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Cold Food Chain Report Summary (November 6, 2018)

1 Background

The Global Food Cold Chain Problem

The integration of agriculture and livestock as a source of livelihood led to an arising problem of transporting the food to the people in urbanized areas. The problem with transporting the cultivated food, however, is that from the period it is harvested, its freshness begins to deteriorate with respect to time. Micro-organisms such as mold, bacteria and food enzymes all contrive to cause the food to spoil, become inedible and, sometimes, even become hazardous when it is consumed. Thus, the food cold chain was developed to address the need of the population to transport foodstuffs from the food source to the people, in a fresh and consumable condition. As civilization progressed, advancements in transportation and food preservation methods triggered the expansion in the trade of food goods. In each stage of development in the Cold Food Chain, technology and innovation has supported the food supply chain, not only aiding in faster and farther food transports, but also in maintaining freshness and safety of the food consumed by the population. The progression of time and technology also paved the arising new problems regarding the food cold chain such as its environmental impacts and efficiency both in terms of process and energy consumption.

The Food Cold Chain is a logistics system that deals with ensuring that a specific good will maintain a specific temperature from raw material handling to consumption. The cold food chain primarily revolves on the refrigeration process which is vital for food preservation, the transport of perishable foods in the appropriate temperature range that would slow the biological decaying processes, and the delivery of safe and high-quality foods to consumers. Refrigeration stops or diminishes the rate at which changes occur in food. These changes could include: 1) microbiological changes - growth of microorganisms, 2) physiological changes - e.g. ripening, senescence and respiration, 3) biochemical changes - e.g. browning reactions, lipid oxidation and pigment degradation, and/or 4) physical changes - e.g. moisture loss. Refrigeration is what keeps the food within the safe levels of microorganism content. Thus, it is a significant challenge to maintain the temperature of perishable food in the desired range in all the stages of the cold food

chain. Ensuring the integrity of the cold chain for temperature-sensitive food products also involves additional requirements related to proper handling, packaging, temperature protection, and temperature monitoring.

The cold chain has been critical specifically for the food industry because it reduces food wastages and expired stocks. Consequently, overproduction of food to compensate for food losses is also reduced significantly, as well as energy consumption and the negative environmental effects that go along with the food chain. In addition, an efficient cold food chain improves customer satisfaction through food safety and security.

2 Country Context

Philippines

Food Cold Chain Situation

Over the last few years, there has been an increase in the number of temperature-controlled facilities in the country. Driven by the mounting concerns over food safety, there has been an ongoing shift in consumer habits to patronize fresh and frozen products from supermarkets rather than from traditional wet markets. The growth of e-commerce and online grocery shopping has also bolstered the demand for frozen food. Lastly, the continuous growth of production in the Philippine Agriculture has also contributed to the growing need for cold chain systems. In the last quarter, January to March of 2018, PSA has highlighted a growth of 1.47% in the performance gains of crops, livestock and poultry subsectors. At current prices, gross value of agricultural production amounted to PhP 444.0 billion. This was 8.94 percent higher than last year's earnings. The crops subsector which contributed 53.76 percent to total agricultural output went up by 1.79 percent. The livestock subsector registered a 2.11 percent growth in output. In the poultry subsector, production expanded by 5.24 percent. Lastly, the production in the fisheries sub sector declined by 4.61 percent. Except for skipjack and seaweed, all the major species recorded lower production levels. The aforementioned trends have all contributed to the rapid increase in the number of cold storage facilities and investments in required and ongoing infrastructure improvements.

But the explosion in numbers of such facilities and specialist services in the Philippines is not just based on internal factors: Philippines' agricultural exports have

increased dramatically in recent years. In the last quarter of 2016, the Philippine Statistics Authority noted that agricultural exports rose 42.2 percent year-on-year. Agriculture-based products amounted to US$1.03 billion, ranking them second in overall exports. (Kok, 2017).

With the aforementioned growth in temperature controlled facilities, it becomes imperative to examine the efficiency with which these facilities are being operated as well as its potential negative impact to the environment and to the human health. Commonly known to all, these facilities require a huge amount of energy to operate and use different kinds of cooling agents, such as refrigerants, in their cooling systems. As such, the ozone depletion potential (ODP) and global warming potential (GWP) of these refrigerants require critical attention from both government and the private sector. It has been reported that, between 1900 and 2005, there has been a 0.45 °C rise in average world temperature (Carbon Disclosure Project, 2006). The rate of rise appears to be increasing with a 0.1 °C rise in the last 9 years. Local rises in temperature can be much higher. In the UK in the first quarter of 2007, temperatures were on the average 2.1 °C warmer than in the first quarter of 2006 (Department of Trade and Industry, 2007). In Australia (Commonwealth Scientific and Industrial Research Organisation, 2001), it is estimated that global warming will cause temperatures to rise 0.4–2 °C by 2030, and 1–6 °C by 2070. The year 2014 was the warmest year on record with an average global temperature of 0.69°C above the 20th century average (https://www.rappler.com/move-ph/issues/disasters/114004-changing-normal-philippine-climate).

Another reason for the need to further study the existing Cold Chain System of the country is to ensure food security by minimizing food losses. Table 2.1 shows the food losses for the crops sub sector alone.

Table 2.1 Summary of Food Losses in the Crops Sub Sector

Agricultural Crops	Estimated Percent (%) Loss	Causes	Technologies/ interventions	References
Banana	**3-30%** (0.54 - 3% Post-harvest, 6-12% WS, 16-19% Retail)	Premature ripening, weight loss, mechanical damage, disease and rotting	Use of ethylene adsorbents, careful handling, alum treatment, use of cold	Nuevo and Apaga, 2010 BPRE and

			storage	PHTRC, 2009
Calamansi	**5-32%**	Disease, oleocellosis, yellowing	Curing, MAP (Modified atmosphere packaging)	Nuevo and Apaga, 2010
Mango	**2-33%** (15% Post-harvest, 3.83% WS, 3% Retail)	Cracking disease, latex damage	HWT (hot water treatment), careful handling, alum treatment	Nuevo and Apaga, 2010 BPRE and PHTRC, 2009
Papaya	**27-44%**	Disease, mechanical damage	Wrapping of fruits, HWT	Nuevo and Apaga, 2010
Carrot	**7-12%** (6.08 Post-harvest, 4.17% Retail)	Crack/cut, rot disease, soft rot, punctures, abrasion, cuts, forking, damaged top leaves	Use of plastic crates as packaging material; surface drying or air drying of carrots after washing; use of refrigerated trucks for transport	Nuevo and Apaga, 2010 BPRE and PHTRC, 2009
Cabbage	**29%** (6.27% Post-harvest, 23% Retail, 0.8% WS)	Disease, mechanical damage	Use of refrigerated trucks; careful handling, passive cooling using block ice or evaporative coolers	Nuevo and Apaga, 2010 BPRE and PHTRC, 2009
Eggplant	**10-40%** (35.44% Post-harvest, 5.44-7.75% distribution)	Insect damage, weight loss	Careful handling	Nuevo and Apaga, 2010 Flores et al, 2016
Tomato	**11-38%**	Rotting disease and weight loss	Use of MAP and ethylene adsorbents; careful handling: use of plastic crates	Nuevo and Apaga, 2010
Onion	**35%** (5% Farm, 12% Wholesale 18% Retail)	Disease, mechanical damage	Curing, careful handling; use of cold storage	BAS, 2010 PHilMECH, 2015

Food loss and waste are becoming increasingly critical to the Philippine farmer and is considered a threat to agricultural sustainability and food security because the Philippines is mainly an agricultural country. Understanding the current situation of the

different levels and sub-levels in the Food Cold Supply Chain is essential in order to identify the most suitable projects that must be undertaken for the improvement of the Philippine cold food chain.

3 Analysis of the Current State of the Philippine Cold Food Chain System

Farming Stage

Agricultural Practices

Gibbs et al. (1990) pointed out that the highly inadequate knowledge of agroforestry techniques was probably the weakest aspect in the successful evolution of the government's Integrated Social Forestry Program. Another study conducted by Manalili (2003) was about the Kapatagan Supply chain. Kapatagan is a vegetable-producing village of gently rolling hills on the slopes of Mt. Apo in Davao del Sur Mindanao, Philippines. Kapatagan is conducive to raising vegetables such as cabbages, tomatoes, potatoes, carrots, Chinese cabbage, chayote, bell pepper, eggplants, and okra. Manalili shared that farms are not specialized where several crops are grown either together in different parcels or in a system of rotation. In the end, low crop productivity reflected production inefficiencies, that unless addressed, no amount of improvement in the succeeding steps will lead to cold chain efficiency enhancements.

For the fishing sub-sector, pond farming is the most popular method in the Philippines for tilapia farming, and accounts for 62% of annual tilapia production (BFAR 2015). A milkfish production (Bangus) project was conducted through the Philippine Cold Chain Project (PCCP). Raising milkfish requires attention to climatic changes and biological factors. This is why good knowledge and application of improved and updated techniques and cold chain technologies result to minimized losses and better quality of produce. The Small Input-Grants (SIG) Program of the Philippine Cold Chain Project, help farmers, such as the case of milkfish fingerling-raisers in Buenavista, Agusan del Norte, by introducing to them the refractometer device, which can now give real-time

results when testing water salinity. PCCP is currently processing approved applications from 322 farmers (livestock, horticulture, fishery) in Caraga for assistance.

For the livestock and poultry sub-sector, it is known that the production in this sub-sector is the number one contributor to GWP because they emit a lot of CO2 and methane through their waste. This is where an efficient cold chain becomes helpful and significant in terms of reducing food losses, thereby indirectly reducing the need for overproduction of these livestock.

Post-harvest Stage

Harvesting and Handling

The physiological maturity of any fruit at harvest has an important effect on postharvest quality of that fruit. Unfortunately, most producers harvest their fruits when they are partially or fully ripened. Fully ripened fruits are susceptible to mechanical injuries during harvesting, resulting in shorter shelf life and consequently, food wastes. This negates the positive effects of pre-cooling on shelf life during and after the post-harvest stage. Therefore, care must be taken as to when to harvest the fruit in order to attain the best quality. Night or early morning harvest is sometimes an option for harvesting produce when internal temperatures are relatively low, reducing the energy needed for subsequent cooling. Any practice that reduces the number of times the produce is handled will also help reduce losses. Field packing (selection, sorting, trimming and packaging of produce at the time of harvest) can greatly reduce the number of handling steps the produce must undergo before marketing. Furthermore, the Bureau of Postharvest Research and Extension has been implementing the National Cold Chain and Tramline program in isolated highland areas as an alternative transport system to promote the adoption and utilization of cold chain and tramline systems after harvest in order to reduce losses brought about by manual hauling. The inability of producers to follow these simple but vital harvesting procedures coupled with some inefficiencies in the cold food chain may explain the reasons why there are lots of losses in the fruits harvested at fully ripened state.

Pre-cooling

In the Philippines, there are only a few cold storage facilities available for small to medium scale farmers, hence, food loss occurs during prolonged storage. Cabbage is estimated to have **29%** food loss due to inadequate pre-cooling. Evaporative coolers for lowland vegetables like tomato and eggplants are used to avoid weight loss, shrinkage and retain moisture content. The very high temperature and relative humidity due to the tropical nature of the country is also one of the reasons for the quality deterioration of crops for small to medium scale farmers who cannot afford cold storage facilities. Big companies, on the other hand, may yield more sales due to reduction in storage losses, but also contribute to the increase in carbon emissions in order to maintain cooler temperatures. It is estimated that 1 kilo of HFC is equal to 20,000 kilos of CO2 greenhouse gas. In pre-cooling, proper temperature management should be observed. Indeed, cooling may slow the ripening of some fruits but it may also cause damage such as chilling injuries if the temperature is not controlled well.

In small scale fishing, fishermen make use of ice buckets to pre-cool fresh catch. With advancing technology, use of solar energy for freezing fish products at sea ("bangka" with ice chiller run by solar energy) is already being studied. For freezing at sea, the refrigerating capacity of fishing trawlers can be generated by NH3 screw compressors, which are used for both refrigeration plants and plate freezers. Such systems are cooled by seawater. Lastly, ohmic thawing of blast frozen big fishes has enabled companies to thaw in only half the required time compared to the usual eight hours thawing using running water. This technology is commercially available but expensive.

For the livestock and poultry sub sector, rapid cooling of the meat surface not only slows the development of surface micro-organisms but also reduces weight loss and discoloration of the surface owing to hemoglobin oxidation. The cold chambers must have a low air temperature, a high air speed, a high relative humidity and a high refrigerating capacity. Occasionally cold chambers are refrigerated in advance to reach lower temperatures than those in operation (-5°C/-6°C for beef; -10°C/-12°C for pork), taking advantage of thermal inertia to offset the effect of warm meat loads. Low energy operation

meat displays in place of meat chillers have also been observed in the Cebu Carbon Market where they use Closed Display chillers for sanitation and cost effectiveness.

Grading

Grading is one of the most important procedures that must be practiced during the post-harvest stage. The grading outcome is affected by the shelf-life and the quality requirements of the buyer. It determines the price of the food traded or sold. As an example, bananas are sorted out based on its physical appearance such as size, clear banana skin, color, shape, and fruit-bruising. Such grading is manually done in small operations. Bananas that are premature, overripe, bruised, or diseased are discarded, used as feeds, or sold at an extremely low price for processing as ketchup or chips. However, this grading standard for most fruits and vegetables is rarely practiced at the producer level. It must be noted that pre-cooling of fruits, vegetables and meat products becomes critical in determining the grading outcome as it significantly prolongs shelf life of these fruits/vegetables and satisfies the cooling/quality requirements of meat processors.

Cleaning and Packing

In the packing facility, the fruits are submerged in water with a little amount of chemical such as chlorine for cleansing. The fruits are packed in polyethylene plastic bags individually or put together in big bags and packed in corrugated cardboard boxes. The said boxes are loaded together onto pallets. The pallets are carried by trucks which are then transported to the container yard. In here, trucks locate themselves outside the refrigerated containers for unloading from the trucks and loading into the containers. The nature of packaging and its atmosphere often results to fruit damages caused by perforation and tight packing of the fruits. A common problem experienced during packing is when traders pack with excessive weight (Gonçalves and Kernaghan, 2014). Packaging using plastic are some of the simplest form where vegetables such as sayotes, leafy vegetables, cabbages, and pechays are sacked. On the other hand, wooden crates are used for tomatoes and potatoes.

Sacks or crates are usually fitted to the brim wherein the top of the sacks is left uncovered and exposed subject to handling/tying bruises.

The choice of packing and handling materials during post harvest is critical in determining the quality of the fruits and vegetables as they flow downstream through the food cold chain. Crates and pallets actually play a big part in the cold chain. Without proper crates and pallets, the cold air cannot flow around the products during refrigerated transport and while they are stored in cold storage facilities. Cooling depends on airflow. Additionally, without crates, the product has to be handled many times which contribute significantly to food losses. During transport, the crates also protect the product from downward pressure coming from the top load. A joint study done 15 years ago by the packaging division of DOST and Sanko Plastics Phils. Inc. found that 60% of products are destroyed by the time it reaches the public markets in Manila. The study was conducted to promote proper packaging and proper handling as well as to maximize the benefits of cold storage.

Processing

In the processing stage, leafy vegetables such as cabbage and lettuce are preprocessed at the farm level. On the other hand, low graded fruits that are not sold are processed into jams, chips, desserts, canned goods, etc. This is done through washing, reducing or cutting, blanching, cooling, sterilizing and to some extent, dehydration. In the fisheries subsector, most of the handline catch supply fresh and frozen sashimi grade to the export processors and some to the domestic market. Currently, there are more than 17 frozen tuna processors in the Philippines. As for processed meat, Francis Penaflor, DTI - BOI Sectoral Champion, shared last May 12, 2016 that only a small portion (15%) of the total raw material requirements of the local meat processing industry is supplied by local livestock and poultry raisers. The rest (85%) are imported. The reason for this is that there is a technical mismatch in terms of processors requiring “industrial grade meat” whereas local raisers primarily sell their produce without proper refrigeration to wet markets as “table meat.” Refrigeration requirements of processors are not met by local

livestock/poultry producers. Quality, grading outcome and value of products are all enhanced if these products are properly pre-cooled and flow through the cold chain properly.

Laws have also been in place to ensure the preservation of food quality during the processing stages. Upon the ratification of R.A. 10611 (National Food Safety Act of 2013), its strict enforcement has also led to the stringent evaluation of accredited Cold Storage Warehouses (CSW) in accordance to DA Order No.21 series of 2011, guidelines and procedures for the mandatory accreditation of CSW for Agricultural and Fisheries products. The criteria is divided into 4 major components; Physical Structure (30%), Equipment and Facilities (30%), Sanitary Facilities and Control (35%), and Quality Safety and Assurance Program (5%).

Marketing and Trading

The lack or absence of pre-cooling facilities in and around farm and trading areas has contributed significantly to the quality deterioration and increased food losses along the food cold chain. Traded vegetables are just deposited around the trading facility under direct sunlight, uneven dusty and rocky ground and left on that condition until trading transaction has been completed and truck for loading has arrived, which could last for hours. The trading could either be initiated by the seller or the buyer where the initiation process is followed by commodity inspection, weighing (using portable scales too small in size compared with the size of the sacks/crates and finally marking of the sacks/crates) by the buyer who likewise records the weight of the traded vegetable. After this, the seller waits until collecting trucks arrives while buyer moves on to the next seller. While all of these are happening, the products are subjected to prolonged exposure to heat without the benefits of pre-cooling to preserve food quality.

Philmech echoed the sentiment of stakeholders in the food chain that the current food loss problem experienced in the Philippine food cold chain is largely attributable to the marketing system that is currently practiced. How the farmers will respond to

marketing innovations and to the market demand are critical issues to consider. Cold chain systems work for contract growing required by institutional markets since they are very specific on the timing of harvest, food grading, quality standards, and premium pricing requirements. Farmers, however, have very negative perceptions about contract growing due to bad transactional experiences with businessmen and also the fact that they shoulder all the production risks in cases of natural calamities. Thus, there is a clear disconnect for farmers to smoothly adapt to cold chain systems. For farmers and public markets, the cold chain system is just added cost for them. The current practice of "farmer to consolidator without sorting/grading" results in huge rejects and low revenues for farmers because consolidators have specific requirements that only a continuous and sustainable cold chain system can satisfy.

With this growing concern, the Glory to God Forever (GTGF) Corporation answers the growing demand for high quality, reasonably-priced processed vegetables, fruits and food in the Philippines. The company established a manufacturing plant at San Mateo, Rizal to locally process vegetables, fruits and ready cooked meal products for Metro Manila consumption and nearby provinces – enabling higher income for farmers and lower prices for consumer. Vegetables are sourced from farmers in Benguet through the La Trinidad Trading Post and through the formation of collaborative farmer groups. Freshness and quality is maintained through the extensive use of cold storage at each step in the marketing system. The cold chain system for the lettuce involves harvesting and packing by the farmers. The harvest is then transferred to a pre-cooling plant where the lettuce are sorted, graded, packed, stored and later loaded onto a refrigerated truck for transport directly to the plant in Metro Manila for processing and subsequent dispatch. The cold chain was established in coordination with the DA-CAR, Benguet Vegetable Enterprise Multipurpose Cooperative, Bureau of Postharvest Research and Extension, Bureau of Agricultural Research and BSU.

Trading platforms such as the Agro Processing Center (APC) serve as the market conduit or consolidators and transact with the traders and end users. There is a need to support APC with equipment for sorting, handling, grading, washing, packing and preparing crops for selling. The APC provides an avenue for the farmers and the end

market to meet (as it markets and finances the produce of the farmers and transacts with the trader). This prevents the farmer from being exploited by the traders in terms of pricing. In connection to this, the Department of Agriculture and the provincial government in Nueva Vizcaya, Bayombong has recently built a P.5 million trading center to help organic farmers in promoting and marketing their products.

Furthermore, the Department of Agriculture Bicol has also turned over Php 15.8 worth of various interventions to individual farmers, farmers' associations and 37 LGUs of Camarines Sur. Located near the national highway and the Agriculture Research Training Center, the Organic Farmers Trading Center in barangay Magsaysay in this town is a one-stop shop among consumers patronizing organically—produced vegetables, poultry and pork. Lastly, the Agricultural Credit Policy Council (ACPC) released a total of P741.96 million in loans under the Production Loan Easy Access (PLEA) and Survival and Recovery (SURE) Assistance Programs by the end of the third quarter of 2017. Under the PLEA, a total of P675 million were released to 25,256 small farmers and fisherfolk (SFF) through 84 lending conduits. The program covers a total of 49 areas identified by the DA based on poverty incidence and concentration of marginal farmers and fishers unserved by banks. On the other hand, SURE has released loans of P66.96 million to 4,129 calamity affected SFFs through 11 lending conduits serving areas which have been declared under a state of calamity by the concerned local government units. The SURE Assistance Program is a quick-response, post-disaster support facility for calamity affected small farmers and fisherfolk and their households. Other private companies such as iFarms, Inc. and TraXion have also leveraged on advanced technologies such as eWallet to sustainably connect farmers to retail, provide insurance and give blockchain solutions for enterprises with technological advising and consulting.

As part of the Philippine government's fishing ports development project in 1979, Japan Bank for International Cooperation (JBIC) provided support for the yen loan funded "Nationwide Fishing Ports Project", the objective of which was to develop five modern fishing port complexes (Iloilo, Zamboanga, Lucena, Camaligan and Sual) equipped with docking and cold storage facilities. The five port complexes were completed in April 1992. Phase II of this project was planned with the primary objective

of increasing supplies of aquatic product by reducing post harvest losses to be achieved via the construction of fishing port complexes, which were sorely underdeveloped, and the development of basic infrastructure including cold storage to cover every stage of the fishing process from production to distribution. One such project was the Davao Fish Port Complex (DFPC). Through this project, one berth (total length 235m), a 350-meter breakwater, a 480-meter sea wall, one market hall (total area 1,700m3), an ice-making facility (production capacity: 30 tons/day), freezers (270kg/day × 2), cold storage (80 ton capacity), a sewage treatment plant (300 tons/day), and administrative buildings were developed at the DFPC. Another project was the General Santos Fish Port Complex (GSFPC). It was officially completed in December 2000. Basic facilities that are operational is comprised of three berths and three market halls, plus functional facilities such as ice plants and refrigerators.

In the livestock and poultry sub-sector, a study conducted by Luna (2008) stated that Livestock Auction Market System (LAMS) promotes fair trading between farmers and buyers where animals are graded and assessed at market value. Currently, marketing of live animals is done through middlemen. The benefits of a livestock formal market, based on actual experiences of farmers and traders doing transactions at the Padre Garcia LAM, are access of farmers to cold chain resources, support services and modern infrastructure, proper documentation of animals which lessens the fear of buying stolen animals, encouragement of farmers to increase production and farm income, wide choices of animals for buyers and fair trading between sellers and buyers. One of the negative impacts of LAMs is the effect on the environment. If not properly taken care of, the wastes will increase with the increase in the volume of animals brought into the market without the benefit of an efficient cold chain system. Moreover, possibility of traffic congestion is expected due to added trucks of traders coming into the area.

Hog production in Caraga region is dominated by backyard raisers (95%) and very few from commercial farms (5%). Production is very low, thus, favoring the importation of hogs and meat products in the region. It is against this backdrop that the swine farmers in the province take the colossal challenge to increase production with the backing of feed producers, micro-finance institutions, technology service providers from

the private and government sectors and the support from the local government units and agencies. With this, the Winrock International – Philippine Cold Chain Project (WI-PCCP) under the support of the United States Department of Agriculture (USDA), organized and sponsored an event to 61 swine industry value chain players across Caraga last April 19-20, 2018. Realizing the importance of linking the different segments of the industry and working together, the need to form a working group was well supported. Ten participants from across the value chain volunteered to be a part of the group, now dubbed as Caraga Swine Industry Development Working Group (CSIDWG).

Distribution Stage

Handling and Transporting

Land transportation is usually done by trucks from the packing facilities to the terminals and ports for distribution internationally. On the other hand, jeepneys and tricycles are usually used for transport straight to the local wholesalers and retailers. For fruits to be marketed to the northern part of the country where the major domestic market is situated, crops from the southern part where they are produced are usually shipped through reefers or refrigerated cargo ships. If there are no delays, transit time is about 36 hours (Nuevo and Apaga, 2010). The refrigerant gas R404A that is used is a colorless odorless mixture of CFCs (chlorofluorocarbons) and HCFCs (hydrochlorofluorocarbons). As seen in Figure 3.3 the Global Warming Potential (GWP) of this particular mixture is 3,921.6. On a per hour basis, the cooled transport uses 1.5 g of refrigerant per truckload.

compound	Percentage present in refrigerant gas R404A	GWP for 100 year-time interval	% x GWP
CHF_2CF_3 (HFC-125)	44%	3,500	1,540
CH_3CF_3 (HFC-143a)	52%	4,470	2,324.4
CH_2FCF_3 (HFC-134a)	4%	1,430	57.2
Total	**100%**		**3,921.6**

Figure 3.1 Compounds and GWP of the Refrigerant gas R404A

Source: http://cameochemicals.noaa.gov/chemical/26023; PAS 2050

After the ship has docked, it takes about five to six hours for the fruit to be released (Nuevo and Apaga, 2010). If the fruit is bulk loaded, it takes another sixteen hours for its stripping. Loading and unloading are done manually which often results to mechanical

injury. In this stage, mechanical damage of the fruit is precedent to major food losses due to the deteriorative nature of those mechanical injuries (Mopera, 2016). Moreover, fruits are transported in open air and unrefrigerated trucks and jeepneys. Poor roads, inefficient logistical management and lack of proper vehicles for transport are often the cause of food loss. Vehicles are usually overloaded to maximize the use per vehicle, which in turn results to the compressional damage of the fruits, especially those at the bottom. Similarly, vehicles used for loading vegetables are usually uncovered trucks (forward with open sides or the enclosed type large jeeps with windows). Wooden crates of tomatoes are usually loaded side by side with sacks of leafy vegetables leaving lots of opportunities for bruising and other damages while in transit. Truck loaders who are regular features of trucking services throw sacks/crates atop trucks or push hard inside jeeps oblivious of handling damages. They usually sit on top of loaded vegetables while vehicle is in motion or while waiting for other goods to be loaded. Common constraints and challenges for cold chain transportation development include high electricity price and insufficient supply of electricity, underdevelopment of transportation infrastructure, unorganized farmers, lack of consumers' awareness of cold chain, and heavy traffic congestion and restriction in Metro Manila. **Exceptions to these poor transport practices include those crops transported using refrigerated vans from La Trinidad through the Benguet Cold Chain Project. However, it has been observed that in order to maximize the capacity utilization of these refrigerated vans, different fruits and vegetables requiring different maintaining temperatures are loaded altogether in one refrigerated van where a fixed cooling temperature was set. This is clearly an indication of the cold chain system's inability to match production capacity at the farm level and demand at the retail distribution level.**

In the fisheries subsector, there is an estimated total loss of 25-30% of catch due to improper handling. Once a processing plant has completed an order and the relevant paperwork at the BFAR has been obtained, all items are loaded into a reefer container. Around 40 feet reefers are used which are then picked up by a truck owned by the shipping agent or processing plant. The reefer is then transported to one of the country's main harbors that is in the closest vicinity of the processing plant (Manila, Batangas, General

Santos/Davao or Cebu). Problems related to internal transport and logistics in the Philippines had been cited in the literature as well. For agricultural products, participants in the food cold chain lament the inefficient road and port networks that constrain the transport of goods from key production areas to markets (Llanto 2012). Results of the study reveal that one of the main problems is limited road capacity. Overall, domestic logistics services in the fisheries supply chain are also seen as inadequate in terms of expertise, capacity, and overall service quality. **It must be noted that a critical factor in maintaining food quality throughout the cold chain is the continuity of efficient cold chain practices from the farm/sea all the way to the market. Any break in this cold chain system due to transport/infrastructure constraints or even just the absence of pre-cooling facilities around farms or the absence/lack of cold storages in public markets will drastically decrease food quality and increase food losses as food moves down the supply chain.** It is imperative, therefore, that connectivity between fish-producing and fish-processing islands should be pursued, such as by further improving roll-on roll-off (RORO) shipping.

Eutectic Plates

Eutectic plates are isothermal containers used for the storage and transport of chilled and frozen products at a controlled temperature (refer to Figure 3.2). They are suitable for logistic operators, chilled or frozen food distributors and manufacturers, and supermarket chains that require multiple drop-off locations for multiple food products requiring varying maintaining temperatures during transport. These plates may be transported using single conventional non-insulated vehicles where chilled, frozen and ambient temperature products can be simultaneously transported as these virtually maintenance free plates can be set to maintain various temperatures for different applications (refer to Table 3.1). Total compliance with the cold chain at all stages of transport is guaranteed, hence avoiding any detrimental breaks in the food cold chain as these plates can be loaded inside the cold room of the wholesale midpoint and unloaded at the refrigerated counter of the destination supermarket. Furthermore, these plates are fully

recyclable at the end of their operating life. The use of eutectic plates is a good alternative to other cooling mediums such as dry ice and normal ice because they are reliable, environmentally friendly, re-usable and do not evaporate into smoke or melt into water to be thrown away (refer to Table 3.2).

Figure 3.2 Eutectic Refrigeration System

Table 3.1 Maintaining Temperatures for Different Applications of Eutectic Plates

Cooling Capacity (in degrees Celcius)	**0**	**-5**	**-11**	**-15**	**-21**	**-25**
Kept at freezing temperature (before use in degrees Celcius)	**< -10**	**< -10**	**< -10**	**< -10**	**< -10**	**< -10**
Melting point of the plate (in degrees Celcius)	**0**	**-3**	**-11**	**-15**	**-21**	**-24**

Table 3.2 Benefits of Using Eutectic Refrigeration System

Eutectic Refrigeration System	**Air-blown Refrigeration System**

Zero-emission	**High carbon emissions**
Zero-noise operation	**High level of noise**
Low operating cost	**High operating cost**
No fuel or energy required for refrigeration during delivery	**Runs on vehicle engine or auxiliary engine**
No connection to vehicle engine	**Runs on vehicle engine or auxiliary engine**
Maintenance-free	**High maintenance**
Skilled labour not required for maintenance	**Skilled labour required for maintenance**
Merchandise is preserved in case of vehicle failure	**Vehicle failure may cause product safety issues**

Zero Emission and silent operation

Eutectic system does not use diesel, making refrigerated bodies with eutectic cooling an eco-friendly alternative, compatible both with electric trucks and internal combustion engines. Due to zero emissions and an absence of engine noise, such refrigerated trucks are ideal for multi-drop operations, especially in urban areas.

Low operating cost

Compared to conventional truck refrigeration systems which require an auxiliary engine or power from the main engine to run the compressor, eutectic refrigeration system provides improved fuel economy and more consistent refrigeration performance. The eutectic plates are charged at night on mains power when electricity is most affordable. They store the cold energy and gradually release it in the form of cold air, thus refrigerating the area around. No fuel or energy is required for refrigeration during delivery.

No connection to the vehicle engine

Refrigerated body with eutectic system is completely independent from the chassis, therefore stable temperature is ensured at all times. Once the eutectic plates are charged, they provide a reliable, rapid cooling for a specific duration of time even with frequent door openings. Merchandise is also preserved in case of vehicle failure.

Maintenance-free

Refrigerated bodies with eutectic refrigeration require only very basic maintenance, mainly cleaning, lubricating and taking care of the refrigerant level. Skilled labor is not required for the daily operation and maintenance.

Storage

The cold storage industry in the Philippines is growing and many of the market players are expanding and increasing their capacity to accommodate the demand for cold storage facilities. Most of the cold chain system in the Philippines are developed and operated by major local logistics companies and retailers (superstores and convenience stores) that sell imported agri-products and foods (refer to Table 3.3).

Table 3.3 Cold Storage Facilities of Major Logistics Companies

Cold Chain Facilities of Major Logistics Companies in the Philippines

Company Name	Capital	Location	Cold Chain Facilities
Royal Cargo Inc.	Philippines	Manila	Freezing & refrigeration storage: 37,000 ㎡ Cold trucks: 185
Koldstor Centre Philippines Inc.	Philippines	Imus	Freezing & refrigeration storage: 4,660 MT Blast freezer: 14 MT
Igloo Supply Chain Philippines	JV (Singapore-Philippines)	Manila	Freezing & refrigeration storage: 9,400 ㎡ Cold trucks:25
		Davao	3 Freezing storages 37 meter long temperature controlled receiving & loading bay
Polar Bear Freezing and Storage Corp.	Philippines	Pasig, Davao, Cagayan de Oro, Bicutan	Freezing & refrigeration storage: 36,600 ㎡ Blast freezers
Glacier Refrigerated Services Corp.	Philippines	Manila, Quezon City	Freezing & refrigeration storage: 14,400 ㎡ Blast freezers
Icebox Logistics Services Inc.	JV (Philippines -US)	Manila	Reefer containers: 140 Reefer vans

Source: JETRO (2014) "Study on Cold Chain in Major Countries and Regions: the Philippines" and website of each company.

There are very little problems experienced with cold storage facilities and operations. Problems are mostly related to energy efficiency. High energy costs in the Philippines relative to its Asian peers coupled with process inefficiencies and financial constraints of most SMEs make it difficult to achieve energy efficiency. As an evidence, energy audits conducted by the DOST-ITDI Energy Division on 34 cold storage SMEs from 2003-2017 reveal that potential savings ranging from Php 4,000 to Php 1.6 million may be realized over a six month period if process and equipment inefficiencies are eliminated (refer to Table 3.4). Among the companies audited, two companies namely: Global Food Solutions Inc. and Roel's Food Corp. implemented the process and equipment recommendations provided by DOST-ITDI Energy Division field personnel. These implementations led to an actual realized savings of Php 516,650.00 for Global Food Solutions Inc. and Php1,874,581.18 for Roel's Food Corp. over a six-month period. A cold storage design and installation company puts it this way: Fixing the building envelope and the process first **then using the best technology alongside the "optimal" process ensures the achievement of energy efficiency. This means that building code standards for the use of proper building materials should be in place. There must be standards for copper piping, bracing, ducting and insulation materials, among others.**

Currently, many building and material standards used in the Philippines are adopted from other countries and may not be relevant for tropical countries like the Philippines. Government support is needed for setting up, implementing and monitoring these standards.

Table 3.4 DOST-ITDI Energy Audit Results

NUMBER	NAME	LOCATION	SCOPE OF AUDIT	DATE OF AUDIT	TOTAL POTENTIAL ANNUAL SAVINGS (PhP)
1	Ajinomoto	Pasig City	Boilers, chillers, motors	May 5-8, 2003	**383,057.59**
2	MEKENI Foods Corp.	Porac, Pampanga	Boilers, motors, lighting, air Comp, CT, steam system	June 15-16, 2006	**1,621,991.23**
3	Mother Earth Prod. Inc.	Mabalacat, Pampanga	Lighting, chillers, boiler, Process, motors	April 16-20, 2007	**589,258.56**
4	Malow's Meat Prod.	Guagua, Pampanga	Lighting, refrigeration, Process, motors	July 23-24, 2007	**125,746.24**
5	Arbee's Food Prod.	San Fernando, Pampanga	Lighting, refrigeration, Process, motors	July 25, 2007	**143,604.72**
6	**Roel's Food Corp.**	Mabalacat, Pampanga	Motors, refrigeration, air comp, lighting, boiler, process	Aug 28-Sept 1, 2007	**808,634.00**
7	Pacific Isles Int'l Trading	Rodriguez, Rizal	Reefer Van, motors, lighting, Furnace, pumps	Nov 27-28, 2008	**78,678.00**
8	Dairyman Ice Cream	Plaridel, Bulacan	Refrigeration, motors, air comp, boiler	Sept 15-18, 2009	**25,027.60**
9	Marigold	Pasig City	Boiler, chillers, motors, lighting, process	June 17-18, 2010	**163,800.00**
10	**Global Food Solutions Inc.**	San Pablo City	Boiler, process, motors, lighting	Oct 18, 2010 & Dec 6, 2010	**118,643.61**
11	JBC Food Corporation	Caloocan City	Chillers, air comp, motors, process,	Feb 10-11, 2011	**225,523.79**

			MDP		
12	Cenmaco Inc.	San Juan City	Boiler, cold storage, motors, lighting, process	May 3-4, 2011	**361,396.06**
13	Fitrite Inc.	Novaliches, Q.C.	Boiler, motors, lighting, process	May 6, 2011	**799,296.30**
14	RJ Valor	Marikina City	Cold storage, motors, lighting	July 7, 2011	**55,662.86**
15	Pastel Deli	Marikina City	Chillers, aircon, motors, lighting, process	May 28, 2012	**13,211.07**
16	Majestic Monarch	Marikina City	Chillers, aircon, motors, lighting, process	May 30, 2012 &	**24,242.35**
17	LJK Fish Dealer	Jaro, Iloilo City	Lighting, Refrigeration, elect	November 13, 2013	**17,098.84**
18	Wiggie's Ice Cream	Balanga City, Bataan	Lighting, refrigeration, aircon, motors	June 25-26, 2014	**34,421.77**
19	Dialyn's Bakeshop	Baler, Aurora	Lighting, refrigeration, oven, motors	July 9-10, 2014	**3,758.14**
20	Nueva Ecija Federation of Dairy Carabao Coop. (NEFEDCCO)	Talavera, Nueva Ecija	Lighting, refrigeration, aircon, boiler, motors	July 10-11, 2014	**9,853.87**
21	Angel Famous Gourmet Food Corp.	Mabalacat, Pampanga	Motors, lighting, refrigeration	October 7, 2014	**517,233.49**
22	FNC-Nathaniels Food Corp.	San Fernando, Pampanga	Motors, refrigeration, lighting	November 7, 2014	**282,793.03**
23	Ocean Deli Packing Corp.	Gen. Santos City	Motors, lighting, refrigeration	November 25, 2014	**432,231.61**
24	Aloot Foods	Koronadal City	Motors, lighting, refrigeration	November 28, 2014	**52,554.78**
25	R.D. Alpine Ice Cream	Tacurong, Sultan Kudarat	Motors, lighting, refrigeration	September 16, 2015	**18,732.47**
26	AF Global Foods Inc.	Guiguinto, Bulacan	Motors, lighting, refrigeration	October 6, 2015	**305,827.33**
27	Bidasoy Nutrifood Products	Cabanatuan City, N. E.	Motors, lighting, ref & ACU	December 10, 2015	**18,444.44**

28	Geno's Ice Cream	Orani, Bataan	Motors, lighting, refrigeration	May 4, 2016	**16,141.43**
29	Phil Carabao Center - CDCPF	Muñoz, Nueva Ecija	Motors, lighting, refrigeration	June 6, 2016	**35,546.19**
30	Vegie Mix Food Corp.	Pasig City	Motors, lighting, refrigeration	June 16, 2016	**518,003.57**
31	Rolsen Food Manufacturer	Sta Rita, Pampanga	Motors, lighting, ACU, ref	April 4, 2017	**216,390.96**
32	DVF Dairy Farm Inc.	Talavera, Nueva Ecija	Motors, lighting, ACU, ref	June 6, 2017	**19,458.54**
33	Gem's Ice Cream Facility	Tacurong, Sultan Kudarat	Motors, lighting, ref, ACU	October 25, 2017	**34,971.49**
34	De San Antonio Ice Cube	Koronadal City	Motors, lighting, ref, ACU	October 26, 2017	**23,932.46**
TOTAL:					**8,095,168.39**

To ensure energy efficiency in cold storage facilities, pre-cooling of harvested crops is necessary in order to prepare the crop for proper temperature input into the cold storage process. However, these facilities are lacking both in the northern and southern farms in the Philippines. Since majority of transport facilities currently used to bring these vegetables to Manila do not have refrigeration, the cold chain system is already broken and it becomes useless to pre-cool considering that the six hour trip to Manila is without refrigeration anyway. Fruits and vegetables are just transported during the late hours of the night to dawn in order to take advantage of the cooler ambient temperature. Hence refrigerated transport and innovative transportation systems such as those using eutectic plates play very significant roles in ensuring the efficiency of the entire food cold chain from farm to market.

The important stakeholders here are local government officials and farmers as they have to address the current lack of facilities in ensuring that harvested crops preserve their quality when they reach the intended customers. On the other hand, careful assessment of the most appropriate location of these facilities should also be considered. The BAPTC (Benguet Agri-Pinoy Trading Center) is a $16 milllion-worth facility which serves as a trading platform for more than 6,000 farmers in the Cordillera Province, a major

agricultural area in the north of the Philippines, about a 6-hour drive from Manila. Situated on a 4-hectare land owned by the Benguet State University (BSU), BAPTC has three buildings housing trading spaces and processing facilities for highland vegetables such as carrots, lettuce and broccoli. This center also has 12 cold storage facilities but no precooling facilities which are critical to effective food preservation. It is important to note that these cold storage and processing facilities are currently unused by the accredited cooperatives that are running the center. Harvested crops, especially during peak seasons, change hands so quickly such that cold storage facilities in locations near the farms are no longer necessary. The crops are transported from the farms to the trading center within 6-10 hours and are usually traded and ready for transport to Manila in a matter of a few hours. Cold storage facilities are intended as holding areas for food quality preservation where there is expected to be significant waiting times. As such, it may be better to focus on establishing pre-cooling facilities near farms and a cold chain transportation component to ensure high quality deliveries to Manila coupled with strategic cold storage facility locations in distribution points or selling areas where these crops/meat are expected to have significantly longer waiting times before being sold to customers. Cold storage must be positioned in or near distribution points where consolidation of produce takes place and not at the trading centers where goods are supposed to move quickly through the supply chain. Strategically located food terminals with the required cold storage and processing facilities reduce food waste significantly. Fast cooling, sorting, grading, and packing are desired immediately after harvest to condition the produce for the cold chain and to maximize their benefits from the cold chain features (refer to Figure 3.3). For cold chain transportation systems, it may be helpful to have regulations that require transporters to have data logging technologies so that temperature readings throughout the transport duration may be monitored by the recipients of these food deliveries.

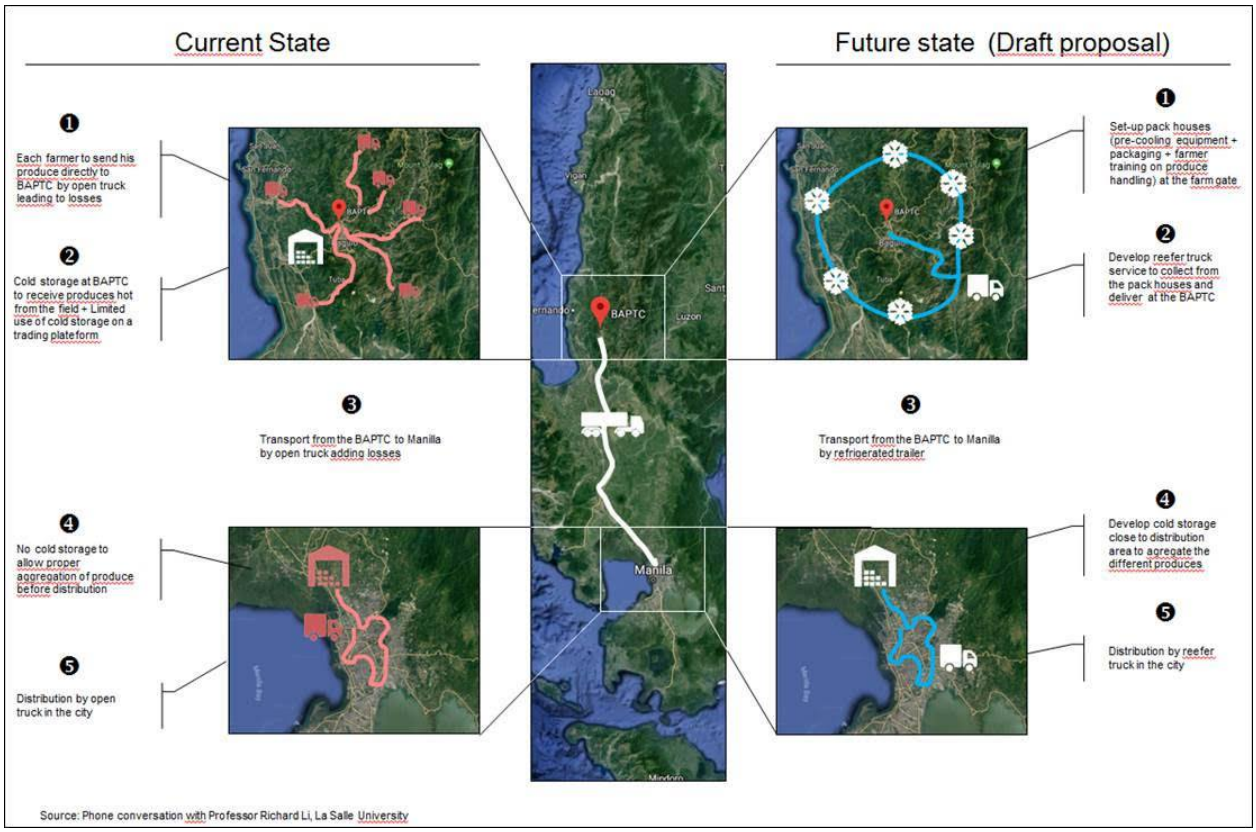

Figure 3.3 Current and Future State of Cold Chain System Diagram

Another evidence of poor cold storage would be the cooling practices in supermarkets. In the following pictures, it can be seen that the supermarkets in the Philippines do not observe proper temperature management as the poultry products are only placed on top of crushed ice (refer to Figure 3.4a and 3.4b), thereby exposing the meat to an open environment and the cooling property escapes into the said environment. Such practice is also seen in traditional trading outlets, or wet markets, where the merchandise is stored in buckets of ice or displaced on top of ice. Meat products are just displayed by hanging them using hooks without ice or any form of cooling medium. Open freezers as seen in the supermarket picture (refer to Figure 3.4c) are very low in energy efficiency as the cooling property escapes into the environment. Nonetheless, green freezers have been observed in the storage of ice cream products (refer to Figure

3.4d) which should also be observed in all sorts of refrigerating technologies in the supermarket.

Figure 3.4a Chicken Handling Process Inside Supermarket

Figure 3.4b Poor Temperature Management in Supermarkets (meat color turning brown)

Figure 3.4c Open Freezer Technology

Figure 3.4d Use of Greener Freezer Technology

Cold storage facilities make use of refrigerants to keep the temperature cool. However, most common refrigerants used in the market today have a large negative impact on the environment. An example of which is R-22 which is high in both ODP and GWP. Due to varying factors such as improper handling, refrigerants are discharged or

leak into the environment leading to an unsustainable environment. Ozone-depleting substances (ODSs) are usually those first and second-generation refrigerants (Thomas and Muñoz H., 2017). These substances destroy the ozone gas in the atmosphere eventually through a series of chemical processes (Thomas and Muñoz H., 2017). Chlorofluorocarbons (CFCs), hydrobromofluorocarbons (HBFCs), methyl, bromide, hydrochlorofluorocarbons (HCFCs), carbon tetrachloride, and halons (are part of the ODS family (Carpenter and Reimann, 2014). In continuation, the effects of the ODS can be better expressed through the ozone depletion potential (ODP). It is defined as the chemical ratio of the amount of stratospheric ozone destroyed by the release of a unit mass of that chemical at the Earth's surface to the amount destroyed by the release of a unit mass of chlorofluorocarbon 11, CFC-11 ($CFCl_3$) (Thomas and Muñoz H., 2017). In other words, the ODP of CFC-11 (also known as R-11, where "R" stands for refrigerant) is fixed at one (1.0), and the ODP of other chemicals is expressed relative to this. Additionally, global warming continues to be a threat. With this, the global warming potential (GWP) is defined to measure the relative radiative forcing impact of a particular greenhouse gas (Houghton, Meira Filho, et al., 1995). Figure 3.5 shows the ODP and GWP values of a few common refrigerants

Refrigerant Type and Name	ODP	GWP	Use
Chlorofluorcarbons			
CFC-11	1.0	4,680	Centrifugal chillers
CFC-12	1.0	10,720	Refrigerators, chillers
CFC-114	0.94	9,800	Centrifugal chillers
CFC-500	0.605	7,900	Centrifugal chillers, humidifiers
CFC-502	0.221	4,600	Low-temperature refrigeration
Hydrochlorofluorocarbons			
HCFC-22	0.04	1,780	Air conditioning, chillers
Hcfc-123	0.02	76	CFC-11 replacement
Hydrofluorocarbons			
HFC-23	< 4 x 10-4	12,240	Ultra-low-temperature refrigeration
HFC-134A	< 1.5 x 10-5	1,320	CFC-12 or HCFC-22 replacement
HFC-245FA	~10-5	1,030	Insulation agent, centrifugal chillers
HFC-404A	~10-5	3,900	Low-temperature refrigeration
HFC-407C	~10-5	1,700	HCFC-22 replacement
HFC-410A	< 2 x 10-5	1,890	Air conditioning
HFC-507A	~10-5	3,900	Low-temperature refrigeration
Natural refrigerants			
Carbon dioxide (CO_2)	0	1	
Ammonia (NH_3)	0	0	
Propane (C_3H_8)	0	3	

Figure 3.5 Examples of ozone depletion and global warming potentials of refrigerants (100-yr values)

Given the growing concern of the negative impact of refrigerants, low environmental impact solutions should be observed as substitutes to the old refrigerant technologies. Such include natural refrigerants, not-in-kind (NIK) solutions, and new low-impact refrigerant blends. Natural refrigerants include CO2, hydrocarbons, ammonia, water, and air. These climate- and ozone friendly refrigerants are increasingly available for some RACHP applications. Safety measures will need to be carefully put in place for some of these refrigerants that are toxic or flammable. CO2 systems have high operating pressures, even higher than R-410a, and need to be designed accordingly. Care must be taken to ensure that CO2 levels do not rise in occupied spaces because of the toxicity aspect. Another would be Hydrocarbons refrigerants which are natural compounds that are generally available at a low cost and have excellent thermodynamic properties. HC refrigerants include propane, butane, ethane, isobutene, and isopentane. These refrigerants (e.g., propane and propylene) have been used for over 10 years in small capacity chillers (up to 200 kilowatts). The recent development of domestic refrigerators and freezers using HCs as refrigerants has contributed to the use of these refrigerants in small air-conditioning units. Air-conditioning units using HC technology have a high energy-efficiency rating and can be designed to achieve good safety measures. Another would be Unsaturated HFCs or Hydrofluoroolefins (HFOs) refrigerants. Their GWPs (for a 100-year span) are around 20 or less. They are thus called low-GWP HFCs. HFOs are becoming available as refrigerants and for some foam-blowing applications. At present, a few low-GWP HFCs are being either phased in or proposed as substitutes for HCFCs and for some of the high-GWP HFCs (with lifetimes from several to tens of years). Examples include HFC-1234yf, as a substitute for the refrigerant HFC-134a; HFC-161, as a substitute for the refrigerant HCFC-22; and trans-HFC-1234ze, as a substitute blowing agent for some thermal insulating foams. Another would be Ammonia (NH3) based refrigerants. Ammonia is widely used in industrial applications because of its excellent thermodynamic performance. However, it cannot be safely used for food storage because it will contaminate food if it leaks. Some use secondary refrigerants like glycol instead. Furthermore, ammonia equipment are expensive. An example of an ammonia based refrigerant would be the R-717. Lastly, water is used for making ice in limited industrial applications. Because of its very low vapor pressure, its machine size per unit

capacity is of an order of magnitude larger than current building machinery. Although it is the main gas responsible for the absorption of infrared radiation in the atmosphere, its very short atmospheric lifetime (nine days) makes any anthropogenic emission completely benign.

ANNEX

Eutectic Plates

Phase change materials (PCMs) have been considered as an innovative technology that can reduce the peak loads and heating, ventilating and air conditioning (HVAC) energy consumption in buildings. Basically they are substances capable of storing or releasing thermal energy as latent heat. Because the amount of latent heat absorbed or released is much larger than the sensible heat, the application of PCMs in buildings has significant potential to reduce energy consumption. However, because each PCM has its own phase change temperature, which is the temperature at which latent heat is absorbed or released, it is important to use an appropriate PCM for the purpose of building envelope design.

There are four working temperature ranges for phase change materials. (1) The low temperature range from (-20°C to +5°C) where the PCMs are typically used for

domestic and commercial refrigeration; (2) the medium low temperature range from (+5°C to +40°C) where the PCMs are typically applied for heating and cooling applications in buildings; (3) the medium temperature range for solar based heating, hot water and electronic applications from (+40°C to +80°C); and (4) the high temperature range from (+80°C to +200°C) for absorption cooling, waste heat recovery and electricity generation. Different types of phase change materials applied to each temperature range are reviewed and discussed, in terms of the performance, heat transfer enhancement technique, environmental impact and economic analysis. The review shows that, energy saving of up to 12% can be achieved and a reduction of cooling load of up to 80% can be obtained by PCMs in the low to medium-low temperature range. (A Review of the Applications of Phase Change Materials in Cooling, Heating and Power Generation in Different Temperature Ranges, Kun Du and Hao Liu, 2018)

One of the beneficial applications of Eutectic plates is in the transportation of perishable foods and temperature sensitive pharmaceuticals which require refrigerated trucks. Such refrigerated trucks are prohibitively expensive to operate as they use diesel as source of energy. Cost of diesel-generated energy is 6 times higher as compared to conventional electricity cost. Thus, phase change material store energy using a cheap source of power and release it when that cheap source of power is not available.

Insulated containers use phase change material that allows chilled and frozen products to be transported in non-refrigerated trucks at the same time. Placed at the top of the insulated container, the color coded eutectic phase change plates (refer to Figure below) allow you to determine the individual container's temperature.

The operating principle of the eutectic plates system is quite simple, and is similar to how the refrigerator in your home works. While the truck is parked, the refrigerating system is recharged. The eutectic liquid inside the eutectic plates is frozen at -40°C (for

negative temperatures) by the circulation of the Freon pumped by the motocompressor. Cold temperature is generated by the heat exchange between the surface of the eutectic plates and the inside environment. Subsequently, when the eutectic solution defrosts, it releases the “cold” previously stored in the plates, thus recovering the cold loss caused by the opening of the doors, so as to preserve the products correctly. The refrigerated body with eutectic plates imposed itself on the EEC market as the most suitable and most efficient equipment for the daily distribution of ice cream and frozen foods and it is also the ideal solution for the distribution of fresh products (dairy, meats, sausages and vegetables). Eutectic plates system is ideal in the distribution of frozen food, at negative temperatures from -18°C/-35°C. Highly cost effective, the eutectic plates system is superior to an air-blown system in multi-drop city deliveries configuration. For the whole duration of a standard delivery route, the inside temperature will be stable and gradually increase but remain within safe limits.

The vast majority of refrigerated vehicles on the market employ vapour compression refrigeration systems, operating from the vehicle’s engine or from an auxiliary diesel engine. In today’s business environment, where fleets in major cities are facing stricter regulations regarding vehicle emissions, one must look for alternatives to conventional diesel-powered transport refrigeration units. Eutectic refrigeration might be the answer. Eutectic systems consist of hollow tubes, beams or plates filled with an eutectic brine to store energy and produce a cooling effect whenever necessary to maintain the correct temperature in the refrigerated container. Eutectic system is suitable for long distance distributions as well as door-to-door deliveries and is ideal for an operation with multiple stops and door openings. The operating principle of the eutectic refrigeration system is just as simple as it is efficient. Unlike conventional systems, eutectic refrigeration uses cold source provided by an eutectic solution instead of direct expansion of refrigerant gas. The eutectic plates or beams are charged at night on main power using off-peak electricity. They store the cold energy and gradually release it in the form of cold air, thus refrigerating the area around. Refrigerated body with eutectic system is completely independent from the chassis, therefore stable temperature is ensured at all times. Once the eutectic plates are charged, they provide a reliable, rapid cooling for a specific duration of time even with frequent door openings. Merchandise is

preserved in case of vehicle failure. Eutectic system also does not use diesel, making refrigerated bodies with eutectic cooling an eco-friendly alternative, compatible both with electric trucks and internal combustion engines. Due to zero emissions and an absence of engine noise, such refrigerated trucks are ideal for multi-drop operations, especially in urban areas.

Eutectic Plates Simulation Exercise

The van simulation exercise of a 1 tonner truck from F2 Logistics took place in Sta. Rosa Ice Cream Plant last 15th of January, 2013. Twenty (20) Eutectic plates were used for the purpose of this exercise, wherein 4 of them were not frozen during blast freezing at Ugong, Pasig. Gauge temperature of the van upon departure at Ugong was -14°C.

The van arrived at Sta. Rosa Plant 10:00 A.M. at -14°C. Ice cream samples were loaded to the van in the following quantity: FN FBS Cotton Candy (78 cases), EML Ube 1.5L (155 pcs.) and EFD Macapuno Ube 1.5 L (171 pcs.). Five randomly selected samples from each variant were labeled as per trial. These samples were considered as the representative of the whole variant for observation. Ice cream products subjected to this trial were guaranteed of good condition.

Prior to loading, gauge temperature of the van and actual temperature inside were measured and recorded. Actual temperature of van was recorded by measuring the four corners of the van (Table 1). It was noticed that the actual temperature was not aligned with the gauge temperature. The latter displays lower temperature than the average temperature of four corners (Figure 1). Specific time intervals were set wherein the van roams around the plant partly subjected under direct sunlight and under the shade. It is to evaluate the van under close circumstances of the actual delivery travel time and condition.

Table 1. Actual temperature inside the van

F2 Trucking	Temperature (°C)			
	upper left	upper right	lower left	lower right
1st drop	-14	-14	-19	-21
2nd drop	-5	-3	-5	-8
3rd drop	-3	-2	-3	-3.5
4th drop	0	0	-3	-4
5th drop	-2	-2.5	-7	-9

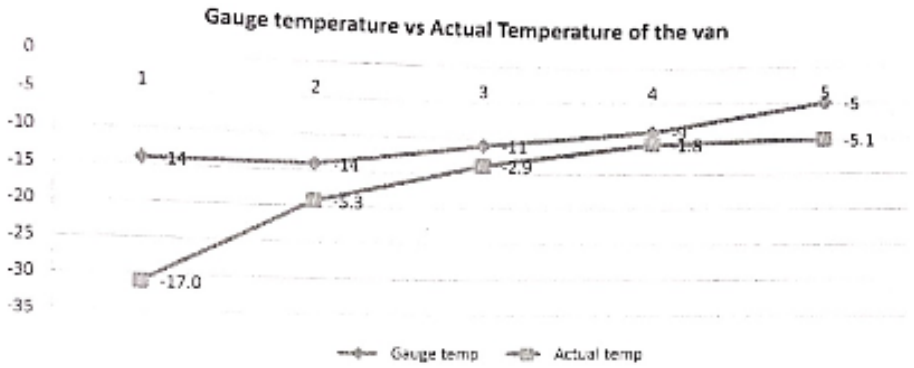

Figure 1. Gauge temperature vs actual temperature of the van.

Results showed that maximum temperature reached by the van using eutectic plates was -14°C and by the end of the trial it was -5°C. There was an increase in temperature of about 36% after almost 9 hours of usage. Temperature increases as you prolong the time and number of drops (Figure 2). Data logger was placed inside the van to monitor random changes on its actual temperature. However, results were not yet reviewed and validated.

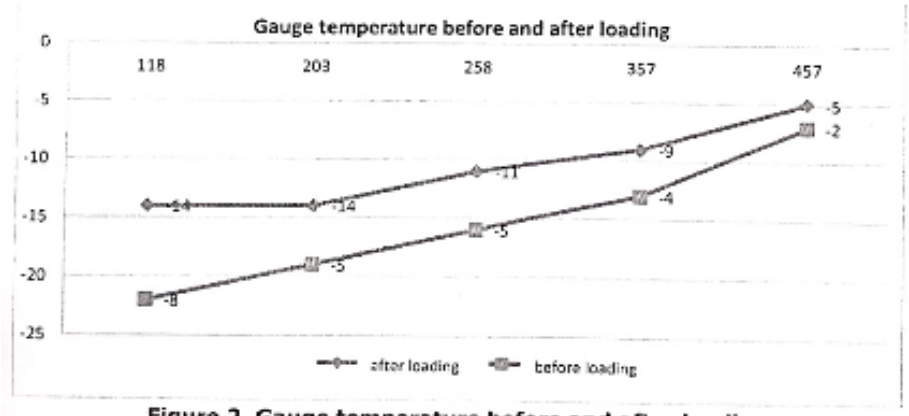

Figure 2. Gauge temperature before and after loading

It was observed that from an increase in temperature after loading, the actual temperature of the van returned to its initial temperature before loading. It is due to temperature of the ice cream itself as it equilibrates with the temperature released by the eutectic plates.

Both EML Ube 1.5L and EFD Macapuno Ube 1.5L samples were all considered in good condition at every trial drop. However, the required temperature of the ice cream

product was not maintained all throughout the series of drops (Figure 3). For the case of FBS Cotton Candy, samples dropped on the third up to fifth trial were slightly soft when pressed. All the products were generally acceptable after each drop of the five trials.

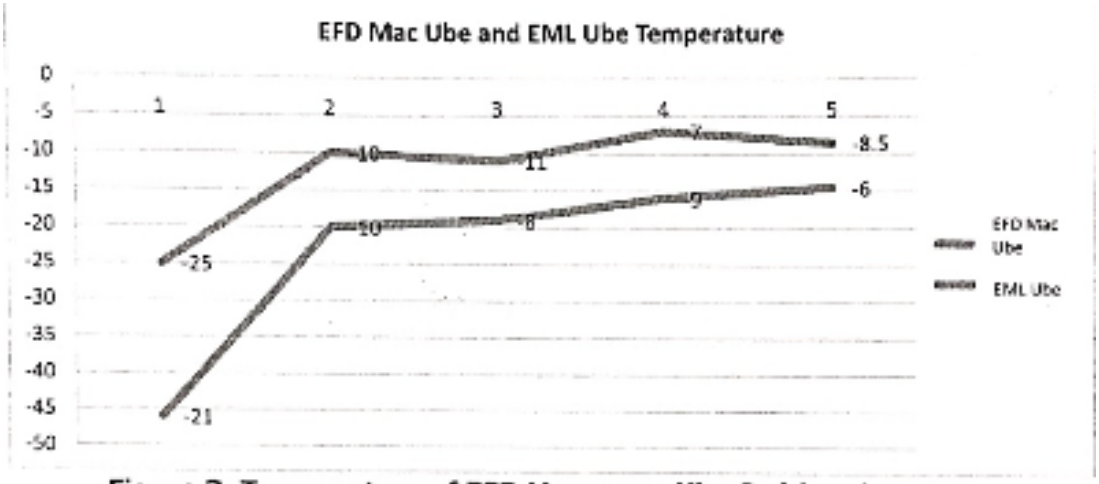

Figure 3. Temperature of EFD Macapuno Ube Swirl and EML Ube

In bulk ice cream, considering that the product is still within the required temperature, the van is suitable for only one to two drops as observed in the actual product temperature. However, it can go further until five drops considering that although the products' temperature is beyond the required, the products are still in good condition.

For the case of frozen novelties on cartons, products are in very good condition after one to two drops. It turned out that after third to fifth drop, the product is slightly soft when pressed, yet still acceptable but not at the best of its quality.

All data gathered can be validated and supported by the results from the data logger. As per the exercise, which consumed 9 hours, it is comparable to the actual duration of delivery, as well as the number of drops. However, it is very critical in terms of how long the travel time, actual loading and unloading period, and product handling and travel time from parking to storage. It is important that the trucker should practice proper palletizing for more efficient product handling.