceutical products. By ensuring consistent cold storage and reducing reliance on grid electricity or diesel generators, they address critical challenges in post-harvest management. The systems use solar energy to power refrigeration during sunshine hours while TES stores cooling energy to maintain operations during non-solar periods. Designed for off-grid applications, they include provisions for grid connectivity during extended cloudy conditions. The guidelines cover systems in capacities of 2 MT, 5 MT, 10 MT, and 20 MT, with temperature ranges from -5°C to 4°C. Cold rooms are insulated with polyurethane foam (PUF) for efficiency and equipped with essential safety features and remote monitoring systems. TES utilizes phase change materials (PCMs), which reduce long-term costs through efficient energy storage and extended operational life.

Performance requirements specify that systems must support daily precooling of 10% of the total storage capacity for two days, ensuring cold storage autonomy. Solar PV panels and TES deliver high efficiency, reinforced by robust design standards for durability and safety. Testing procedures outlined in the document provide clear protocols for measuring cold storage performance, TES capacity, and solar system efficiency, including autonomy tests to evaluate temperature maintenance and system performance under varying conditions.

The adoption of these systems significantly reduces post-harvest losses, enhances the incomes of small-scale farmers, and supports sustainability by minimizing greenhouse gas emissions. To ensure effective operation, comprehensive manuals are provided, detailing system components, safety precautions, troubleshooting, and maintenance procedures. Additionally, a five-year maintenance guarantee ensures long-term reliability and system performance. These guidelines form a crucial step in promoting renewable energy applications in the cold storage sector, combining sustainability, efficiency, and economic benefits.

Over 1400 solar cold storage systems have been installed in the country, so far. These guidelines will act as guidance to Ministry of Agriculture and concerned state government departments who are installing solar cold storage. It will help in preparing bid documents for solar cold storage.

Guidelines on Design Specifications, Performance Guidelines and Testing Procedure for

Solar Cold Storage with Thermal Energy Storage Backup

1. Scope

These Guidelines provide basis for performance guidelines, design specifications, and testing procedure for Solar Cold Storage with Thermal Energy Storage (TES) Backup. The Solar Cold Storage which runs on Solar Photovoltaic (SPV) system and has Thermal Energy Storage (TES) as a backup for various agricultural, fish, dairy and pharma commodities. The system is powered entirely by Solar PV as Distributed Renewable Energy Source (DRE). However, systems should have a provision of grid connection and can be switched to grid during cloudy days.

2. Definition of System and Parameters

System: Solar Cold Storage with Thermal Energy Storage Backup System

The solar cold storage enables effective use of solar energy for cooling of perishable items to store and preserve them for longer duration. The cold storage unit in off-grid operation, primarily runs on power generated from Solar Photovoltaic and can be switched to grid during cloudy days. During sunshine hours the electricity generated from solar photovoltaic is used to provide cooling through a vapor compression refrigeration cycle to cool a cold room as well as store cooling energy in a Thermal Energy Storage (TES) System. In Thermal Energy Storage (TES) system the cold energy is stored in phase change material such as water or water salt eutectic mixture and transferred to the cold storage unit depending on the usage needs. During non-solar hours, the cooling needs of cold storage unit are met through the stored cooling in the thermal energy storage system. Use of solar photovoltaic and thermal energy storage backup eliminates dependency on grid and need of diesel generator as a backup device. The system is powered entirely by Solar PV as Distributed Renewable Energy Source (DRE). However, the system should have a provision of grid connection and can be switched to grid during cloudy days.

The system comprised mainly of the following components and equipment:

Cold Room, SPV System, Solar Controller, Refrigeration System consisting of Condensing and Evaporating unit, Thermal Energy Storage (TES) System & Batteries for Auxiliary Load. The combination of all these components shall be unique. Any change in combination will be treated as a different model of Solar Cold Storage System.

2.1 Cold Room

The cold room is a Poly-Urethane Foam (PUF) insulated room that maintains desired temperature and humidity for storage of commodities. The cold room is equipped with refrigeration unit which provides necessary cooling by circulating cold air to the commodities for preservation.

2.2 Solar Photovoltaic (SPV) System

The SPV system generates electrical power during sunshine hours which is used to operate the cold storage system. It provided electricity for running refrigeration system and auxiliary load.

2.3 Solar Controller

The controller converts the DC power (DC voltage & Current) of the SPV array into a controlled high or low DC voltage power and converts this DC power into single or multi-phase alternating-current power (voltage or alternating current) suitably for driving the refrigeration system. The Controller may also include equipment for MPPT, monitoring, metering and sine wave filters.

2.4 Refrigeration System

The refrigeration system consists of condensing unit and evaporating unit working on vapor compression cycle. The condensing unit generates cooling energy which can be used for charging the Thermal Energy Storage (TES) system and to provide cooling to the cold storage depending upon design of Solar Cold Storage system.

2.5 Thermal Energy Storage (TES) System

In Thermal Energy Storage (TES) system the cold energy is stored in phase change material such as water or water salt eutectic mixture and transferred to the cold storage unit depending on the usage needs. During non-solar hours, the cooling needs of a cold storage unit are met through the stored cooling in the Thermal Energy Storage (TES) system.

2.6 Electric Battery System for Auxiliary Components

The electrical batteries are meant to provide electricity for auxiliary electrical loads such as fans of evaporator unit, thermal energy storage control panel, temperature controller unit, lighting, and data monitoring system.

3. System Working and Architecture

During daylight hours, solar panels harness abundant sunlight to generate electricity, which powers the refrigeration system and simultaneously charges a thermal energy storage (TES) unit. The TES unit stores thermal energy in the form of a PCM, allowing for consistent refrigeration even during non-solar hours and grid outages. Due to its efficiency and versatility, this system can be employed to maintain the desired cold storage temperatures to increase the shelf life of farm produce. The cooling system utilizes the stored thermal energy during off-peak or grid-down periods, reducing the reliance on conventional grid electricity and minimizing greenhouse gas emissions. This system also enables small farmers in remote areas to increase their incomes by reducing post-harvest losses.

The electric energy generated by solar photovoltaic panels directly powers a variable speed compressor. The speed of the compressor is directly proportional to the instantaneous solar radiation intensity. The compressor generates cooling, which is stored in the form of thermal energy storage. When solar energy is low or not available, cooling in the cold storage is provided by the thermal energy storage. The entire system can be switched over to grid in case of extended non-solar / cloudy days. The overall system architecture is depicted in Figure 1.

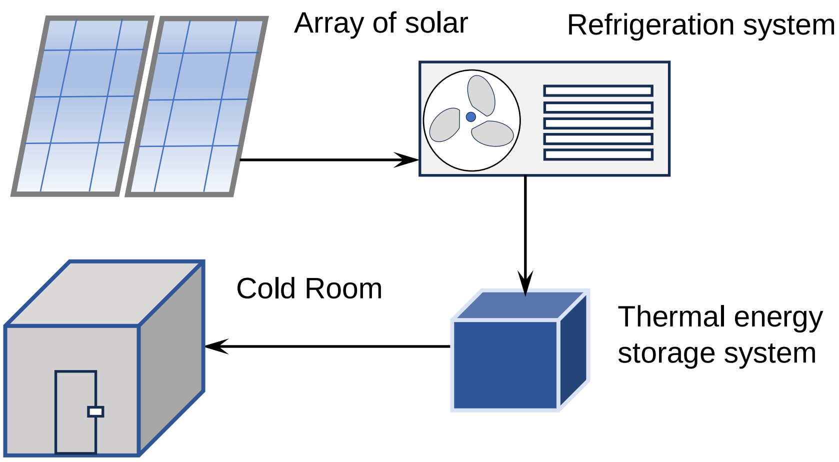

Figure 1: System architecture of a solar energy based cold storage system

Part 1

Design Specifications, Performance Guidelines

1. Scope

These Guidelines provide basis for design specifications and performance guidelines for 2 MT, 5 MT, 10 MT and 20 MT capacities of solar cold storage with Thermal Energy Storage (TES) as backup. The guidelines are based on three different minimum temperatures.

- Minimum 4 ºC
- Minimum 1 ºC
- Minimum -5 ºC

Please refer to the storage guidelines of fruits, vegetables, pharmaceutical, fishery, dairy, etc from respective departments on application of these temperature ranges. The National Center for Cold Chain Development (NCCD) references for storing different fruits and vegetables are listed as Annexure 1.

2. Performance requirement

Cold storage is loaded with perishable items daily. Due to varying output from the perishable commodities such as fruit, vegetable, fish, meat, dairy, etc, it is assumed that 10% of the overall capacity will be loaded on daily basis.

For baseline performance it is proposed that the system is powered entirely by Solar PV and should have sufficient capacity of TES to provide cooling autonomy in absence of solar and grid electricity.

Precooling of 10% of the total storage capacity for continuous two days is considered as the base line requirement. The minimum performance requirement is listed in Table 1 of Annexure 2.

3. Minimum design specifications

Based on Performance requirement, the minimum design specifications of various components of Solar Cold Storage with Thermal Energy Storage (TES) as Backup are as follows:

3.1 Cold room

The cold room is a Poly-Urethane Foam (PUF) insulated room that maintains the desired temperature and humidity for storage of commodities. The cold room is equipped with refrigeration unit which provides necessary cooling by circulating cold air to the commodities for preservation.

i. Internal volume of temperature-controlled cold room storage space shall be 150 cubic feet per MT irrespective of the product stored.
ii. The external and internal body of the cold room shall be
    a. Pre-painted galvanized iron (PPGI) with minimum of 0.5 mm thickness for application in fruits & vegetables
    b. Stainless Steel 304 grade with minimum of 0.4 mm thickness for application in fishery, meat or dairy
iii. The internal height of the cold room is recommended to be not more than 8 ft to avoid difficulty/inconvenience in placing crates.
iv. The insulation of walls, ceiling, flooring and door shall be composed of Polyurethane Foam with density of 40+/-2 kg/m3.
v. The door shall have the minimum opening of 6 feet height x 2.5 feet width.
vi. There shall be the provision of PVC curtain before the door.
vii. The door shall have provision to open from inside even if it is locked.
viii. Proper lighting should be provided inside the cold room.
ix. The water proofing of the cold room shall be based on corrugated sheet. Sealing with tape or silicone sealant is not allowed.
x. The design calculation is based on 10 times door opening in a day.

3.2 Refrigeration unit

i. The refrigeration system consists of a condensing unit and an evaporating unit
ii. HFC refrigerants shall be zero Ozone Depletion potential.
iii. Compressor shall be directly powered with solar photovoltaic panels without electrical batteries.
iv. Compressor shall have variable speed.
v. Compressor capacity shall be based on the certificate provided by the original equipment manufacturer of compressor. Compressor capacity shall be defined at 0 Deg. C subcooling temperature and 20 Deg. C suction gas temperature for standardization purpose.

vi. The system should have low and high-pressure protection switches, a receiver tank, a filter drier on the liquid line and a thermostatic expansion valve.

3.3 Thermal energy storage

There should be a provision to store cooling in a thermal storage system to provide cooling during the off-sunshine period and store excess solar energy in case it is not utilized. The charging and discharging of the thermal storage shall occur simultaneously. The energy storage medium should be phase change material (PCM) such as water or water salt eutectic mixture. The purpose of using phase change material is that it has much lower initial cost and have longer life than electrical batteries to store energy.

Thermal energy storage capacity is based on 2 days of autonomy assuming daily precooling 10% of cold storage capacity. This will also avoid wastage of solar energy on days when cold storage is not utilized for its full load capacity. The excess solar energy will be stored in thermal storage, which will be utilized to provide higher pull-down (precooling) capacity or increased autonomy for cloudy/rainy days.

The Specifications suggest TES capacity for 2 days. However, the customer can also opt for one day storage, if the site conditions/ other conditions suitable. The general requirement of TES us as follows:

i. Thermal storage medium shall be phase change material.
ii. The energy storage capacity of thermal storage should be monitored and displayed with a minimum of ten linear graduations from minimum to maximum storage capacity.
iii. Phase change material shall have minimum 10 years of life.
iv. Phase change material shall be non-toxic for usage with food commodities.

3.4 Solar System

3.4.1 Solar Photovoltaic (SPV) System

The SPV system generates electrical power during sunshine hours which is used to operate the cold storage system. It provides electricity for running refrigeration system and auxiliary load. Enough modules in series and parallel could be used to obtain the required voltage or current and power output. The SPV system shall have the following specifications:

i. PV modules used must qualify to the latest edition of IEC/BIS PV module qualification test
ii. All PV modules should have STC testing certificate from an NABL accredited test laboratory

iii. The manufacturer should warrant the Solar Module(s) to be free from the defects and/or failures for a period of 10 years from the date of sale to the original customer
iv. PV modules should be warranted for their output peak watt capacity, which is not less than 90% at the end of 10 years and 80% at the end of 25 years

3.4.2 Module Mounting Structures

i. 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 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.
ii. 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 the foundation design.
iii. These are indicative of minimum standards and a manufacturer/ Implementing Agency may use better designs for higher standards.

3.4.3 Earthing Arrangement

i. A lightening arrestor shall be provided with every solar sold storage.
ii. Separate earthing may be provided for AC Side (compressor/AC supply), DC Side (structure/controllers/modules), and lightning arrestor.
iii. Earthing shall be done as IS 9283 in accordance with the relevant provisions of IS 3043.

3.4.4 Solar charge controller

i. 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.
ii. The controller must have protection or shall be housed in a cabinet having at least IP-65 protection. Adequate protection should be provided in the controller to protect the Solar cold storage against any open circuit, accidental output short circuit, under voltage, reverse polarity, SPD to arrest high current surge.

iii. Adequate protections shall be provided in the controller to protect the Solar Cold Storage against any open circuit, accidental output short circuit, under voltage, Reverse polarity, SPD to arrest high current surge.

3.4.5 Cables

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.

3.5 Electric battery bank for auxiliary components

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.

i. The battery type shall be either lead acid or lithium ion
ii. The overall auxiliary load on the battery shall be less than the discharge rating of the battery as specified by the battery manufacturer
iii. Original equipment manufacturer of the battery should provide minimum 5 years of warranty.

3.6 Remote monitoring system

The system should have remote monitoring system based on the internet connectivity. The data shall be saved on the online server. Following are the parameters:

i. Room temperature
ii. Room humidity
iii. Ambient temperature
iv. Solar generation
v. Compressor on/off status
vi. Evaporator fan on/off status
vii. TES charge level
viii. Battery voltage
ix. Door open/close status
x. Grid status

The consolidated Minimum Design specification is listed in Table 2 of Annexure 2. Also, a Template for providing technical specifications is Annexure 3.

4. 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 Various Components of system including Solar photovoltaic modules, Cold Room, Refrigeration System, Solar Controllers, Battery, Data Monitoring and Loging system, etc.

It should also have clear instructions about:

- Operation of System
- Safety Precautions about the system
- Maintenance of the System
- DO's and DONT's and on regular maintenance and Trouble Shooting of the system.
- A warranty card for the system components and sub components and should also be provided to the beneficiary.
- 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.

4.1 Comprehensive Operation and Maintenance

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

Annexure 1

NCCD references for Commodities Classification with Temperature ranges

Type - I F (Up to 2°C) for Fruits

Sl. No.	*Products*	*Temp*	*Humidity*	*Holding Time*
1	Apples	0-2° C	90-95%	1-6 months
2	Apricot	-0.5 - 0°C	90-95%	1-3 Weeks
3	Blackberry	-0.5-0°C	90-95%	3-6 days
4	Blueberry	-0.5 - 0°C	90 - 95%	10-18 days
5	Cherries(sour)	0° C	90 - 95%	3-7 days
6	Cherries(sweet)	-1-0°C	90 - 95%	2-3 weeks
7	Grapes	-0.5-0°C	90 - 95%	1- 6 months
8	Kinnow	1°C	95%	
9	Kiwi	0° C	90 - 95%	3-5 months
10	Litchi	1-2°	0.95	3-5 weeks
11	Orange(FL humid areas)	1 - 2°C	85 - 90%	8-12 weeks
12	Peaches	-0.5-0°C	90 - 95%	2-4 weeks
13	Pears	-1.5-.0.5° C	90-95%	2-7 months
14	Plum	-0.5-0°C	90-95%	2-5 weeks
15	Raspberry	-0.5-0°C	90-95%	3-6 days
16	Strawberry	0-1°C	90-95%	7-10 days

Type - II F (2°-5°C) for Fruits

Sl. No.	*Products*	*Temp*	*Humidity*	*Holding Time*
1	cranberry	2-5°C	90-95%	8-16 weeks
2	Tangerine	3-6°C	85 - 90%	2-4 weeks
3	Pomegrenate	5°C	90-95%	2-3 months

Type - III F (5°-10°C) for fruits

Sl. No.	*Products*	*Temp*	*Humidity*	*Holding Time*
1	Guava	5 - 10°C	90%	2 - 3 weeks
2	Melons	5-10°C	85-90%	2-3 weeks
3	Avocado	5-8° C	85-90%	2-4 weeks
4	Papaya	7-13°C	85-90%	1-3 weeks
5	Dragon Fruit	4-10°C	90-95%	2-3 weeks
6	Pineapples	7-13° C	85-90%	2-4 weeks

Type - IV F (above 10°C) for fruits

Sl. No.	*Products*	*Temp*	*Humidity*	*Holding Time*
1	Passion fruit	10	85-90%	3-4 weeks
2	Rambutan	12	90-95%	1-3 weeks
3	Mango	12 - 13°C	85 - 90%	14 - 21 days
4	Banana	12 - 15°C	80 - 95%	14 - 21 days
5	Custard Apple	13°C	90-95%	2-4 weeks
6	Jackfruit	13°	85-90%	2-4 weeks

TYPE-I Vg (Up to 2°C) for Vegetables

Sl. No.	*Products*	*Temp*	*Humidity*	*Holding Time*
1	carrot (Bunched)	0°C	98-100%	10-14 days
2	carrot (Topped)	0°C	98-100%	3-6 Months
3	cauliflower	0°C	95-98%	3-4 weeks
4	Corn	0°C	95-98%	5-8 days
5	Garlic	0°C	65-70%	6-7 months
6	Mint	0°C	95-100%	2-3 weeks
7	Lettuce	0°C	98-100%	2-3 weeks
8	Mushroom	0°C	90%	7-14 days
9	Radish	0°C	95-100%	1-2 months
10	Spinach	0°C	95-100%	10-14 days
11	Sprouts	0°C	95-100%	5-7 days
12	Turnip Root	0°C	95%	4-5 months
13	Beet (Bunched)	0°C	98-100%	10-14 days
14	Beet (Topped)	0°C	98-100%	4 Months
15	Broccoli	0°C	95-100%	10-14 days
16	Cabbage (early)	0°C	95-100%	3-6 weeks
17	Cabbage (late)	0°C	95-100%	5-6 months
18	Peas	0-1°C	90-98%	1-2 weeks
19	Shallot	0-2°C	65-70%	1-2 weeks
20	Water Chestnut	1-2°C	85-90%	2-4 months

TYPE-II Vg (2°-5°C) for Vegetables

Sl. No.	*Products*	*Temp*	*Humidity*	*Holding Time*
1	Oregano	0-5°C	90-95%	1-2 weeks
2	Tamarind	2-7°C	92-95%	3-4 weeks
3	Tomato	3-4°C	85-95%	10 weeks
4	Beans	4-7°C	95%	7-10 days

TYPE-III Vg (5°-10°C) for Vegetables

Sl. No.	*Products*	*Temp*	*Humidity*	*Holding Time*
1	Potato (late)	4-12°C	95-98%	5-10 Months
2	Potato (early)	10-15°C	95-98%	10-14 days
3	Chilli	5-10°C	85-95%	2-3 weeks
4	Olives	5-10°C	85-90%	4-6 weeks
5	Okra	7-10°C	90-95%	7-10 days
6	Squash (courgette)	7-10°C	95%	1-2 weeks

TYPE-IV Vg (above 10°C) for Vegetables

Sl. No.	*Products*	*Temp*	*Humidity*	*Holding Time*
1	Bitter Gourd	10-12°C	85-90%	2-3 weeks
2	Cucumber	10-12°C	85-90%	10-14 days
3	Eggplant	10-12°C	90-95%	1-2 weeks
4	Lemon	10-13°C	85-90%	1-6 months
5	Watermelon	10-15°C	90%	2-3 weeks
6	Pumpkin	12-15°C	50-70%	2-3 months
7	Squash (calabash)	12-15°C	50-70%	2-3 months
8	Ginger	13°C	65%	6 months
9	Sweet Potato	13-15°C	85-95%	4-7 months
10	Onion	25-29°C	60-65%	

Annexure 2

Table 1: Minimum performance requirement for different capacities of solar cold storage

Particulars	**2 MT**	**5 MT**	**10 MT**	**20 MT**
Base line performance requirement	Two days of daily precooling of 10% of the total storage capacity and maintain the cold storage temperature for the balance period primarily on thermal energy storage			
Daily Precooling capacity	200 kg	500 kg	1000 kg	2000 kg
Daily precooling temperature and duration	Cold Room temperature from 35~30 to 4 ºC within 24 hours for 4 ºC application Cold Room temperature from 35~30 to 1 ºC within 24 hours for 1 ºC application Cold Room temperature from 30~25 to -5 ºC within 24 hours for -5 ºC application			
Cold Room Temperature maintenance	4 to 6 ºC for up-to 48 hrs. for 4 ºC application 1 to 3 ºC for up-to 48 hrs. for 1 ºC application -5 to -3 ºC for up-to 48 hrs. for -5 ºC application			

Table 2: Design specifications of solar cold storage

S. No	**Particulars**		**2 MT**	**5 MT**	**10 MT**	**20 MT**
Cold Room						
i.	**External & Internal Body**		Pre-painted galvanized iron (PPGI) with minimum of 0.5 mm thickness or Stainless Steel with minimum of 0.4 mm thickness			
ii.	**Indicative External Dimension (L×B×H), ft**		8×8×8 ft	20×8×8 ft	40×8×8 ft 20×16×8 ft	80×8×8 ft 40×16×8 ft
			Note: *The dimensions are indicative and may be changed as per requirement but shall meet the Minimum Internal Volume.*			
iii.	**Minimum Internal Volume of storage area, CFT**		300	750	1500	3000
iv.	**Minimum Cold Room Insulation**	**4 ºC application**	100 mm PUF thickness on door, wall & ceiling 60 mm PUF thickness on flooring PUF density to be 40 ± 2 kg/m3			
		1 ºC application	110 mm PUF thickness on door, wall & ceiling 70 mm PUF thickness on flooring PUF density to be 40 ± 2 kg/m3			
		-5 ºC application	120 mm PUF thickness on door, wall & ceiling 80 mm PUF thickness on flooring PUF density to be 40 ± 2 kg/m3			
v.	**No. of door**		1	1	1-2	1-2

	(As per need)					
vi.	**Door type**		Minimum Opening of 6 feet Height x 2.5 feet Width			
Refrigeration System						
vii.	**Cooling system type**		Air Cooled Vapor Compression System with Variable Speed Compressor			
viii.	**Compressor capacity, TR**		1.5	2.5	4.75	8.3
			Compressor TR is based on ✓ *-5 ºC evaporating and 50 ºC condensing for 4 ºC application* ✓ *-10 ºC evaporating and 50 ºC condensing for 1 ºC application* ✓ *-15 ºC evaporating and 50 ºC condensing for -5 ºC application*			
ix.	**Refrigerant**		HFC refrigerants with Zero Ozone Depletion potential example R134a/ R407F/R407C etc.			
Thermal Storage System						
x.	**Thermal storage medium**		PCM (Water or other relevant PCM)			
xi.	**Cooling Capacity (Minimum) for 48 hrs autonomy**		120 MJ	245 MJ	440 MJ	800 MJ
xii.	**Cooling Capacity (Minimum) for 24 hrs autonomy**		75 MJ	145 MJ	250 MJ	440 MJ
			Note: The Specifications suggest TES capacity for 2 days. However, the customer can also opt for one day storage, if the site conditions/other conditions suitable.			
xiii.	**Useful life of phase change material**		Minimum 10 years to minimize long-term expenditure associated with PCM replacement			
Solar System						
xiv.	**Photovoltaic panels type**		Crystalline Silicone or Thin Film Based Technology Module			
xv.	**Solar Power Capacity (Minimum)**	**4 ºC application**	4 kWp	7 kWp	12 kWp	20 kWp
		1 ºC application	4.6 kWp	8 kWp	13.8 kWp	23 kWp
		-5 ºC application	5.2 kWp	9 kWp	15.6 kWp	26 kWp
xvi.	**Battery type**		Lead acid/Li-Ion			
xvii.	**Battery Capacity (Minimum)**		5.2 kWh	7.2 kWh	12 kWh	19.2 kWh

xviii.	**Exemplary Battery Size**	3 x 12 V 150 Ah	3 x 12 V 200 Ah	5 x 12 V 200 Ah	8 x 12 V 200 Ah
xix.	**Battery Warranty**	The battery should be warranted for a minimum of 5 years.			
xx.	**Module Mounting Structures**	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.			
xxi.	**Solar Controller**	i. 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. ii. The controller must have protection or shall be housed in a cabinet having at least IP-65 protection. iii. Adequate protections shall be provided in the controller to protect the Solar Cold Storage against any open circuit, accidental output short circuit, under voltage, Reverse polarity, SPD to arrest high current surge. iv. Minimum MPPT efficiency of 95%.			

Annexure 3

Template for providing technical specifications

Specifications	**Parameters**	**Value**
Cold room		
External Dimension (L×B×H)	ft	
Total internal volume	CFT	
Indicative storage capacity	MT	
Wall, door and ceiling PUF thickness	mm	
Floor PUF thickness	mm	
Inner & outer finish (PPGI / SS304)	Material & thickness	
Floor finish (Kota / Aluminum)	Material & thickness	
No. of Doors	No's	
PVC door curtains	Yes	
Cold room roof water proofing sheet	Material & thickness	
Storage temperature range	Deg. C	
Solar		
Solar panels type and capacity	Technology / Per panel capacity	
Total solar capacity	kWp	
Solar structure material of construction and wind rating	Hot dip galvanized / kmph	
Solar structure tilt	Degrees	
Separate earthing for DC, AC & lightening arrestor	Yes	
Lightning arrester	Yes	
Electrical battery bank		
Electrical battery type	Lead / Lithium	
Total electrical load connected to the electrical batteries	VA	
Discharge rating of the battery bank as per OEM	VA	
Battery bank capacity	Vah	
Refrigeration system		

Compressor capacity	TR	
Compressor type	Scroll / Reciprocating	
Refrigerant	R134 / R407f / etc	
Condenser and evaporator fan type	Yes	
Total evaporator fan airflow	CFM	
Total condenser fan airflow	CFM	
Thermal energy storage system		
Phase Change Material	Material Name	
Phase change material quantity	kg	
Freezing Temperature of PCM	Deg. C	
Latent Heat Capacity of PCM (Material test Report to be attached if not water)	MJ/kg	
Estimated cooling delivery from TES = 70% x Latent MJ/kg x PCM quantity in kg	MJ	
Actual thermal storage capacity if testing done by accredited laboratory	MJ	
Number of linear indication of thermal storage capacity	Nos	
Entire thermal storage capacity is accessible to either chamber in case of multi chamber	Yes	
Others		
Alternate power supply	Voltage & Power	
List of remote monitoring parameters	Specify	

PART 2
Testing procedure

1. Scope

Testing procedure lays down basis for testing Solar powered cold storage with Thermal Energy Storage (TES) as Backup with different capacities, namely, 2 MT, 5 MT, 10 MT and 20 MT.

2. Test setup

2.1 Cold storage temperature measurement

The cold storage temperature needs to be recorded for the test by using a temperature sensor with minimum repeatability of ±0.1ºC. The sensor should be placed at the suction of evaporator fans (not more than 200 mm away from the evaporator inlet) to measure the return air temperature inside cold storage. The sensor should not be in contact of any surface which can cause error in room temperature measurement.

2.2 Electric air heater with energy meter

An electric air heater shall be placed inside the cold storage which will be treated as heat load to measure the TES system capacity. An electric heater of specified rating as per the system capacity shall be used whose operating switch should be located outside the cold storage, such that the heater can be switched ON/OFF from outside without disturbing the inside temperature of cold storage. The rating of electric heater for different capacity of cold storage system is provided in Table 1.

Table: Electric heater rating for different capacity of cold storage system

S. No	Cold Storage Capacity (MT)	Recommended Heater Rating (Watts) for testing purpose
1.	2	500
2.	5	1000 (500×2)
3.	10	2000 (500×4)
4.	20	4000 (500×8)

To measure energy consumption of the electric heater, an energy meter, with accuracy class of 0.5 as prescribed in 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 meter and energy consumption should be measured in kWh.

2.3 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 as prescribed in IEC/AS Standard 62053-11, will be installed to monitor the total energy consumption by the complete system. It will correlate to the energy consumed by system in charging the TES system as explained in Test 1. This energy meter is termed as Grid energy meter and the TES system energy consumption shall be measured in kWh.

2.4 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 Solar inverter / charge controller / converter 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 should be used separately to measure energy consumption by auxiliary load. To measure the energy consumption of auxiliary load, the energy meter is connected on the output of chemical batteries during the discharge tests.

3. Test precautions

Before conducting the test of Solar cold storage system with Thermal energy storage (TES), following precautions must be followed:

1. The cold storage door should always be kept close during the test except when required by the test procedure.
2. All sensor devices should be calibrated to avoid error in recording test data with an accuracy of ±0.1ºC.
3. Connection of sensor devices to monitor and recording test data should be proper.
4. All electrical connections shall be proper to avoid any spark due to lose connection or wire break.
5. Earthing process should be strictly adhered for system protection and human safety.
6. Check cold storage system is working as per design like 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.

7. Electrical continuity shall be verified to ensure electrical connections are made as per design electrical diagram.
8. TES capacity indication shall be monitored during the test. TES capacity indication will be provided by the manufacturer which shall be a numerical value.
9. All temperature monitoring shall be on minimum every 1-minute basis.

4. Test procedure for performance evaluation

Test 1: Test for the cooling delivery capacity of TES, minimum achieved temperature specifications

This test is to ascertain temperature achievable in cold room is as per the defined minimum temperature specifications when cooling through TES and the cooling delivery capacity of TES. Below is the stepwise procedure for carrying out the test:

Step 1: Charging Thermal Energy Storage (TES) system to 100%

i. Switch ON both grid and solar supply to refrigeration condensing unit.
ii. Switch OFF grid supply to air heater placed inside the cold storage.
iii. Switch OFF the cooling requirement of cold storage from set point controller.
iv. When TES is completely charged (100% capacity), the operation of condensing unit should automatically turn OFF.
v. Switch OFF both grid and supply to refrigeration condensing unit.

Step 2: Discharging of Thermal Energy Storage (TES) system to cooling delivery capacity of Thermal Energy Storage (TES)

i. This procedure starts after TES is 100 % charged.
ii. Switch OFF grid/solar supply to refrigeration condensing unit
iii. Note down heater energy meter reading. It will be termed as Initial Heater Energy (I_{HE}) in kWh.
iv. Also monitor the thermal storage capacity to ascertain the linear graduation.
v. 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.
vi. Change cold room set point temperature to (Minimum specified temperature + 0) °C as cut in temperature. The cut out temperature shall be additional 2 °C.

vii. Switch OFF the Heater once the cold room temperature is more than (Minimum specified temperature + 6) °C for more than 15 minutes.

viii. Note down heater energy meter reading. It will be termed as Final Heater Energy (F_{HE}) in kWh.

ix. The difference between F_{HE} and I_{HE} will be total electrical energy consumption (E_{HE}) by the air heater.

x. Cooling delivery capacity of TES will be the sum of total energy consumed by air heater, external heat influx energy and internal heat energy influx from evaporator fan.

xi. Rate of External heat influx energy and internal heat energy influx from evaporator fan is also included in cooling rate calculation.

Note:

1. In regard to the measurement of Storage Capacity of thermal storage system the temperature of the outer temperature surface is monitored. -. 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 ambient temperature. The conductivity of the room shall be fixed at 0.027 W/m^2K. 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.

Test 2: Solar Performance & Autonomy Testing - Solar PV Array Simulator Based

This test is to ascertain the performance of solar system including SPV system and solar controller. This test is carried out by using SPV array 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. 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. The profile provided here is for Global Normal Irradiance (GHI) and need to be converted to the plane of the tilt of the module in the simulator or using a suitable model. The simulator output is connected to the system through the controller and the profiles are run on 1X speed.

Below is the stepwise procedure for carrying out the test -

Step 1: Bring the TES level and Electric Batteries to 0 %

i. TSS need be 0% charge level.
ii. Battery needs to be externally discharged to 11.5 V for 12 V battery.

Step 2: Charging on Hot profile day

iii. Switch OFF grid/solar supply to refrigeration condensing unit and to auxiliary power system.
iv. Switch OFF the cooling requirement of cold storage from set point controller.
v. Start the profile using the sun simulator for charging TES and Electric Batteries.
vi. Note down the TES level and Electric Batteries charged at the end of profile.
vii. If TES and electric batteries are not fully charged, continue the same test for another day.
viii. Stop solar simulator when TES is fully charged. Note down the time, battery voltage etc.

Step 3: Autonomy Test of System

This test is to ascertain the Autonomy of the system including Thermal Energy Storage (TES) System and Electric Batteries. Below is the stepwise procedure for carrying out the test:

i. Once TES Level and Electric Batteries are 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.
ii. Water Bottles should be placed in standard crates and distributed uniformly inside the cold storage across all its floor area. Initial temperature of water bottles has to be in the temperature range of 30 to 35 ^{O}C
iii. Monitor temperature of 5 water bottles (4 near corners and 1 in center).
iv. Switch OFF grid/solar supply to refrigeration condensing unit and to auxiliary power system.
v. Set cold storage temperature to (Minimum specified temperature + 0) °C as cut in temperature. The cut out temperature shall be additional 2 °C.
vi. Continue the test for a period of 24 hours.
vii. The minimum temperature achieved at the end of 24 hours is will noted and reported.
viii. Repeat the test with replacing the water bottles for the second day. Old water bottles need **not** to be removed. New crates shall be placed over the old crates. Initial temperature of

water bottles has to be in the temperature range of 30 to 35 °C. Sensor need to be removed from old to new water bottles.

ix. Continue the test for another 24 hours.

x. During the test, if battery is completely drained, the test will continue after externally powering the battery. Same will be reported in the test results.

xi. The test results will be quantified as the time period for TES and battery to precooling water bottles within 18 hours and maintain balance time the system is able to maintain the temperature within (Minimum specified temperature + 0) °C to (Minimum specified temperature + 2) °C.

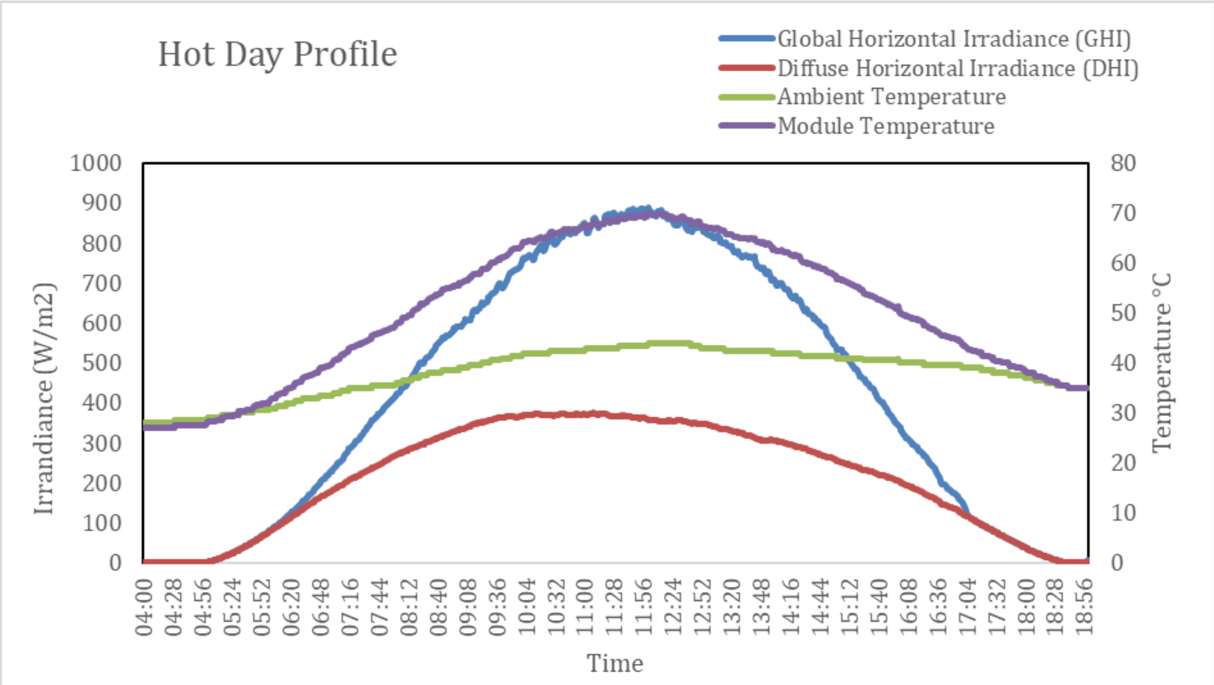

Figure 1 – Typical Solar Radiation Hot Profile

Test 3: Power Source Switching Operation Testing - Grid to Solar to Grid (Automatic)

The system would be tested for switching from solar operation to grid operation and vice 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 single/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.

5. Measurements and Apparatus

Measurement of temperature, Electricity load is to be done at various locations during the various test. The various parameters shall be monitored and reported.

a) Measurement of Temperature

Temperature should be measured by using a temperature sensor with minimum repeatability of ±0.1ºC at following locations:

i. Cold storage temperature needs to be monitor at the suction of air circulation fans mounted on evaporator inside the cold storage
ii. Ambient temperature
iii. Temperature of water bottles of at least 5 samples (4 near corners and 1 in centre).

b) Measurement of Electricity Load

Electricity load should be measured by using an electric meter at following loads:

i. Electric Heater used in testing
ii. Refrigeration Unit load (load on solar or grid)
iii. Auxiliary load of system (load on electrical batteries)

c) Calibration of Apparatus

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

d) Template for Readings and Observation

Specifications	Parameters	Value
Test 1: Cooling delivery capacity of TES, minimum achieved temperature specifications		
Total energy consumed by Heater	kWh	
Total run time of Heater	mins	
Total energy consumed by evaporators	kWh	
Average cold storage temperature for the entire test	C	
Average ambient temperature for the entire test	C	
Total heater energy for the entire test	MJ	
Total energy consumed by evaporators for the entire test	MJ	
External Heat Influx during Test	MJ	
Total delivery capacity of thermal storage	MJ	
Test 2, Part 1: Solar Performance - Solar PV Array Simulator Based		
Solar panel tilt in actual product	Degrees	
Solar panel tilt in simulator	Degrees	
Total battery capacity	VAh	
TES level at the start of the Hot Profile day 1	%	
TES level at the end of the Hot Profile day 1	%	
Time and day when TES is fully charged		
Battery bank voltage at the start of the Hot Profile day 1	V	
Battery bank voltage at the start of the Hot Profile day 1	V	
Battery bank voltage at the start of the Hot Profile day 2	V	
Total solar generated by PV panels from TES level 0 to 100% (Calculated from hot profile, panel efficiency)	kWh	
Total solar energy consumed by the overall system from TES level 0 to 100% (Solar simulator output)	kWh	
Total solar energy consumed by the refrigeration system from TES level 0 to 100% (DC energy meter connected on solar panel side before MPPT of refrigeration system)	kWh	
Total solar energy consumed by the battery bank system from TES level 0 to 100% (DC energy meter connected on solar panel side before MPPT of battery system)	kWh	
Solar charge controller efficiency		
TES efficiency, (TES delivery capacity from Test 1 / Total solar energy consumed by the refrigeration system)		
Overall system efficiency		
Test 2, Part 2: Autonomy system test		
Individual and average temperature of five sample water bottles on Day 1: 0 hours		

Individual and average temperature of five sample water bottles on Day 1: 18 hours		
Individual and average temperature of five sample water bottles on Day 1: 24 hours		
Individual and average temperature of five sample water bottles on Day 2: 0 hours		
Individual and average temperature of five sample water bottles on Day 2: 18 hours		
Individual and average temperature of five sample water bottles on Day 2: 24 hours		
Cold room temperature on Day 1: 0 hours		
Average cold room temperature on Day 1: 18 to 24 hours		
Cold room temperature on Day 2: 0 hours		
Average cold room temperature on Day 2: 18 to 24 hours		
TES level on Day 1: 0 hours		
TES level on Day 1: 18 hours		
TES level on Day 1: 24 hours		
TES level on Day 2: 0 hours		
TES level on Day 2: 18 hours		
TES level on Day 2: 24 hours		
Duration when battery got completely discharged and grid need to reconnected only on battery (0 to 48 hours)		
Electrical energy consumed by the battery bank after battery bank got discharged for the 2 days autonomy test	kWh	
Overall Test Summary		
TES delivery capacity	MJ	
Solar charge controller efficiency		
TES efficiency, (TES delivery capacity from Test 1 / Total solar energy consumed by the refrigeration system)		
Overall system efficiency		
Minimum cold storage temperature (Average temperature of five sample water bottles after 1 day autonomy test)	C	
Average temperature of five sample water bottles after 2 days autonomy test	C	
Average cold room temperature during last 6 hours for the 2 days autonomy test	C	
Battery autonomy duration (0 to 48 hours)	Hours	
Electrical energy consumed by the battery bank after battery bank got discharged for the 2 days autonomy test	kWh	