Project Report on ISHRAE Student Project Grant – SRPG Post Graduate – 2022-23

Title: A PORTABLE, SUSTAINABLE, AND LOCAL COLD STORAGE FOR FARMERS AND LOCAL VEGETABLE VENDORS

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a. Introduction:

India is a fast-developing country with agricultural sector driving its economy. India's climatic diversity ensures the growth of most varieties of fresh fruits and vegetables, ranking second in the world, only next to China. As per National Horticulture Database (3rd Advance Estimates) published by National Horticulture Board, India produced 107.24 million metric tonnes of fruits and 204.84 million metric tonnes of vegetables, during 2021-22[1]. However, almost 16% of this produce goes waste post-harvest resulting in a monetary loss of about 40.8crores per annum.[2]

As per National Centre for Cold-Chain Development (NCCD) under the Department of Agriculture and Co-operation (DAC), GoI, cold storage facilities are spoken only at retailer end which are large / bulk storages. A cold storage facility at the farmer's end is given least significance, in spite the fact that, post-harvest immediate cooling is a critical step in preservation and shelf-life extension of the perishable fruits and vegetables.

b. Objectives:

Development of

- Portable, movable and affordable storage option
- Cold storage with electrical and thermal (hybrid) energy storage incorporated
- IoT system included to have precise control system and energy management

c. Methodology:

The process flow chart elaborating the methodology undertaken to carry out this work is as shown in Figure 1.

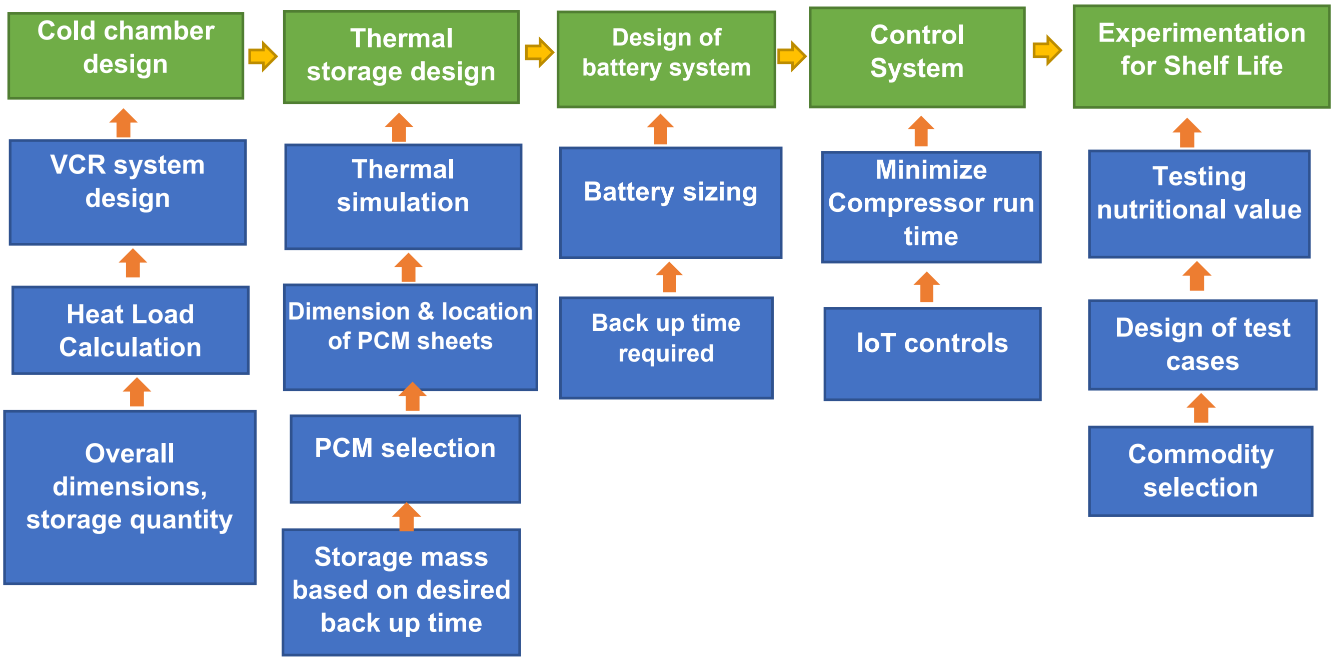


Figure 1. Process flow chart

d. Technical details:

Figure 2 shows the schematic of the proposed portable cold storage unit. As proposed the micro cold storage facility will operate using the vapour compression system (the evaporator, compressor, drier, expansion valve and condenser), the PCM unit, the air circulation system and the humidifier.

Features of the refrigeration unit are as follows:

1. Use of eco-friendly and low Ozone Depletion Potential (ODP) refrigerant- R134a.
2. Temperature, humidity, ethylene and CO_2 sensors to maintain the air temperature and quality within the storage unit
3. Optimized design of electrical and thermal storage unit
4. Designed to maintain appropriate storage conditions for ambient temperatures up to 45°C.
5. Well-designed stacking arrangement for adequate air circulation

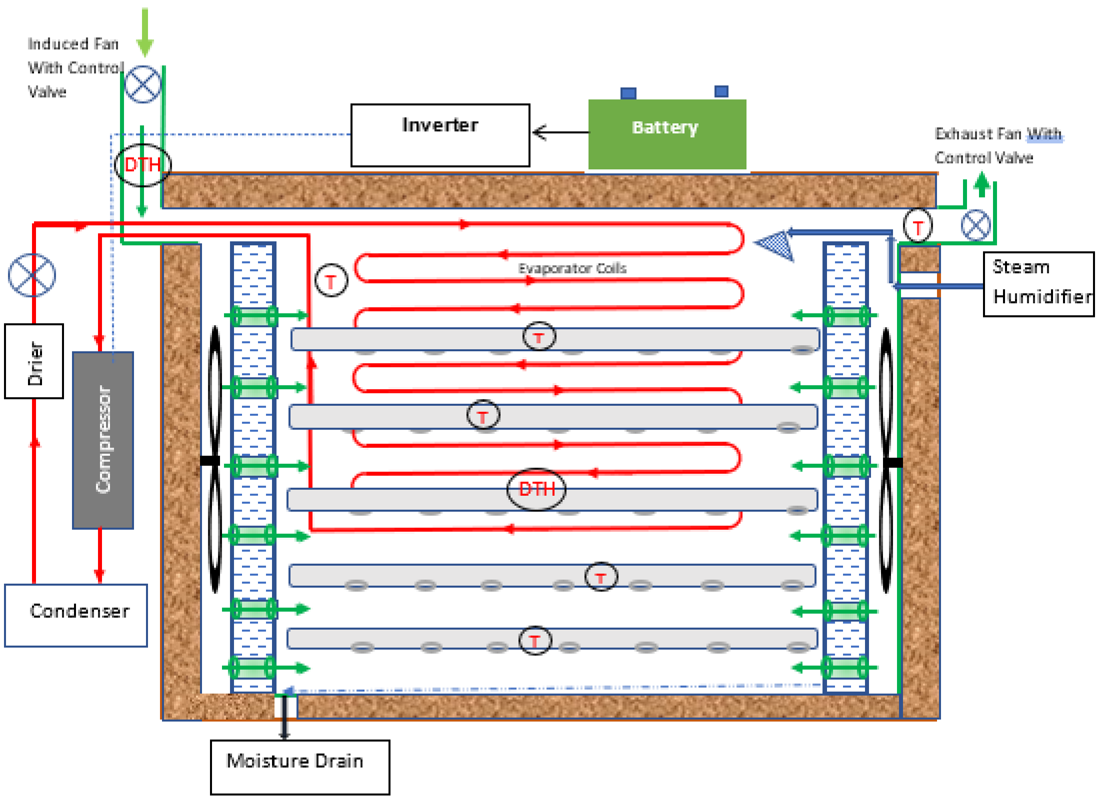


Figure 2. Schematic diagram

Table 1. Specifications of a full-scale storage unit

Parameters	*Specifications*
Dimensions	1.8 m x 1.2 m x 1.8 m (6 ft x 4 ft x 6 ft)
Total Volume	4 m^3 (144 cu feet)
Total floor area	2.22 m^2 (24 sq. feet)
Storage Mass	0.5 MT (minimum)
Minimum Inside Design Temperature	0 °C
Outside design temperature	45 °C
Cooling capacity	1 TR
Power requirement	1.5 kW

A distinguishing feature of the cold storage is the design of the PCM filled heat exchanger units which is designed to minimize charging as well as discharging time. The energy required for operating the portable cold store is provided through proper integration of grid supply with hybrid storage. The system is designed considering energy generation and storage system for 20 h of compressor run time inclusive of auxiliary energy consumption. The electrical storage i.e. the battery back-up will be provided for 12 h in case of power outage. The phase change material that serves as a thermal storage unit is designed to maintain the temperature within the unit up to 6 h once the desired temperature is reached and providing a cushioning in case of power failures. Table 1 provides the specifications for the cold storage unit

Heat enters the cold store through various means and disturbs the optimum storage temperature to prevail within the system. For positive temperature cold storages, the heat ingress is mainly attributed to the following:

Type of load	**Value, W_{th}**
Transmission load through walls	150 W
Infiltration	25 W
Product Load	123
Steam humidification	1218
Miscellaneous (lighting)	120
Total heat load	**1636**

Considering heat exchanger (evaporator) effectiveness as 0.7,

cooling capacity required = 1636/0.7 =2337 W_{th} = 0.7 TR

The above calculations are carried out based on the climatic conditions of Pune, Maharashtra with following considerations

- Temperature range: 0 to 10 ^{0}C.
- CO_2 level: Not more than 4000 ppm during loading and 2000 ppm during holding.

- Loading Rate: 4% (at 25^0 C) to 5% (at 20^0 C) of the total storage capacity

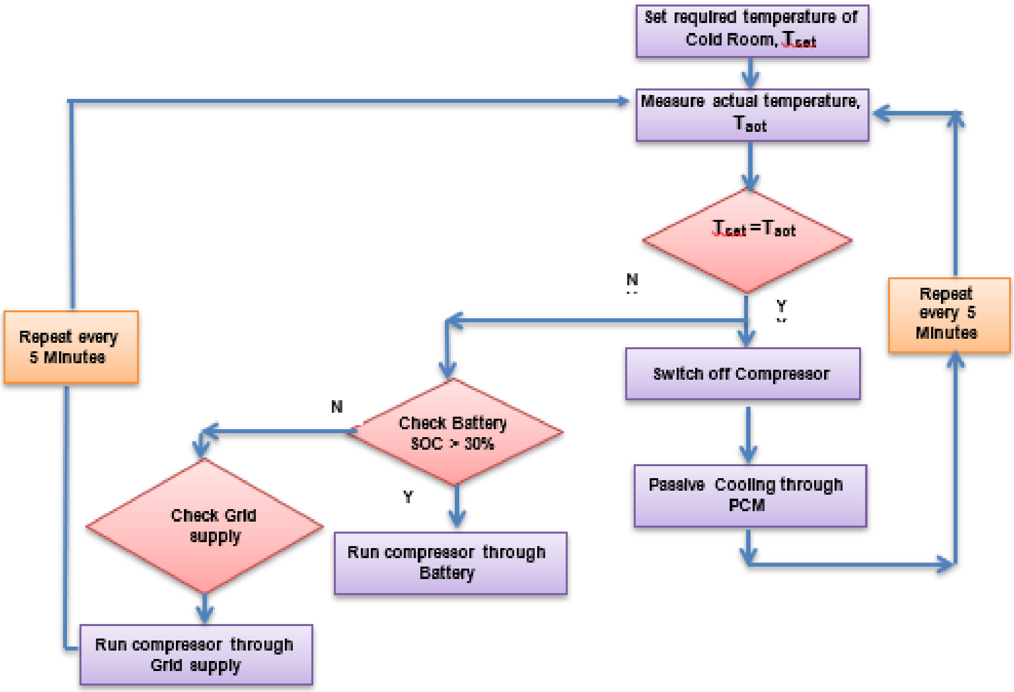


Figure 3. Control of power supply option

The temperature within the cold room is measured by a temperature sensor connected to the controller. Figure 3 depicts the logic governing the operation of the controller. The required temperature (T_{set}) is set on the device. If the actual measured temperature (T_{act}) is more than T_{set}, the compressor continues to run either through grid electricity or battery power. When T_{set} and T_{act} become equal, the compressor is switched off. The PCM evaporator has a separate fan which is continuously in operation. Cooling action however continues by passive cooling through the PCM. The controller checks the temperature every five minutes and ensures that the set temperature is maintained. This control logic would ensure minimum compressor run time on grid electricity.

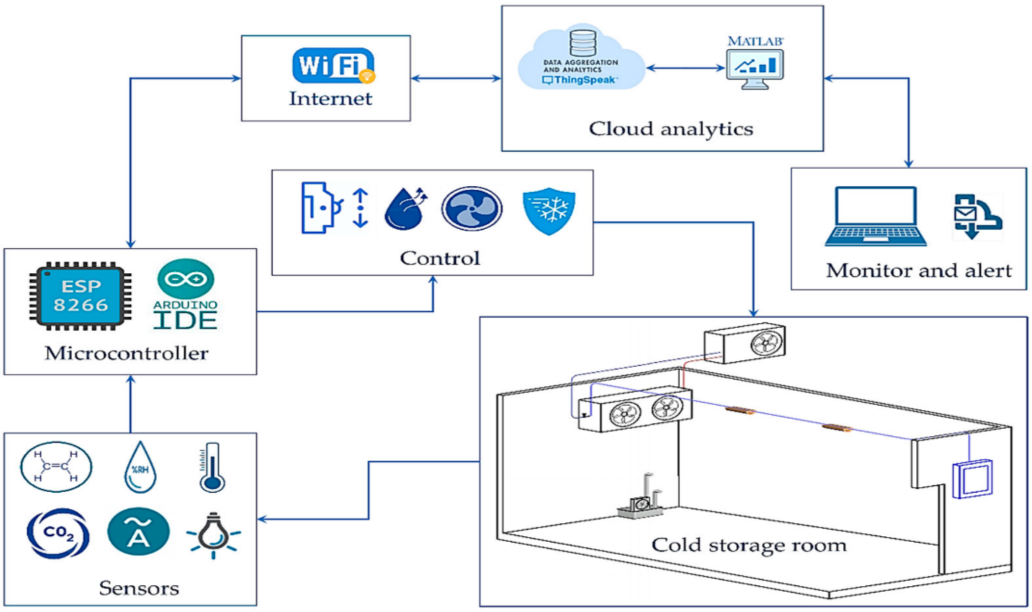


Figure 4. IoT enabled Embedded System for SMART Cold storage

Smart Features of Smart Cold Storage is schematically elaborated in Figure 4 and is as follows:

1. The micro-controller would work on logic to minimize the compressor running time based on a programmed operating strategy based on feedback received from various sensors
2. Real-time monitoring of the condition (temperature, relative humidity, weight) of vegetables, fruits, packed edible and drinkable items, etc.
3. Allows farmers/illiterate persons to select the type of commodity being loaded. Storage temperature and humidity will be automatically set
4. Smart display to see various notifications about the cold store.
5. Getting alerts automatically on smartphones about the real-time conditions of eatables.
6. Depending on the alerts received, the system can automatically check the market condition and suggest suitable sell plans.
7. It will give an alert when the load in the refrigerator exceeds the thresholding value.
8. Anti-theft alarm will be integrated by combining biometric information of operators

Battery Sizing:

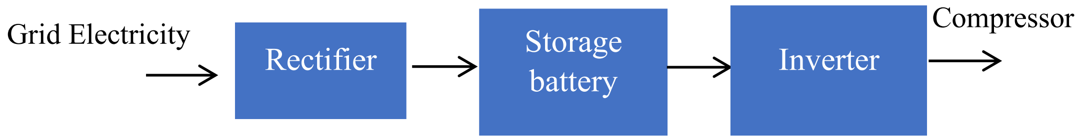
As proposed the portable cold storage would run on grid supply and battery in the absence of grid electricity.

Cooling Energy Demand = Desired Refrigerating Effect= 2337 W_{th}

Power requirement = Refrigerating effect / COP

Assuming COP = 2, the power demand is worked as follows:

$$P = 2337\ W_{th} / 2 = 1.16\ kW$$



The energy required to be stored in the battery is worked out so that it can supply the load of 1.16 kW for a period of 3 hour along with an inverter of with an efficiency of (η_{inv})95%.

Energy required from the battery is $E_b = \frac{1.16\ x\ 3}{0.95}$= 3.66 kWh

Assuming a deep discharge 48V Lithium Iron Phosphate battery, with depth of discharge of 90%, battery capacity in Ah is:

Battery capacity in Ah = $\frac{E_b}{Vx\ DOD} = \frac{3660}{48\ x0.9} = 95\ Ah$

Specifications	**Value**
Battery Type	Lithium Iron Phosphate
Voltage	48 V
Capacity	100 Ah
Depth of Discharge	90%
Rated Current	33 A
No of hours of back up	3

Currently, we are working on the PCM sizing and the heat exchanger design

The set up has been ordered and will be received in a period of 1 month.

e. <u>Schedule for project completion:</u>

Sr. No	**ISHRAE Project Major Activities**	**Months of 2023-24**											
		Apr	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*
1	Size of Cold Room												

2	Material for cold room												
3	Sizing of VCR components and calculating PCM mass												
4	Selection of PCM												
5	Design and Positioning of PCM Heat Exchanger inside Cold Room												
6	Battery Sizing												
7	Manufacturing & Assembly												
8	Pilot Experimental Testing												
9	Project completion & Report submission												

References:

[1] "FFV @ apeda.gov.in." [Online]. Available: https://apeda.gov.in/apedawebsite/six_head_product/FFV.htm#:~:text=It ranks second in fruits,million metric tonnes of vegetables.

[2] NITI AYOG, "PrintRelease @ pib.gov.in." 2020. [Online]. Available: https://pib.gov.in/newsite/PrintRelease.aspx?relid=190984

[3] M. D. Fruit, P. S. Chain, and S. C. Management, "Analysing NDDB Cluster model for marketing of Vegetables," pp. 1–22, 2017, [Online]. Available: https://www.nccd.gov.in/PDF/Analysis_NDDB_veg_model.pdf