



Dr. B. C. Roy  
Polytechnic

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# A Review on Solar-Powered Cold Storage System for Rural Areas

**Sourav Dey**

*Dept. of Mechanical Engineering  
Dr. B. C. Roy Polytechnic  
Durgapur, India  
[sdey.dey1989@gmail.com](mailto:sdey.dey1989@gmail.com)*

**Chiradip Pal**

*Dept. of Mechanical Engineering  
Dr. B. C. Roy Polytechnic  
Durgapur, India  
[chiradippl@gmail.com](mailto:chiradippl@gmail.com)*

**Amlan Dutta**

*Dept. of Mechanical Engineering  
Dr. B. C. Roy Polytechnic  
Durgapur, India  
[amlandutta0091@gmail.com](mailto:amlandutta0091@gmail.com)*

**Sayan Pramanik**

*Dept. of Mechanical Engineering  
Dr. B. C. Roy Polytechnic  
Durgapur, India  
[sayanpramanik689@gmail.com](mailto:sayanpramanik689@gmail.com)*

## ABSTRACT

In India, one of the main reasons for the financial struggles of farmers is the shortage of proper cold chain facilities, which leads to heavy post-harvest losses of fruits and vegetables. To overcome this, there is a growing need to build more cold storage systems across the country. However, traditional cold storages are expensive to install and operate, making it difficult for most farmers to afford them. A practical way to cut down on operating costs is by using solar-powered cold storages instead of relying entirely on grid electricity. This paper looks into different solar energy systems that can be used to power such cold storage units.

**Keywords**—Cold storage, Power generation, Solar PV panels, Solar Collectors, VARS, VCRS

## 1. INTRODUCTION

All over the world, both developed and developing countries are increasingly turning to renewable energy to generate power. Among the different sources available, solar energy stands out as one of the most practical and useful for many applications. For farmers, post-harvest losses of fruits and vegetables directly affect their income. When market prices are low, they often need to store their produce until prices improve. To keep fruits and vegetables fresh for longer periods, a proper cold chain system is essential, ensuring the right temperature and humidity for each crop. Some produce, like oranges, grapes, chilies, brinjals, and melons, need to be pre-cooled before being stored. Conventional, grid-powered cold storages are expensive to install and operate. While installation costs are hard to reduce, operating costs can be lowered significantly by using renewable energy instead of relying solely on the electricity grid [1]. Because of this, many researchers have focused on developing solar-powered cold storage systems using both Vapor Compression Refrigeration Systems (VCRS) and Vapor Absorption Refrigeration Systems (VARS). Solar

power for these systems is typically harnessed through two main methods.

## 2. SOLAR PHOTOVOLTAIC PANELS

Various solar photovoltaic (PV) panels have been used to convert sunlight into electricity for powering cold storage systems, reducing reliance on the grid. Some systems include

battery backups to ensure power availability during nights and cloudy days. For instance, Mishra et al. developed a solar-powered cold storage with a capacity of 10 tons and a 2-ton split air conditioner, using 22 polycrystalline solar panels of 325 W each [2]. A battery bank supported power supply during low sunlight, while IoT sensors-maintained temperatures between 6°C and 7°C and humidity around 94–95%. This setup aimed to lower operating costs so groups of farmers cultivating similar crops could collectively install the system, reduce post-harvest losses and increase their yearly income. The design proved more energy and cost-efficient and simpler than traditional cold storage. It cost about ₹14L, with estimated annual savings of ₹6L.

Anish et al. created a hybrid solar cold storage system using 43.6 V solar panels combined with 16 kg of phase change material (PCM) [3]. During the day, solar panels powered a vapor compression refrigeration system to keep temperatures between 4°C and 7°C. The PCM, housed in aluminum tubes within the walls, absorbed heat while cooling and released coolness at night to stabilize temperature.

Ramen et al. developed a solar-driven cold storage using both parabolic trough solar collectors and PV modules [4]. They compared single-effect and double-effect vapor absorption refrigeration systems. The double-effect system, which had two generators and heat exchangers,

outperformed the single-effect system with 80% higher efficiency and 16% better energy use. Payback periods were approximately 4 years for the double-effect and 3.5 years for the single-effect system.

Surender et al. designed a solar hybrid cold storage for mobile transportation, running a vapor compression refrigeration system powered by solar PV panels [5]. An electronic circuit-controlled compressor speed to maintain desired temperatures. The system operated about 12 hours daily, with PCM maintaining cooling for an additional 7–8 hours. While installation costs were higher, running costs were lower than conventional refrigeration for transport. Bharj et al. improved this design by combining DC inverter technology with solar PV panels, making the system economically viable and versatile for various uses [6].

Nantambi and Namazzi (2019) built a solar-powered cold room using PET bottles for insulation, helping farmers keep fruits and vegetables fresh longer and reduce food waste—this means more time to sell and better prices [7]. Huang et al. (2015) tested solar air conditioners that run without grid power, showing it's vital to size the solar panels just right and use batteries to keep things cool when sunlight dips [8]. Beldar et al. (2021) created an easy-to-use, energy-saving cold storage system powered by both solar and grid electricity, letting small farmers safely store their harvest with less hassle and cost [9].

Overall, integrating solar PV technology with advanced cooling systems and thermal energy storage materials offers a promising way to reduce costs and improve energy efficiency in cold storage applications, especially benefiting agricultural communities.

### 3. SOLAR COLLECTORS

Researchers have been actively investigating solar-powered technologies for cold storage systems to reduce reliance on conventional energy sources. Traditionally, solar photovoltaic (PV) panels have been used to power these systems, but their dependency on costly batteries for energy storage has posed economic challenges. To address this, scientists have turned their focus to solar thermal systems, which have proven to be more cost-effective, especially when integrated with absorption refrigeration technology.

Ramen et al. developed a solar-based cold storage setup and compared the performance of single-effect and double-effect vapor absorption systems [4]. Sadi et al. examined three types of solar collectors—flat plate (FPC), evacuated tube (ETC), and parabolic trough (PTC)—to design a 5 TR cold storage system for potatoes. In their configuration, PV panels supplied electricity for auxiliary equipment such as pumps and fans, while the collectors arranged in series provided the thermal input for the absorption chiller. Their findings revealed that although PTCs had higher installation costs, their system efficiency (COP) was lower than that of FPC and ETC systems. However, by using PTCs, CO<sub>2</sub> emissions were reduced by 53% compared to conventional

natural gas-powered chillers [10]. It shows the variation of COP over time, with most systems achieving around 0.74.

Bahram et al. designed a system using solar dish collectors, each with an area of 12.56 m<sup>2</sup>, to operate an ammonia–water absorption chiller capable of reaching a temperature of -23.5°C. Their experiment, conducted in Bandar Abbas, Iran, incorporated phase change materials (PCM) to store the cooling energy generated during the day for use at night [11]. The system absorbed 1649 kW of solar heat and produced 373.5 kW of cooling output, resulting in an exergy efficiency of 45.14%.

Tushar Sharma proposed and built a solar-powered cold storage unit with a capacity of 200 kg for potatoes. The system included PV panels, a compressor, condenser, expansion valve, evaporator, and an ice thermal energy storage (ITES) setup [12]. During the daytime, solar energy powered the system directly, while at night, the stored ice-maintained cooling. The integration of ITES proved to enhance energy efficiency significantly.

Lin et al. developed a solar air-conditioning system paired with microencapsulated PCM to optimize energy use [13]. Using evacuated tubes as a thermal source, it provided cooling during daylight hours and stored excess energy in PCM for backup on cloudy days or at night. When the PCM temperature surpassed 10°C, the system automatically switched to compressor cooling, simultaneously recharging the PCM. Compared with a conventional air-conditioning unit, this system achieved 30.5% energy savings while maintaining indoor temperatures between 18°C and 22°C.

Basu et al. designed and analyzed a hybrid solar thermal–photovoltaic (STPV) system for potato cold storage at 10°C [14]. The installation combined 165 PM-150 PV modules with 50 flat plate collectors connected to a lithium bromide–water absorption unit. Their assessment showed the system operated efficiently year-round and produced a net annual energy surplus of 36 MWh.

Finally, Lin et al. evaluated a PCM-based cold storage system integrated with a solar-powered air-conditioning configuration [15]. Their research compared various solar cooling technologies and concluded that integrating PCM with solar energy enhances stability, efficiency, and overall performance while significantly lowering dependence on fossil fuels.

#### 3.1. Non-Concentrating Types & Concentrating Types

Flat-plate collectors use a dark metal plate covered by glass to warm up water or other fluids right there on the spot. Evacuated tube versions work even better in cooler weather, hitting temperatures around 200°C without much hassle.

These rely on mirrors or lenses to beam sunlight onto a smaller area—think parabolic troughs that track the sun in a line for steady heat, or dish shapes that zero in from all angles. They crank up the heat past 400°C, making them great for big-scale power plants.

### 3.2. Main Parts

Most flat-plate setups include a copper or aluminum absorber sheet, see-through cover, cozy insulation, and tubes for the fluid. Concentrating kinds throw in sun-tracking gear and shiny reflectors to catch every ray. Common fluids—water, air, or oils—move the heat where it's needed.

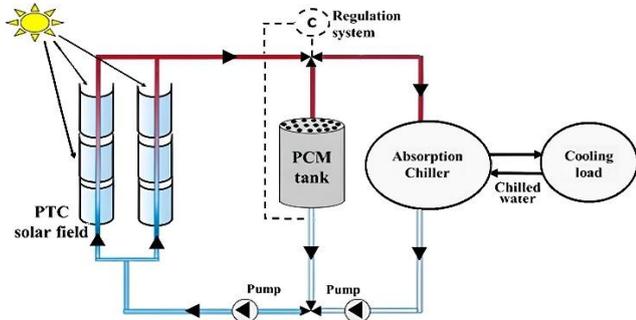


FIGURE 1: HYBRID SOLAR-ASSISTED VAR-BASED COLD STORAGE SYSTEM.

### 4. FUTURE SCOPE

Solar-powered cold storage holds huge promise for rural areas, tackling post-harvest losses and boosting sustainable farming with off-grid power. Better solar panels, smarter batteries, and energy controls will make these systems tougher, cheaper, and more reliable. IoT sensors, smart tech, and AI predictions can fine-tune temps, cut waste, and keep gear running longer without much hassle. Mixing solar with grid, biomass, or wind ensures cooling never stops, even on cloudy days. Government subsidies, rural power schemes, and business partnerships will speed up rollout for everyday farmers. Modular, easy-to-move units will finally put this tech in reach for smallholders everywhere. Over time, these setups can supercharge rural markets, lift farmer earnings, secure food supplies, and build farming that stands up to climate shifts—truly powering greener villages.

### 5. CONCLUSION

In rural areas, where access to reliable electricity remains a challenge, solar-powered cold storage systems present a sustainable and practical solution to minimize post-harvest losses and enhance food security. Utilizing solar energy through photovoltaic panels and thermal collectors allows these systems to operate independently of the grid, reducing operational costs and increasing the longevity of local produce. The incorporation of energy storage options like batteries and phase change materials (PCM) further improves system reliability, ensuring continuous cooling during nights or cloudy days. To cut down on the running costs of cold storage, researchers have explored different ways to use solar energy. Some teams used solar collectors to provide heat for vapor absorption refrigeration systems, which helped create a cooling effect. Others turned to solar panels to generate electricity, storing the power in batteries so the system could keep running even when the sun wasn't shining—like at night or on cloudy days. To make things even more efficient, some

researchers added phase change materials (PCM) to the system. These materials soak up cooling energy while the system is working and slowly release it later, helping keep the cold storage cool even when the system is off.

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### REFERENCES

- [1] Priyanka Sakare " Design of cold storage for thousand tones potatoes " International journal of agriculture and food technology, pg 171-178, 2014.
- [2] R. Mishra, S.K Chauhya, G.M Prasad, S.K Mandal, G Banerjee, "Design of a low cost, smart and stand-alone PV cold storage system using a domestic split air conditioner" Journal of stored products research 89, Elsevier, 17 Oct 2020.
- [3] P. Sarafoji, V. Mariappan, R. Anish, K. Karthikeyan, Jayabharata Reddy, "Performance study of solar photovoltaic cold storage system using phase change materials," Materials today - Proceedings, Elsevier, pg. 2214-7853, July 2020.
- [4] Ramen Kanti De, Aritra Ganguly, " Performance comparison of solar - driven single and double effect LiBr – water vapour absorption system based cold storage" Thermal science and Engineering progress, Elsevier, pg. 2451-9049, 23 Jan 2020
- [5] Surender Kumar, Dr. R.S Bharj "Design for solar hybrid mobile multipurpose cold storage system," IJTRS, ISSN No. 2454-2054, Vol.1 Issue 9, Dec 2016.
- [6] Dr. R.S Bharj, Surender Kumar, "Energy efficient hybrid solar system for cold storage in remote areas," IJERT, ISSN No. 2278-0181, Vo.4 Issue 12, Dec 2015.
- [7] Nantambi, H., & Namazzi, S. (2019). Design and test of an affordable cold room powered by solar for improving storage quality and reducing wastage of horticulture produce.
- [8] Huang, B.-J., Hou, T.-F., Hsu, P.-C., Lin, T.-H., Chen, Y.-T., Chen, C.-W., Li, K., & Lee, K. Y. (2016). Design of direct solar PV driven air conditioner. *Renewable Energy*, 88, 95–101.
- [9] Beldar, M., Vaghela, M., Pathak, H., Patel, D., & Raja, B. D. (2021). Cost effective and low energy cold storage.
- [10] Sadi, M., & Arabkoohsar, A. (2020). Technoeconomic analysis of off-grid solar-driven cold storage systems for preventing the waste of agricultural products in hot and humid climates. *Journal of Cleaner Production*, Elsevier.
- [11] Ghorbani, B., & Mehrpooya, M. (2020). Concentrated solar energy system and cold thermal energy storage: Process development and energy analysis. *Sustainable Energy Technologies and Assessments*, 37, Elsevier.
- [12] Sharma, T. (2018). *Design and development of solar powered cold storage system* (Master's thesis, Hof University of Applied Sciences).
- [13] Zheng, L., Zhang, W., Xie, L., Wang, W., Tian, H., & Chen, M. (2019). Experimental study on the thermal performance of solar air-conditioning system with MEPCM cooling storage. *International Journal of Low-Carbon Technologies*, 14, 83–88.
- [14] Basu, D. N., & Ganguly, A. (2016). Solar thermal photovoltaic-powered potato cold storage: Conceptual design and performance analyses. *Applied Energy*, 165, 308–317.
- [15] Zheng, L., Zhang, W., & Liang, F. (2017). A review about phase change material cold storage system applied to solar power air-conditioning system. *SAGE Open*, 9(6), 1–20.