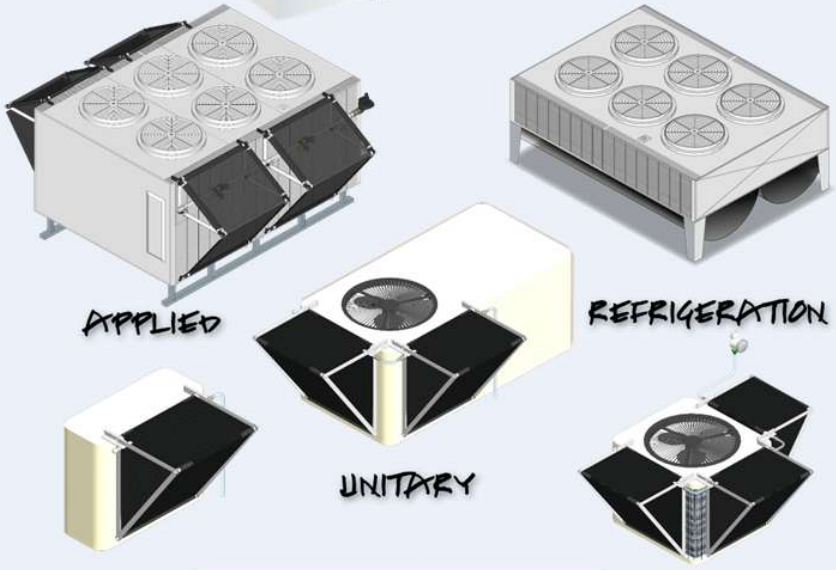
REFRIGERATION







PCM

SOLAR COOLING TO MINIMISE THE FOOD WASTAGE IN AFRICA

Food waste is a major problem facing African countries. Post - harvest losses of food cereals are estimated at 25 per cent of the total harvested crops. The lack of acceptability to cooling facilitate in African countries farmers end up wasting as much as 50% of the produced goods crops such as fruits, vegetables, and root crops, being less hardy than cereals, post-harvest losses (Voices Newsletter, 2006).

In East Africa, economic losses in the dairy sector due to spoilage and waste could average as much as US$90 million/year (FAO, 2004). In Kenya, around 95 million Liters of milk, worth around US$22.4 million, are lost each year. Cumulative losses in Tanzania amount to about 59.5 million Liters of milk each year, over 16 per cent of total dairy production during the dry season, and 25 per cent in the wet season. In Uganda, approximately 27 per cent of all milk produced is lost, equivalent to US$23 million/year (FAO, 2004).

The food currently lost in Africa could feed 300 million people. (FAO, 2013) and in order to minimize this waste Innovate financed a solar driven mobile project whereby UK / Kenyan & Tanzanian partners developed solar driven mobile cold stores based on low carbon solution to reduce food losses and improve the livelihoods of rural farmers and communities in especially Sub-Saharan Africa.

It is critical to cool down the harvested food as fast as possible and the sooner the core temperature drops the longer the shelf life of the produce. Utilising solar energy for food preservation at all stages of the food chain, from farm precooling to storage & distribution is critical to minimize the wastage. Solar driven mobile unit can provide cooling this facility both mobile and static cold storage facility.

The cost might be the main driver for finding the balance between battery vs thermal energy storage for static solar-powered cold chain operation but once it comes to the mobile cold chain cooling applications the main driver tends to be the weight as the heavier the mobile unit the smaller the product volume can be loaded.



SOLAR COLD STORAGE SYSTEMS

Any solar-driven mechanical refrigeration unit must have a battery system, not only for the running time required after sunlight hours, but also it is vital to have battery back-up for the start-up of the compressor which requires 4~5 times higher current to kick in. Most of the cold storage applications are based on ~20 hours pull-down principal and therefore the refrigeration machinery is sized to satisfy the heat gains as well as the product cooling over this period, hence it is unavoidable not to run the refrigeration after the sunset. After sunset refrigeration operates using the batteries charged during daytime and the size of the batteries must be large enough to satisfy this pull-down capacity and time scale.

Batteries are generally costly over their life cycle as they need to replaced frequently over the cold storage lifetime. Although this is a handicap for the static system, using Off-Grid electricity savings may make solar-powered cold storage still economically viable. However, mobile solar-powered cooling applications major obstacle is the weight limits of any vehicles on the road, TES can be considered as a useful tool to minimise the number of batteries required for a given capacity.

Storing energy for after sun hours in order to keep the cooling capacity, designers might have to find the balance between the battery vs. thermal energy storage for both economical as well as the overall weight aspects of their designs to suit the application requirements.

Converting solar energy into electricity tends to be used for mechanical cooling systems such as thermoelectric modules, vapor compression or Stirling machines. The following graph illustrates a typical solar-powered cold storage solution which has been developed in Indonesia and deployed as a stand-alone, Off-Grid, 100% solar-powered cold storage facility for the fisherman on a remote island. This system utilizes thermal energy storage (TES) technology in combination with ultra-efficient compressor packages.



COLD STORAGE TES

Although internal gains and ambient / solar gains tends to be pretty uniform throughout the year but operational patterns, ambient conditions as well as utility / power input for any cold logistic operation varies. Hence, if one be in charge of when to use the energy a TES concept offers significant benefits adding any form of TES capability for cold stores.

How to apply a TES into a cold storage and their benefits can be summarised as below;

1- RUNNING COST SAVING

2- CAPITALISE FREE ENERGY

3- CAPITALISE LOWER OFF-PEAK ELECTRICITY

4- CAPITALISE ENVIRONMENTAL BENEFITS







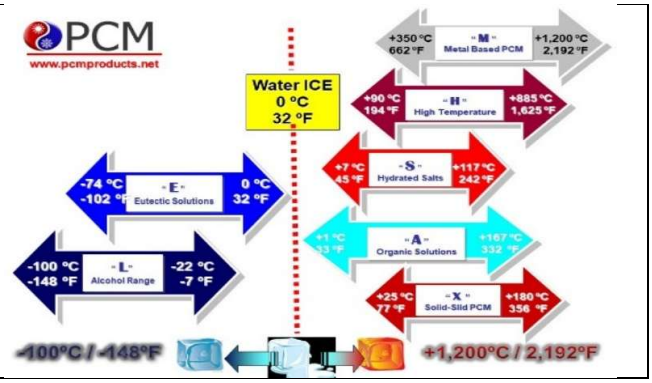
ICE PACKS

Eutectic ice packs are generally used in cool boxes for food and medical applications. In a simple form, plastic ice packs filled with water for chilled applications and some ice packs by adding table salts into the mixture lowers the freezing temperature of the water for frozen applications. Apart from re-usable rigid plastic ice packs, cool logistic companies also use low-cost non-returnable plastic pouches as illustrated below.



At present, globally cooling application requirements are mainly in four temperature range namely

- **Ambient 20~24⁰C (68~75⁰F)**
- **Chilled 2~8⁰C (36~46⁰F)**
- **Frozen -3 ~-34⁰C (25~-29⁰F)**
- **Dry ice range –65~–78⁰C (-85~-102⁰F)**



In order to handle the above applications, the above wide range of PCM options can be applied to satisfy the time scale.

POUCHES

Pouches are the low-cost version of Eutectic application and generally treated as a one-way system i.e. non-returnable applications as part of any temperature controlled logistic shipment. Temperatures ranges could be identical to ice packs and utilising the same PCM options







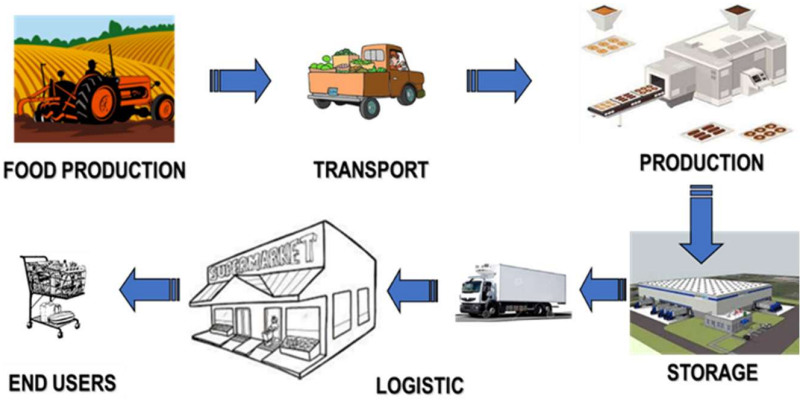






Cold chain for food logistic

The objective of food cooling and chilling is to reduce the rate of biochemical and microbiological changes in foods, in order to extend the shelf-life of fresh and processed foods, or to maintain a certain temperature in a food process. Microorganisms are very active in the temperature danger zone 5~60^{0}C (41~140^{0}F) range and the faster the cooling the lower the microorganism activity. Within this range, temperatures between 20~50^{0}C (68~122^{0}F) allow for the most rapid growth of microorganisms. For this reason, food must pass through this range as quickly as possible.



Cold chain for food logistic

Domestic and commercial refrigerated storage typically operates within the temperature range of 2–8°C (36–46°F) for chilled food and -19 to -26°C (-2 to -15°F) for frozen food applications. However, certain medical, vaccine, and specialized food products, such as tuna, require storage temperatures as low as -70°C (-94°F).

Incorporating Phase Change Material (PCM) thermal mass within refrigerated spaces enhances thermal stability. By absorbing and releasing heat, PCMs help maintain a consistent temperature. As a result, refrigeration units operate more efficiently, running for longer periods without the frequent start/stop cycles commonly seen in standard systems. This not only extends the life of the compressor but also reduces energy consumption, as each compressor typically requires 3–5 times more power to start up. By reducing the number of starts and stops, energy savings of 5–8% can be achieved. Additionally, integrating PCM thermal mass into refrigerated storage offers an added benefit: in the event of power or mechanical failure, the stored energy in the PCM provides a backup, ensuring that the temperature remains stable and protecting frozen products from spoilage. This stand-by capability is especially crucial for maintaining the integrity of sensitive frozen goods



