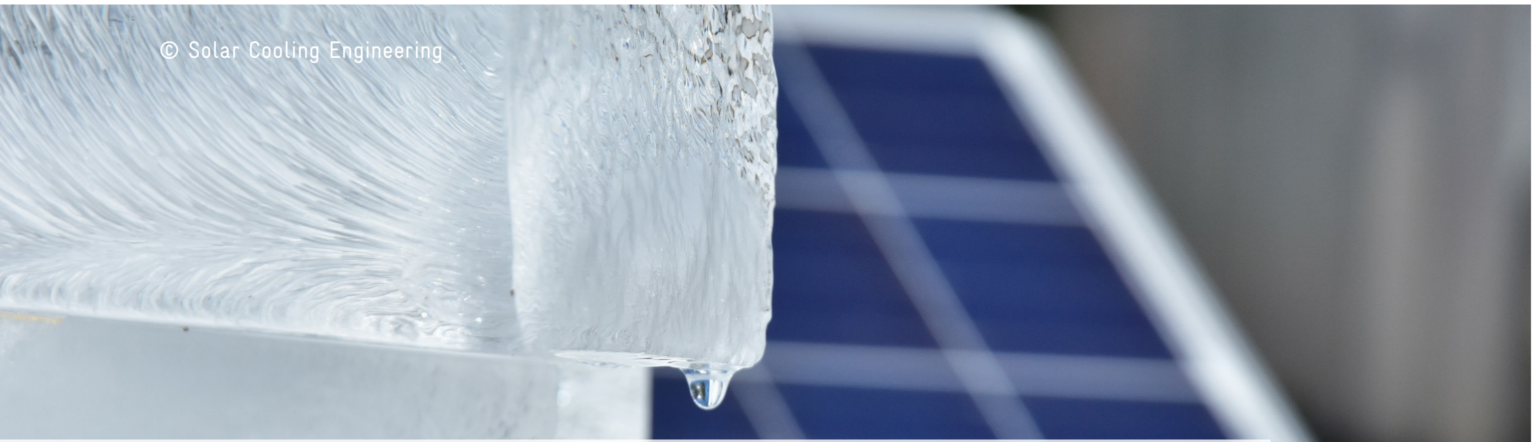


Sustainable Cooling Solutions in agricultural value chains

in sub-Saharan Africa.

Background

According to the FAO, about one-third of the food produced globally is lost or wasted each year[1]. A shocking number with unprecedented economic, social, and environmental consequences. **However, expansion of the cold chain coverage in food value chains can mitigate these negative impacts and provide significant development benefits.**

In Sub-Saharan Africa (SSA), significant volumes of food are lost after harvest. For example, the World Food Program estimates that in Nigeria and Senegal, most farmers experience post-harvest losses of up to 40% before products reach the consumer. Roots, tubers, fresh fruits, and vegetables have the highest proportion of losses and waste.

Picture 1. Conventionally stored potatoes in Mali.

1 12.3.1 Global food losses | Sustainable Development Goals | Food and Agriculture Organization of the United Nations (fao.org)

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Food losses, more specifically post-harvest losses, remain a persistent problem and one of the primary threats to food and nutrition security in SSA. Besides the actual food losses it entails, it is a waste of already scarce natural resources like land, water, energy, and other inputs for food production and processing (e.g., seed, fertilizer, labor, the cost for infrastructure and equipment).

Picture 2. Freshly harvested mango surplus in Mali.

Food losses directly affect seasonal food availability, contributing to high food prices and causing loss of income for various actors along the food supply chain. Given that in most African countries, women predominate in the food retail sector, women are particularly affected by the loss of earnings (shortfall) due to food losses.

If no action is taken, rapid population growth, increasing food demands, and climate change will exacerbate the above-mentioned consequences of food loss. An increase in temperature, heavy rains, floods, and droughts increase the perishability of many agricultural food products and make the use of precarious food storage facilities impossible. Additionally, the food supply chain, specifically post-harvest losses, contributes significantly to climate change. Today's food supply chain accounts for 26% of anthropogenic GHG emissions of which ~40% is emitted after the food leaves the farm[2]. Therefore, **preventing food losses can strengthen the resilience of food value chain actors while mitigating climate change impacts and GHG emissions.** To meet the needs of the growing population in sub-Saharan countries, efforts are primarily focused on increasing agricultural productivity and imports. However, from an economic and environmental point of view, there is a consensus that **preventing food losses is a faster and more efficient way to tackle food insecurity and hunger crises than increasing food production[3].**

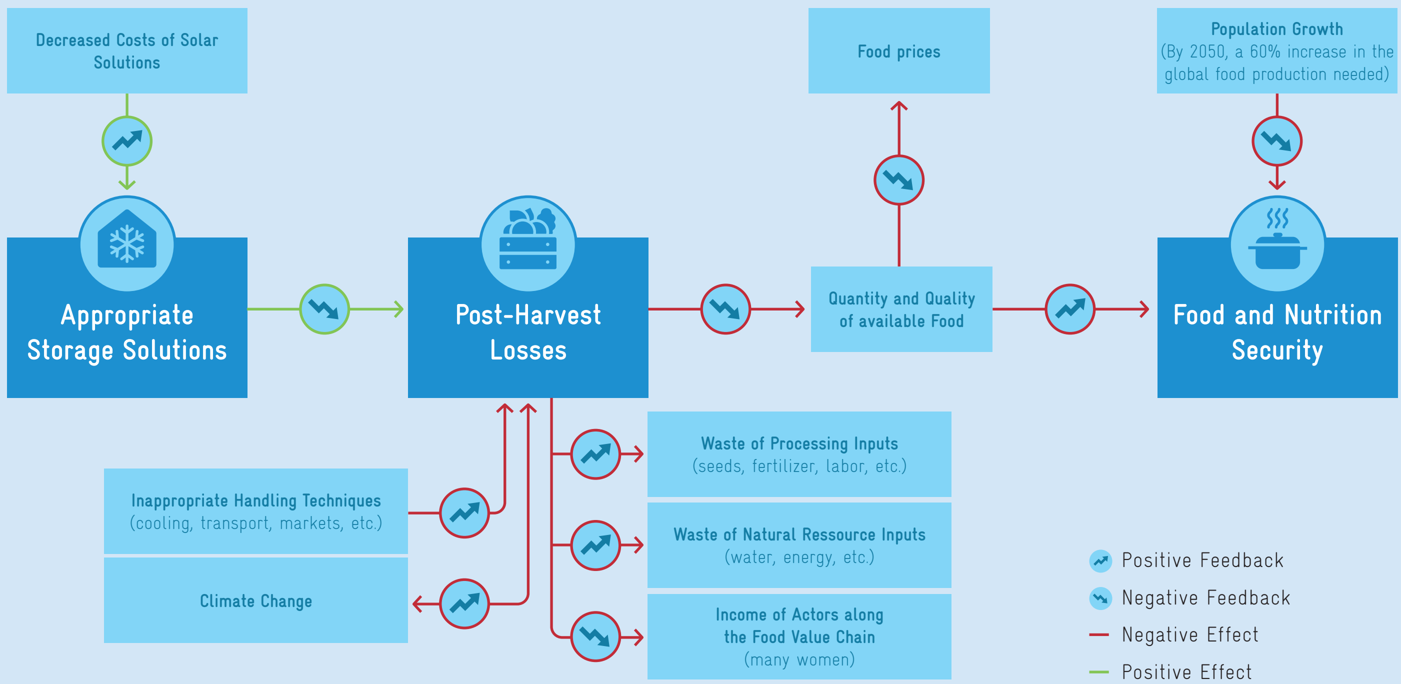
Food losses are attributed to inappropriate handling techniques at the farm level and post-harvest practices such as inadequate storage and cooling facilities, lack of refrigeration, poor transportation conditions and networks, deficient market infrastructure, etc.

It is well established that improving access to suitable storage solutions is a promising approach to extending the shelf life and preserving the quality of foods to decrease food losses, thereby mitigating seasonal food insecurity. In most developing countries, storage facilities are generally precarious and functional cold chains are often absent in rural areas where up to two-thirds of the food losses occur. This significantly constrains the development of high-value products such as fish, milk, fruits, and vegetables.

Overall, the issue of cooling and cold storage has been poorly addressed in value chain development approaches and has received insufficient support in development projects. Various types of local cooling storage facilities have been developed over time. However, in many cases these facilities do not provide optimal storage conditions for the products concerned. Due to the drastic decrease in the cost of solar energy systems during the last decade and the increase in social acceptability and desirability of solar solutions, there is a proliferation of solar cooling solutions in the developing world. A common technology recently being promoted in many countries is 20- to 40-foot solar-powered walk-in containers. However, the high investment costs and the lack of expertise compromise the scaling up in sub-Saharan countries. **In addressing food insecurity, local cooling storage infrastructure powered by sustainable energy technologies is promising and should receive more attention from the private and development sector in the coming years.**

2 Reducing food's environmental impacts through producers and consumers (science.org)

3 https://www.fao.org/3/i4545e/i4545e.pdf



Sustainable Cooling Solutions: what does this mean?

In this paper cooling solutions refers to **pre-cooling, bulk-cooling, and retail-cooling facilities.** The process of pre-cooling allows for the removal of field heat from freshly harvested produce, bulk-cooling ensures the storage of (large) quantities of products after production and initial post-production handling, and retail-cooling refers to short-term storage of products during marketing. The pre-, bulk-, and retail-cooling are components of the food cold chain defined as uninterrupted handling of food products within a low-temperature environment. Food cold chains also entail domestic refrigeration and transportation.

Bulk and retail cooling occur in cool or cold storage facilities with mostly artificially generated temperatures. International standards define cold as very low temperatures close to or below the freezing point and cool as moderate temperatures between cold and warm. In hot developing countries, where the ambient temperature can reach 40-42°C, even 30°C is technically considered a cool temperature.

The assumption that cooling technologies, usually powered by solar PV, are automatically green, environmentally, and climate-friendly is often misleading. To achieve sustainable off-grid cooling solutions, the **environmental, economic,** and **social** aspects need to be taken into consideration. For example, **environmental sustainability** requires considerations about the type of refrigerants used in refrigeration systems or batteries used for off-grid cooling solutions. For **economic sustainability,** the return on the investment, as well as the full life-cycle costs, should be considered, including investment costs, operational costs, and the environmental costs (CO_2 emissions) generated during manufacturing, transport, operation, and its end of life (re-use, recycling, or disposal). Additionally, it must be noted that, in general, the initial investment costs for renewable off-grid green cooling appliances are usually slightly higher than for conventional ones. However, operational costs are usually much lower, reducing the overall life cycle costs. **Social sustainability** requires an understanding of the target group to determine if the project fits into the specific locality and to manage the positive and negative impacts on people. Aspects like willingness to change, distance to farms, distance to markets, means of transport, accessibility of the technology, and possible gender inequalities need to be considered.

Cooling solutions and innovation

Cooling solutions allow food to be stored and sold days, weeks, or even months after the harvest. They range from small, traditional, low-cost passive cooling techniques in remote areas with no or unreliable electricity supply, to bigger, more expensive cooling rooms in peri-urban or urban areas powered by fossil fuels. Intermediate solutions that can better meet the needs of average producers or processors are almost non-existent.

Low-tech and low-cost solutions

Various types of evaporative coolers are available in many areas for both pre-cooling and storage purposes. An evaporative cooler or wet air cooler is a device that cools air through the evaporation of water[4], a technology that has existed for thousands of years. The Yakhchāl, for example, was built by Persian engineers in the desert around 400 BCE to capture and store ice and foods. Nowadays, other traditional evaporative coolers such as the household clay pot cooler or Pot-in-pot refrigerator and the charcoal cooler are used in some African countries. An emerging solution is the so-called Evaporative cooling chambers (ECCs), also known as "zero-energy cool chambers" (ZECCs). These low-tech solutions are built with local materials and do not require external energy input, making them affordable to smallholders. However, since they can only hold small quantities of products, their storage capacity is often lower than the storage needs for farmer organizations or even individual farmers. In addition, they do not always provide the optimal conservation conditions in terms of temperature, humidity, atmospheric composition, which differ from one product to another. Due to their low cost, evaporative coolers are primarily used by women with limited land and production capacities.

Picture 3. Yakhcha-l (traditional evaporative cooler).

Picture 4: clay pot cooler | Zeer Pots designed by Mr Mohammad Bah Abba and Mr Mohammad Bah Abba himself

Picture 5. Charcoal cooler.

Picture 6. Evaporative cooling chamber (ECC). J-WAFS Abdul Latif Jameel Water & Food Systems La

4 https://en.wikipedia.org/wiki/Evaporative_cooler

Modern innovative cooling solutions

Due to the drastic decrease in solar costs during the last decade (about 80% for photovoltaic panels), there has been a proliferation of solar cooling solutions throughout the developing world, particularly in South and Southeast Asian countries like India and Bangladesh.

In some cases, the shift is driven by start-ups, often supported by development agencies through the funding of pilot projects, to further develop and/or scale up such technologies. A common technology being promoted in many countries is 20- to 40-foot solar-powered walk-in containers equipped with a plug-and-play PV system and batteries. They are often used for retail storage for fruits and vegetables.

Smaller devices like solar refrigerators, milk cooling tanks, and ice makers have also recently entered the market. Ice is mostly used for cooling small quantities of fish, meat, and dairy products either applied directly to the produce (top-ice) or kept in an ice bank or ice battery to cool down water or air. The stored produce cools down by being exposed to cold water (hydro-cooling) or the air around the stored produce through natural or fan-assisted convection.

Picture 7. A photovoltaic-driven walk-in cold room container in Kenya.

Scaling up Innovative Sustainable Cooling Solutions

Despite the recent development in cooling technologies, modern cold chains are highly underdeveloped or non-existent throughout most African countries. Experiences have shown that most innovative Sustainable Cooling Solutions rarely reached the targeted users in African countries. The main causes reported by various studies are the deficit of information and awareness about the benefits of these innovations, their unsuitability for the local/rural context, their high costs, and the lack of suitable financing mechanisms. For fully imported technologies, the lack of local specialists and the absence of spare parts for the repair and maintenance are major constraints that often arise in the medium to long term and prevent their scaling up. Also, lacking enabling conditions for these innovations, such as quality standards, taxation, and tariffs are often a hindrance for a higher uptake of cooling technologies. **These challenges need to be addressed to scale SCS, especially challenges related to affordability and financing.**

Picture 8. Solar panel is installed with local resources in Kenya.

Innovative business models tackling this issue (such as Cooling As A Service models, CAAS) are being developed and implemented in some countries. They allow peri-urban farmers, urban farmers, and retailers to collectively use cooling solutions without having to acquire the technology on their own. In Nigeria, the pay-as-you-store model of WE4F partner ColdHubs is quite successful. Farmers pay a daily flat fee of US$ 0.50 for each crate of food they store. The storage capacity of each cold room is about three tons of food; a maximum of ten tons of food is planned. In Kenya, WE4F and WeTu, in partnership with Mideva Venture Labs, are assessing different models of solar-powered ice production to facilitate ice being sold to local fishermen to help preserve the catch and reduce spoilage.

Small and medium sized enterprises (SMEs) play a pivotal role in the development of such models. CAAS models are often offered in urban areas, close to markets. Therefore, the direct acquisition of SCS by farmers, farmer's groups, or other end-users working along the value chains in remote areas where innovative business models are not yet developed, remains important. To promote development, better enabling conditions and suitable financial products through a stronger involvement of financial institutions are essential.

Intermediate/Hybrid Sustainable Cooling Solutions as a promising pathway to scale-up

Traditional cooling techniques, smaller innovative devices, as well as modern cooling infrastructures, are used by producers or retailers with limited quantities of products or by exporters with significant financial resources. Suitable solutions for the largest category of users, those moving between these two extremes, constitute the missing middle. Filling this gap through the promotion of intermediate storage facilities would be a promising option for achieving the long-term deployment and uptake of cooling solutions in African countries and have better economic, social, and environmental impacts.

Intermediate cooling storage facilities should meet the following criteria:

- be sized according to the needs of the end-users, by considering, for instance, the type and average annual production volume that is most subject to cold storage
- private sector driven
- rely on local building and insulation materials (timber, stone, mud and clay, grasses, etc.) or locally available new materials, such as old shipping containers, PET Bottles, used IBC containers, etc.) or waste materials
- able to be further developed, built, and maintained by local experts (strengthening and enhancing local knowledge)
- Integrates sustainable innovative cooling technologies

Hybrid solutions that combine local knowledge with modern innovation would encourage better appropriation. As a result, a continuous integration will foster the local anchorage of the solution. This would be more advantageous from a cost-benefit point of view and create specialized local jobs.

The cooling storage for potatoes built by a potato producers' group in Mali, with the support of GIZ/BMZ project Green Innovation Centre, is a good example of such an intermediate solution. The 150 m2 room has a storage capacity of 50 tons. It's built from local masons with local materials. The room is equipped with ventilators, extractors, and an old air conditioning system taken from a bus all powered by solar panels. It has led to a one-month increase in the shelf life of the potatoes stored, a 15% decrease in loss, and an increase in income of 25%.

The SelfChill approach promoted in some African countries (Kenya, Mali, etc.) by Solar Cooling Engineering, a spin-off company of the University of Hohenheim is a promising model that supports this dynamic. The company provides key components (cooling units, electronics, and sensors) and trains local companies to design, produce, and assemble final cooling systems using locally available components (structural materials, insulation material, solar panels, batteries, charge controllers, etc.). The SelfChill approach is built on the outcomes and experiences of a collaboration between the Powering Agriculture Program financed by BMZ and implemented by the GIZ and the University of Hohenheim.

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