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# Integrating Renewable Energy to Cold Chain: Prospering Rural India

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**Abstract.** India is the largest producer of fruits and milk, second largest producer of vegetables, and third largest producer in the fishing sector in the world. Post harvest losses mainly on account of lack of proper storage and transit facility, account for about 25-30% losses, besides deterioration in quality. Perishable nature of produce requires a cold chain arrangement to maintain quality and extend the shelf life if consumption is not meant immediately after the harvest. Due to unreliable grid power supply, most of the current cold storages use grid power hybridized with DG sets. This paper attempts to provide information on renewable energy based solutions available for providing and maintaining the chamber temperature in range of -7 to 18 degree along with meeting other loads, which may also include village electrification load if so desired. This will ensure self-sustained, environment friendly, economical development of GREEN COLD CHAIN in long run facilitating further the increasing production.

**Keywords:** Cold Chain, Renewable Energy, Green Cold Chain.

## 1. Introduction

India being a country where agriculture sector is one of the key contributors in the National GDP, hence the storage and processing of the harvest is very critical. The cooling of majority of fruits and vegetables needs to be done even before it is transported so as to maintain the freshness and prevent from immediate deterioration.

The cold storage facilities for India's agricultural produce are short by more than 10 million tons [1]. Additionally the energy expenses account for 28% of costs in cold storages. A report commissioned by the Planning Commission of India to study the reasons for post-harvest losses in the key agricultural states like UP and Bihar points to lack of reliable power supply in these states. It also underlines that the larger cold storages located in city centers have been built primarily to store potatoes. Moreover, the greater the distance between the rural producer and the markets, the greater is the risk of post-harvest deterioration. [2]

Hence there is a need for self-reliable and sustainable cold storages near the agricultural fields itself. This will reduce the transportation cost and as a result more farmers will be encouraged to use this facility.

Ironically the either the cold storage facilities at the farms does not exist or it is in very bad shape as most of the agricultural sector is in the rural areas and hence do not have continuous access to good quality grid power; the fact remains that a majority of India's villages are un-electrified and most of the electrified villages receive very little power supply during off-peak hours. A self-sustainable Cold Storage can thus help in saving valuable agricultural produce and also in achieving rural electrification; this will make the farmer energy independent and also ensure the empowerment of the farmers, as they can reap the benefits of high quality vegetable market.

## 2. Cold Storage: Renewable integration

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The cold chain sector is sizable (6,000 nos /30,000 metric ton) and fast growing with many key industry critically dependent on it. However sector faces several constraint in its growth, which not only limits its potential but also results in wastage and loss of value in the industry that depend on it. One of constraints, unavailability of grid power/harnessing renewable energy in OFF grid mode at the point of farm produce and solution thereof is attempted in the paper. In the cold chain we can include renewable energy interventions at various stages to support the development of a self-sustainable model of Green Cold Chain which require little or does not require grid power to drive it, also there can be a technological intervention wherein the renewable infrastructure supporting the Cold Storage facility can also feed electricity to the nearby habitat. This shall safeguard the farmers from unwanted losses due to pilferages, mismanagement of stock and lack of grid supported cold chain infrastructure, also at the same time it can supply electricity to the villages [3]. The renewable energy technologies can be integrated in the existing system or developed in isolation based on three key factors such as:

## 2.1. Stage in the Cold Chain

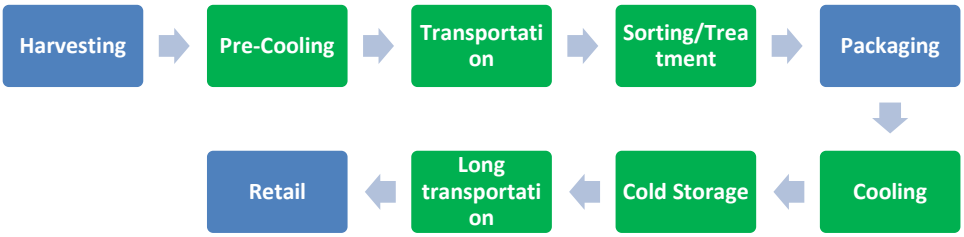


Fig. 1: Green Cold Chain Highlighting Potential Stages for Renewable Intervention [4]

Green technologies can be easily integrated in almost all the stages of the cold chain as indicated in Fig. 1; starting from the very initial level of pre-cooling, transportation and then cold storages.

## 2.2. Type of Stock to be Processed

The need of temperature range for various food and produces varies from sub zero degree to 10 degree Celsius and hence the renewable energy technology shall also vary accordingly to attain the temperature range. Temperature range of various agricultural produce can be seen below at Table 1.

Table 1: Temperature Range For Various Produces [5]

| Sl. No. | Fruits/Vegetables | Temperature range ($^oC$) |
|---|---|---|
| 1 | Apples | -1 – 4 |
| 2 | Bean/Carrots/Cauliflower | 0 |
| 3 | Lychees/ Orange | 4 – 7 |
| 4 | Onions | 0 – 2 |
| 5 | Strawberries | 0 |
| 6 | Sprouts | 0 – 2 |
| 7 | Potatoes | 7 – 10 |

## 2.3. Load Requirement for the Desired Infrastructure

The electrical load requirement for various units as mentioned in Table 2 varies and the load can vary from 3 kW to 125 kW. The renewable energy technology can be used in standalone mode or to supplement the electricity loads of the existing projects.

Table 2: Cold Storage Load Requirement

| | | **Technical Parameters** | | |
|---|---|---|---|---|
| **Capacity (MT)** | | **Dimensions ($m^3$)** | **Temp ($^oC$)** | **Electrical load** |
| **Small units** | 2 – 3 | 3.8x2.2x2.44 | 0 to 15 | 3 kW(with pre-cooling)[6] |
| | 10 | 6x4.6x2.43 | 0 to 15 | 15 kW(with pre-cooling)[6] |
| **Large units** | 5,000 | 4x(21x16x13.70) | -4 to + 4 | 125 kW(without pre-cooling)[7] |

There can be multiple solutions like mobile solar powered vans/solar cooled containers for transporting the stock to nearby cold storage, large cold storages driven by solar thermal/solar PV technology. Solar refrigeration engages a system where solar power is used for cooling purposes [8]. Also renewable energy interventions can be integrated in the existing plants such as Biomass-Gasifier can be coupled with the diesel

gen-sets, this hybrid solution can significantly reduce the cost of fuel [9]. Before various RE options are detailed, brief on renewable energy status in India is described next.

## 3. Renewable Energy Status: India

India's electricity sector is amongst the world's most active players in renewable energy utilization As of March 2013, India had an installed capacity of about 32.7 GW [10] of new and renewable technologies-based electricity. In the last year wind sector achieved an important milestone as it completed 20 GW of installations. Solar PV has been expanding exponentially in the last few years and achieved an installation of 2.6 GW. Solar has the benefit of ease of implementation, irrespective of the location as compared to wind and hence it is seen as an alternative to grid electricity or even diesel.

The renewable potential in India is estimated to be more than 245 GW with over 100 GW of solar energy potential. Various forms of renewable energies contribute to this massive potential. Many sectors including food storage/cold chain can strive for energy security by adopting renewable energy. Renewable energy is now becoming technologically and economically sound alternative to grid power and can be deployed in far remote places at competitive price and to the scale required.

Globally, investments in renewable energy sector are being done at par with traditional energy generation. In the last year in RE sector alone global investments have been 254 billion dollars [11], investment in India standing at 6.5 billion dollar [12]. In new capacity addition, India stands at 6$^{th}$ place globally [13]. Entrepreneur in cold chain sector can evaluate the options available for powering through RE for reliability and profitability by reducing wastage. Options available are detailed in next section.

## 4. Renewable Energy Technological Options for Cold Storage

### 4.1. Solar Photovoltaic Power Pack

Power Pack systems are used to generate electricity for locations where grid is unreachable or the access is expensive. It is a PV based solar energy system, where solar energy is converted into electrical energy and used for refrigeration much like conventional methods [8]. These Solar Power Pack Systems as illustrated in Fig. 2 can also be used in combination with existing grid for uninterrupted supply of electricity. The Power pack consists of Solar PV modules, long life low maintenance batteries, solar inverter cum charge controller and suitable hard-ware. The power from solar photovoltaic cells in case of cold storage chamber/container/van is utilized mainly to drive the compressor of the system.

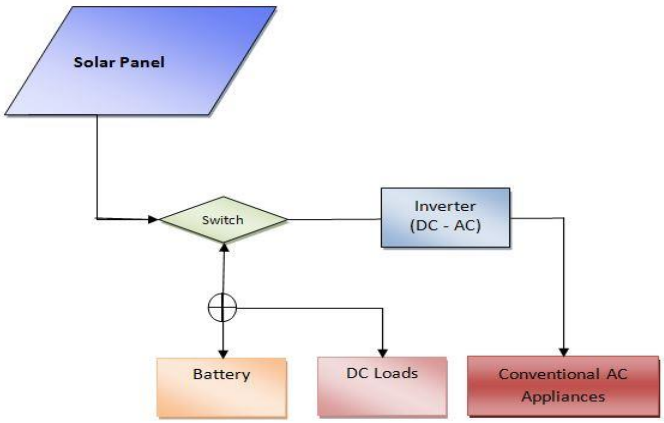


Fig. 2: Solar Photovoltaic Power Pack model [14]

### 4.2. Solar PV System + Diesel Gen-Set Hybrid

A solar PV can be coupled with existing DG set to supply electricity for base load; catering to luminous load. During the non-availability of the grid power the electrical units generated by solar PV can be utilised hence minimising the energy cost of the infrastructure. The operational diagram is shown in Fig. 3. Pilot projects are operational at various locations so as to hedge the cost of diesel consumed for base load. At present there are over 150 cold storages with solar PV set up where the cost of Diesel consumption has gone down steeply with the help of smart controlling and prolonged temperature maintenance.[15]

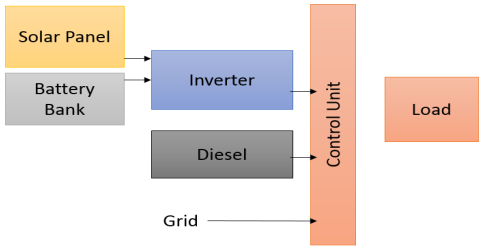


Fig. 3: Solar PV + Diesel Hybrid [15]

## 4.3. Solar PV + PCM

These systems are used to generate electricity as well as maintain the required temperature, with the help of Phase Change Material so as to maintain the required temperature and minimise the load on the compressor which is driven by the electricity produced by solar panels only. As can be seen from Fig. 4, the Electricity from the solar panels is converted into AC so as to feed in to the compressor; separately the thermal energy of the sun is also used to provide energy to PCM for lowering the energy requirement of the system by maintaining the temperature. [6]

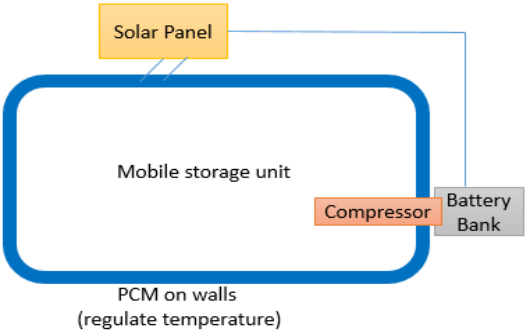


Fig. 4. Solar PV Power Pack To Power the Compressor

## 4.4. VAM Using Solar Thermal Energy

Thermal cooling technology is preferred to PV-based cooling systems because it can utilize more incident sunlight than a PV system. Fig. 5 shows a clear partition of incident solar power when it falls on a formal photovoltaic collector. It shows that most of the total solar energy converts into heat, and a very small portion produces electricity in a PV system. The percentage of rays in the solar spectrum of the incident rays (infrared rays, red and orange) converted into heat energy and only 35% useful for generating electricity in a silicon-based PV system [14]. Therefore, thermal solar cooling is becoming more popular because a thermal solar collector directly converts light into heat. A solar thermal refrigeration system consists of four major components: a solar collector array, a tank for thermal storage, a thermal AC unit and a heat exchanger [16] as seen in Fig. 5.

The thermal collector receives the light energy from the sun and increases in temperature; as a result, the refrigerants inside the collector evacuated tubes become hot through a heat convection process. The thermal storage tank is used for storing the hot refrigerants from the collector tubes. Refrigeration majorly in case of large cold storage units has to be done by Vapour Absorption Machines (VAM). The hot water (feed) for VAM can be provided by Solar Water Heater and gas geysers hence saving a lot of electricity for the purpose of refrigeration.

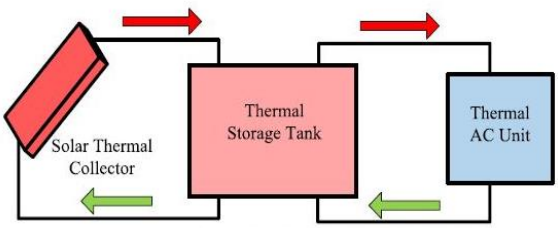


Fig. 5: Vapour Absorption Technology [17]

## 4.5. Biomass Gasifier

Biomass Gasifier based electricity generating systems are a viable option for decentralized electricity production especially in village areas where grid is not available and lot of stock is readily available. As seen in Fig. 6 this setup can provide cold storages with electricity even in standalone mode.

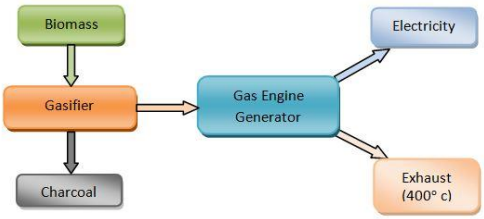


Fig. 6: Biomass Gasifier to Drive the Generator Supporting the Cold Storage [9]

## 4.6. Solar/Biomass co-Generation (Power and Cooling)

In the solar biomass driven cold storage scheme, producer gas from Biomass Gasifier drives gas engine to produce electricity required to drive the electrical demand of the system. A Vapor Absorption Machine (VAM) is driven on the engine waste heat which otherwise would have been rejected to atmosphere [17]. Here, as seen in the block diagram in Fig. 7; the waste heat available from the gasifier engine producing electricity is utilized to power the vapour absorption system.

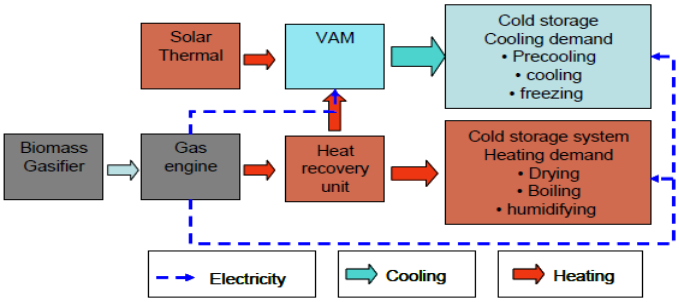


Fig. 7: Solar Thermal and Biomass Cogen Plant [3]

The solar thermal collectors used in the configuration supplements the heat to the vapour absorption system during day time, when it may not be required to operate the electricity generating system. The balance heat available from the engine can be utilized for drying, humidifying, sanitizing needs of the cold storage. [3] This hybrid system thus not only meets both electricity and cold storage needs but also optimizes the use of biomass. Thus every kilowatt of the biomass and solar energy is very efficiently utilized to meet power needs as well as cooling & heating requirement of cold storage [3].

# 5. Economics of Renewable Energy Based Solutions

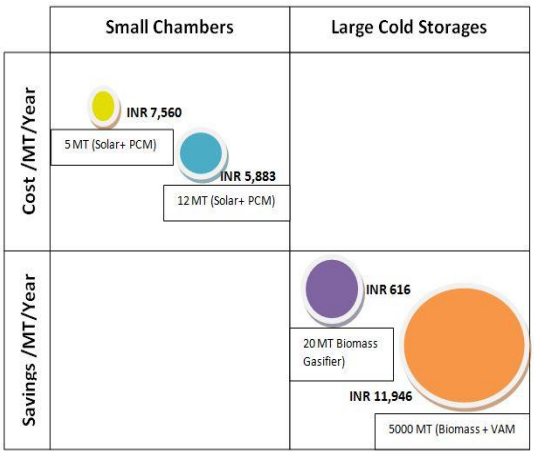


Fig. 8: Cost of RE integration [6], [9]

The renewable energy applications as discussed theoretically can only be implemented and adapted in commercial space if the project is both technologically proven and financially viable. The financial viability in any renewable energy projects can easily be calculated by monetary savings and payback period henceforth. As represented in the Fig. 8 the cost of Solar PV + PCM per MT decreases as the capacity is scaled up. Although the cost is spread over the entire life cycle of the project still the cost is on the positive side as the project includes infrastructure cost as well. On the other hand large cold storages are supported by Biomass gasifiers /Biomass coupled with VAM technology; since these projects only consider the technology cost and not the infrastructure cost of the storage facility, therefore the cost can be easily recovered within the life cycle of the plant, also the project becomes rewarding by further providing monetary gains.

## 6. Conclusion

There are various renewable energy technologies which can be integrated within the cold chain. GOI also provides incentives for integrating RE in this sector through various schemes of MNRE, MoFPI, MoA etcs. Adopting RE serves the purpose of

- Energy security and sustainable energy in case of non-availability of grid or fault in grid.
- Strengthening the agriculture sector and the farmers by reducing wastage and help achieve food security. Further it also helps in creation of job at rural level and elevating the financial status of farmers.

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