BRIEFING NOTE

Sustainable Cold Chain and Food Loss Reduction

NOVEMBER 2019

1.

Introduction

In 2011, the Food and Agriculture Organization estimated that globally about one-third of all food produced is lost or wasted each year.[i] The estimated financial loss is about $940 billion[ii] and it creates greenhouse gas (GHG) emissions of about 4.4 gigatonnes CO_2-eq per year, which is about 8% of the total global emissions of GHGs.[iii,1]

As much as half of some temperature-sensitive produce is lost post-harvest primarily because of lack of or inadequate access to cold-chain logistics, namely, activities, both refrigerated and non-refrigerated, that connect the harvested produce with its intended consumption. With developed countries increasingly sourcing food from less developed countries, the lack of cold-chain logistics is a global challenge. Equally, climate change including the resulting increase in unstable weather patterns, threaten to increase food losses and challenge food security, intensifying the need for cold-chain systems to provide security to deal with some of this impact.

Mere use of refrigeration cannot stop food loss, which is mitigated only by bringing the food to gainful end use. Food in a refrigerated warehouse will still perish, unless connected with consumers. Connecting farmers' and fishers' produce with consumers not only reduces food loss but has a positive impact on the economics of small-holder producers, by opening connectivity to new markets and increasing income opportunities. Reduction in food loss will also help in coping with a growing population and minimize harmful greenhouse gas emissions from such loss.

Cold-chain systems typically use high-GWP (Global Warming Potential) refrigerants and grid electricity based on fossil-fuels, off-grid diesel-based generation and transport. The urgent challenge is delivering social and economic benefits by expanding cold-chain capacity quickly and affordably, while ensuring minimal pollution and adverse environmental effects.

The commitments under the Kigali Amendment to the Montreal Protocol on phasing down HFCs can help mobilise developing and developed countries to work together to use new, sustainable cold-chain systems that are high in efficiency, safe, and use low or zero-GWP refrigerants and renewable energy sources. For developing countries, the benefits would be substantial as their markets would move away from being the recipients of obsolete, low efficiency, and high-GWP refrigerant equipment and technologies.

1 **The greenhouse gas emissions associated with this food loss and waste come from a variety of sources, including on-farm agriculture emissions; wasted electricity and heat used to manufacture and process the food; energy used to transport, store and cook food that is eventually lost or wasted; landfill emissions from decaying food, and emissions from land-use change and deforestation.**

2.

Food wastage

Food is **lost** and **wasted (food wastage)** throughout the supply chain after harvest from producer to final consumption.

- **Food loss:** damage and spoilage from producer to market, including lack of temperature management at harvest, packaging, in transit and storage.
- **Food waste:** discard and rejection of edible foods at the retailer (supermarkets, shops, markets) and consumer (once the food has left the retail space).

While managing both is critical, food loss is the larger issue globally, especially in developing countries; whereas in developed countries food waste by the consumer is dominant.

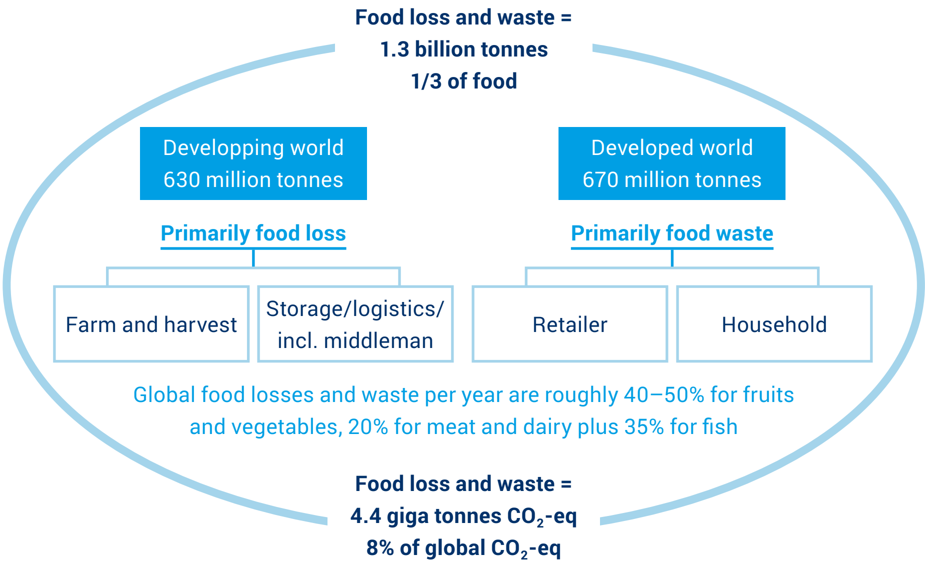


Figure 1. Estimated amounts of food loss and food waste. Peters, 2019

BOX 1: SOCIAL AND ECONOMIC IMPACT OF FOOD LOSS AND LACK OF COLD CHAIN

Today the Food and Agriculture Organization estimates that 14% of food produced is lost each year before it reaches the retailer or consumer[iv].[2] Food loss also means waste of labour and reduced incomes for farmers; and it represents a major waste of energy, land, water and the other resources used to produce the food. In terms of numbers:

- More than 820 million people globally are malnourished.[v]
- More than 735 million people continue to live in extreme poverty[vi], of whom over 80% reside in rural areas and are primarily dependent on agricultural production for economic well-being.[vii]

2 To provide more clarity on Food Wastage, FAO's 2011 estimate is in the process of being replaced by two separate indices: the Food Loss Index (FLI) and the Food Waste Index (FWI). The FLI provides new loss estimates from post-harvest up to, but not including, the retail stage; food waste by retailers and consumers is not included in the FLI.

BOX 1 (CONTINUED)

- Regarding agriculture's importance to employment, as an indicator, 59% of the workforce in India is directly employed by agriculture [viii]; in Rwanda the figure is 72%[ix].
- The World Health Organization (WHO) estimates that 600 million people – almost 1 in 10 worldwide – fall ill every year after eating contaminated food, around 420,000 of whom die.[x]
- It is estimated that 56% more food in 2050 than in 2010 will need to be produced globally to feed the world.[xi]
- Of the total CO_2-eq impact of food wastage, post-harvest food loss due to the lack or inefficiency of cold-chain systems alone accounts for more than a fifth of food wastage and approximately 1 gigatonne of CO_2-eq.[xii]

3.

What is a cold-chain system?

A food cold chain is the integrated set of activities undertaken to ensure that perishable food products are kept at the optimum temperature in the supply chain that stretches from freshly harvested products to the end consumer. This requires a resilient network of temperature-controlled pre-conditioning, packhouses, processing factories, vehicles or containers, cold stores, and wholesale/retail establishments. It also requires temperature control by end users including domestic food consumers and the food service industry (restaurants, etc.). A robust cold chain seamlessly maintains the temperature of sensitive foods while they are moved from farm, harbour or beach to consumption centres across different locations and over time.

A cold-chain system:

- can connect local clusters of farmers, growers and fishers with higher-value local, national and international markets while simultaneously helping to build the sustainable and resilient food supply system necessary to feed a growing population;
- affords market connectivity which incentivises farmers to raise their output because they will earn more from what they produce;
- allows farmers and growers to transition from growing crops of staples to producing higher value, perishable, micronutrient-rich foods, such as fresh fruits and vegetables;
- has the potential to allow higher value to move to rural communities, creating jobs and broader economic growth.

For a majority of agricultural or seafood products, the cold chain can be categorised into six stages.

BOX 2: THE STAGES OF A COLD-CHAIN SYSTEM

1. **Harvesting** – Deterioration of the products' integrity occurs from the moment of harvest. A positive step can be to harvest at the coolest time of day and use shading after the harvest. Fish should be stored in ice. Milk needs cooling immediately after milking.
2. **Preconditioning** – The preparatory phase for onward connectivity to markets. Products need to be cooled to an optimum temperature, sorted and packed. While waiting for onward transport, products have to be kept in refrigerated storage. Many products are cooked and processed, then chilled or frozen prior to onward transport.
3. **Transport** – Various modes of transport form the critical process that interconnects all stages of a cold chain.
4. **Bulk storage** – As products arrive in bulk at warehouse storage (sometimes multiple stages), refrigeration is also required. These stages also buffer the inventory against demand and provide platforms to deconsolidate and undertake last mile delivery. Storage at various temperature levels is required to suit the type of food product.
5. **Retail** – Refrigeration in equipment at merchandising end is required to keep products in a low-temperature environment before purchase by the consumer, both while in temporary storage and on display.
6. **Domestic and food service** – Products that require refrigeration should generally be stored in a refrigerator or freezer until consumed at home or, for food service establishments, cooked and served to customers. This also depends on consumer buying cycles and local supply chain.

4. Climate impact of cold-chain systems

It is estimated that less than 10% of temperature-sensitive perishable foods have access to cold chain systems worldwide [xiii] and many developing countries have a negligible cold-chain capacity. Despite this, current cold-chain practices still have a significant climate impact. There are two different climate impacts caused by cold-chain systems.

Direct emissions (refrigerants): The food supply cold chain has been estimated to account for more than 20% [xiv] of global HFC usage. Keeping products cold throughout the mobile portion of the cold chain (such as while in transit on trucks, trains and ships) represents about 3% to 7% of global HFC consumption, due to high refrigerant leakage and poor end-of-life disposal, contributing as much as 4% to the total GHG emissions of transporting all freight (refrigerated or not).[xv]

Indirect emissions (energy): The global cooling demand for food, producer to consumer, is also energy-intensive. Modelling based on data obtained from GIZ's Green Cooling Initiative points to energy consumption that leads to approximately 1.2 gigatonnes CO_2-eq emission globally. Almost all the CO_2-eq emissions are fossil-fuel based. Cold chain systems rely heavily on diesel, both for transport refrigeration and also off-grid electricity generation, and therefore, tend to have higher indirect emissions than other sectors of the refrigeration and cooling industry. Today, keeping food cold accounts for an estimated 20% of total vehicles' fuel.[xvi, xvii]

5.

Curbing GHG emissions by ensuring sustainable cold chain and reducing food loss

Cold chain helps to reduce the CO_2-eq emissions related to food loss. As demand for cold chain increases, deployment of sustainable, low-GWP and energy efficient cold-chain system would be needed to reduce the CO_2-eq emissions from the cold-chain systems themselves. A 2018 academic study [xviii] showed that introducing cold-chain systems to sub-Saharan Africa that have efficiency levels similar to the United States could result in a net increase in food-related GHG emissions by up to 10%. Strategies and financial investment that allow the developing countries to acquire and apply the most efficient technologies would be needed. In addition to requiring the phase-down of HFCs, the Kigali Amendment has created opportunities to enhance energy efficiency in the cooling sector during the HFC phase-down. Full utilization of the opportunities would ensure that climate benefits resulting from the Kigali Amendment are maximized.

Unless appropriately designed to optimize cooling demand and use non-fossil-fuel, low-GWP refrigerant technologies, growth in cold-chain systems to reduce food loss may create undesirable pollution compromising the socio-economic and climate benefits.

Some solutions are already available to assist the transition to sustainable cold chain include:

1. **Assistive zero-energy systems** such as low-cost vegetable storage using evaporative cooling at the farm where climate allows.
2. **Building design** – thermally efficient, well-insulated buildings with passive cooling approaches. (Insulation is equally important for vehicles).
3. **Best-in-class equipment** – most refrigeration systems will last 14-20 years; therefore, it is essential that as new systems are deployed in the developing markets, they are of the highest energy efficiency, such as variable speed compressors, and lowest-GWP refrigerants feasible, and with good control systems.
4. **Maintenance** – refrigerant leakage rates are high (over 20% leakages per vehicle per year on average, for transport refrigeration vehicles [xix]), and therefore significant direct emissions as well as increased energy consumption can be avoided with better maintenance practices.

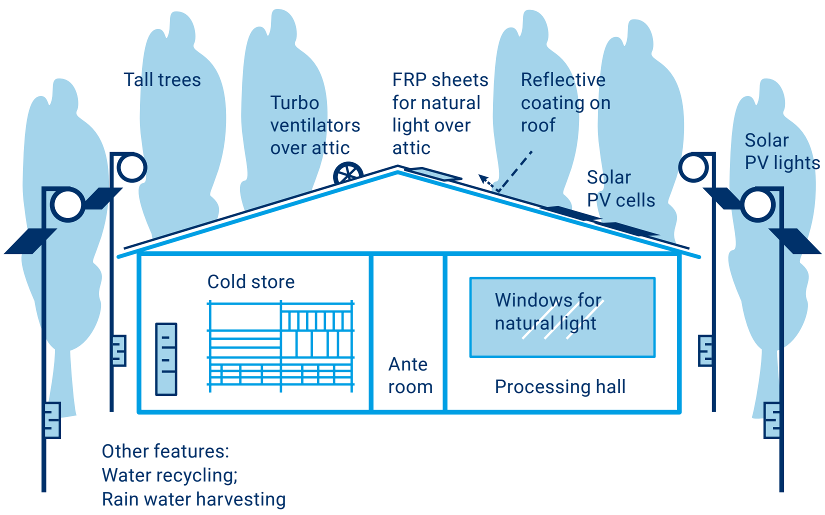
There is also the potential to increase overall system efficiency by a breadth of interventions, from reducing demand to system integration to harnessing waste heat for co-located processes, as well as using thermal storage for time-of-use and demand management and resilience in the event of power failures. As shown in Table 1, a range of interventions could be used.

TABLE 1: EXAMPLES OF INDIRECT EMISSION REDUCTION OPPORTUNITIES

INTERVENTION AREA	EXAMPLE
Behaviour change	Ensuring optimum or acceptable temperature settings
Demand mitigation	Using natural shading, good building design, natural ventilation
	Improving insulation
Efficiency improvements	Improving the efficiency of existing appliances, control systems
	Using thermal storage for time of use management
	Recovering waste heat into co-located service e.g. hot water for cleaning and washing applications in packhouses
Demand aggregation	e.g. Community cooling hubs
Natural energy resources	Using evaporative cooling, sky cooling, river or deep water
	Using low grade geothermal to drive sorption chillers
Waste energy resources	Making use of waste industrial or commercial heat and waste cold using different technologies
System intervention	Making modal shifts (road to rail or even road to drones)

No single technology can profess to be the solution. Answers may be found in energy management through intelligent integration of technologies, that cut across disciplines and functions. Optimising the need for cooling, increasing energy efficiency, mitigating climate impact of refrigerants and shifting to renewable energies are all important elements for establishing sustainable cold chain.

BOX 3: WHAT COULD AN ENERGY-EFFICIENT OPTIMIZED PACKHOUSE SYSTEM LOOK LIKE USING AN INTEGRATED APPROACH[3]



3 **Promoting Clean and Energy Efficient Cold Chain in India, Shakti Sustainable Energy Foundation, 2019.**

BOX 3 (CONTINUED)

Overall system design needs to consider:

- Environmentally friendly location close to sustainable modes of transport;
- Clean energy sources for transportation;
- Thermally efficient, well-insulated buildings with passive cooling approaches and sustainable cooling technologies;
- Minimum, convenient and efficient movement of humans and materials;
- Optimization of the use of energy and water;
- Low-GWP refrigerants;
- Disposal of waste;
- Life Cycle Analysis of building structure, materials and equipment for most moderate environmental impact.

6.

Challenges to sustainable cold chain

In most developing countries there is limited or even negligible cold storage equipment or refrigerated transport, from harvest to retail point. Where there is equipment, it is often old or obsolete, from industrialised markets, and the focus is often on moving food for export. Key challenges include:

1. **Financial capacity of marginal and small farmers:** Farmers may be unable to access finance for purchasing equipment and supporting post-harvest product storage.
2. **Organization:** Lack of collaboration among stakeholders to have common actions and investments.
3. **Awareness, skills and education:** Farmers may lack awareness of simple techniques to take care of produce post-harvest, and training on the usage of relatively sophisticated cold-chain equipment.
4. **Lack of integrated demonstrations:** Lack of large-scale cold-chain demonstrations to showcase its efficacy and impacts.
5. **Lack of "First Mile" infrastructure:** Inadequate agricultural infrastructure or inappropriate vehicles to transport the produce from the farm-gate to the packhouse.
6. **Risk of technology lock-in:** Conventional cooling technologies are being deployed instead of energy-efficient or emerging clean-cooling technologies. If the climate impact of cold-chain systems is not addressed, the cold chain will be dependent on and locked into incumbent technologies, such as diesel generators.

7. **Lack of necessary infrastructure in rural areas:** Cold-chain systems require robust transport and energy infrastructure to be in place to operate reliably with seamless market connectivity.

8. **Lack of drivers for change and attention to cold chain components beyond large-scale storage:** Public sector's attention in developing economies remains focused on the provision of large-scale cold storage (in an average of 100,000m^3 capacity[xx]) rather than encouraging the building of integrated cold chains for market connectivity.

9. **Non-affordability of e-mobility:** Both electrical transportation fleets and on-board battery for cold production can be relatively expensive to purchase and maintain; also, there is a lack of charging infrastructure should there be an effort to support electric transportation and associated transport refrigeration.

7.

The opportunity created by the Kigali Amendment

Optimum, sustainable and climate-friendly cooling and cold chain can be introduced if the systems are designed cohesively and with an integrated systems approach from the outset rather than piecemeal technology deployments.

Development of sustainable refrigeration and cold chain is not only about switching to low-GWP refrigerants, but also giving due consideration to energy efficiency, shifting to renewable energy, and optimizing the need for cooling, within a long-term strategy with objectives, interventions and timelines.

The Kigali Amendment gives cold-chain operators a clear incentive to install low-GWP or zero-GWP refrigerants. It also provides an opportunity to rethink cold-chain strategies that simultaneously advance business and environmental goals.

Such strategies may include ensuring installation of high efficiency, safe, low-GWP systems now which will still be fit for purpose ten years into the future; preventing refrigerant leakage through good maintenance; and planning for decommissioning and end-of-life disposal of equipment.

More strategic approaches could allow packhouses and cold-chain businesses to expand their services and create sustainable community cooling hubs, make use of renewable power, or develop new revenue streams by providing waste heat or excess cold to district services, while at the same time further supporting the Paris Climate Agreement, the Montreal Protocol and its Kigali Amendment, and the Sustainable Development Goals.

Detailed information on technology options for cooling solutions that includes information on costs and emissions impacts can facilitate cost benefit analysis by policy makers and operators whilst developing their own cold-chain plans. Novel business models such as provision of "cold" as a service using Farmer Producer Organizations, farmers' associations or other service providers may be considered within such plans.

With access to robust information, advice and support, including possible financing, farmers, producers and cold-chain operators can make informed and rational choices on sustainable cold-chain development.

The Kigali Amendment has created an opportunity for the cooling sector, including cold-chain businesses, to be a part of a sustainable future while contributing to climate and environmental protection.

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