Innovate for Impact: Siemens Design Challenge

Driving solutions for zero hunger and clean water

Design parameters: Zero Hunger Track

Problem Statement:

Design a postharvest off-grid preservation technology. A way to reduce the farm to table food loss in lower resource settings that lack electricity.

Design Objectives:

Postharvest food loss composes food lost or wasted throughout the food supply chain from the post harvest handling, storage, manufacturing, distribution and retailing to losses at the point of final consumption. The proposed technologies or approaches should reduce food loss at any point in the farm to table supply chain, in environments that have very poor infrastructure including a poor or non-existent electric grid, and be affordable/accessible to the target community or end user.

Background:

Roughly one third of the food produced in the world for human consumption every year — approximately 1.3 billion tons – is lost or wasted at a cost of roughly US $680 billion in industrialized countries and US $310 billion in developing countries. In developing countries, 40% of losses occur during the post-harvest and processing phases of food production.Food waste contributes up to 70 gigatons of greenhouse gases, or 11 percent of total emissions, therefore directly contributing to Climate Change.

In this document you will find additional background information *to provide foundational knowledge and introduce terminology for entrants to investigate further (Section 1). In Section 2, you will find important aspects concerning* design parameters you will need for the challenge.

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SECTION 1: BACKGROUND

1. Introduction

According to the United Nations' Zero Hunger Challenge, one of the elements to achieve Zero Hunger (Sustainable Development Goal (SDG) 2) is to "Adapt All Food Systems to Eliminate Loss or Waste of Food"; this involves "minimizing food losses during production, storage and transport, and waste of food by retailers and consumers; empowering consumer choice; commitments by producers, retailers and consumers within all nations".

2. Defining food losses and food waste

Food losses or waste, as defined by the Food and Agriculture Organization (FAO) are "the masses of food lost or wasted in the part of food supply chains leading to edible products going to human consumption". **Food loss** refers to food, originally produced for human consumption that is lost due to quantity(dry matter) or quality(nutritional value) reasons while **food waste** refers to food appropriate for human consumption that is left to spoil or expire. Read more in the FAO Global Food Losses and Food Waste Report and the Food article on Understanding Food Loss and Waste here.

The food supply chain

Food loss and waste in the supply chain involves different processes starting from the initial agricultural production and ending with household consumption than can be separated into the following different stages according to the 2011 FAO Global food losses and food waste report:

1. Agricultural production
2. **Postharvest handling and storage**
3. **Processing**
4. **Distribution**
5. Consumption

The stages in bold are the stages this challenge aims to address.

In turn these stages can be classified into three major types such as **farm losses/waste** (during agricultural production and harvesting), **postharvest losses/waste** (during postharvest handling and storage, manufacturing, distribution, and retailing), and **consumer waste** (both in household and out-of-home).

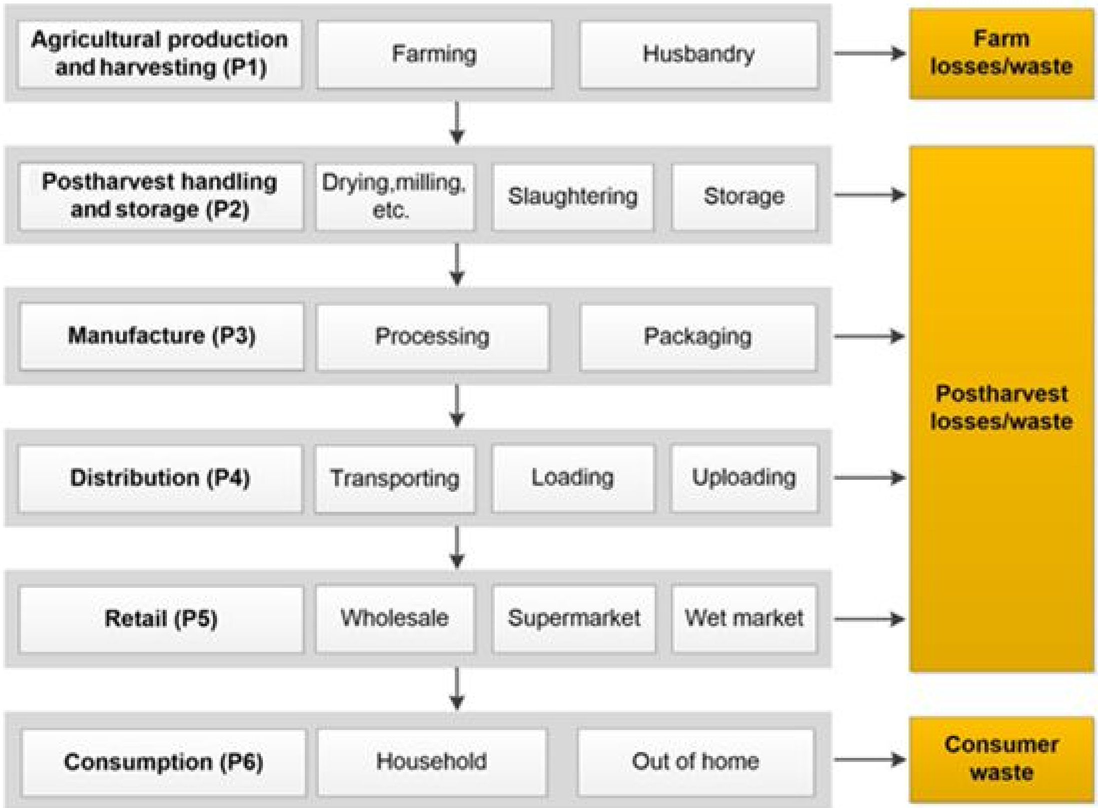


Figure 1. Food supply Chain for food losses and food waste taken from Xue, L., & Liu, G. (2019). *Introduction to global food losses and food waste. Saving Food, 1–31.* Losses are defined for global Losses and Waste Losses by the FAO

Types of food losses/wastes - Food commodities

Food losses and waste amounts that occur at the different stages of the food supply chain will depend highly on the type of food commodities involved with each stage of its production having particular characteristics (different types of issues and waste levels).

Food Losses/wastes can also be classified into the following food groups:

1. Cereal and cereal products (e.g., wheat, maize, and rice);
2. Roots and tubers (e.g., potatoes and cassava);
3. Oilseeds and pulses (e.g., peanuts and soybeans);
4. Fruits;
5. Vegetables;
6. Meat;
7. Fish and seafood;
8. Dairy products;
9. Eggs;
10. Others or not specified.

This classification is based on the following study: Introduction to global food losses and food waste.

Example of Food Losses and wastes for different food types/commodities: According to the existing information, on a per capita level, cereal loss is the largest in comparison to other food commodities such as fruits and vegetables, meat and fish, and dairy products, especially at the consumer phase. Read more in the [2011 FAO Global Food Losses and Food Waste Report]

Food losses and waste according to geographical location

The amount of food losses and waste will also depend on which region of the world is being studied given that this determines what and how much is produced of the different types of food commodity groups in that area. Geographical locations for food and waste losses are usually divided into regions as shown in figure 3 but can also be viewed from and grouped into medium/high-income and low-income countries due to differences in Food supply chain technologies and infrastructures.

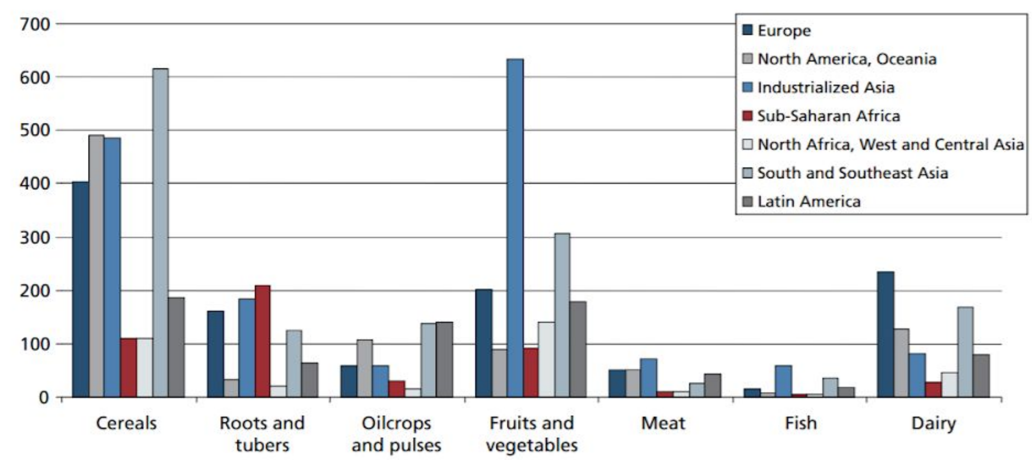


Figure 2. 2007 Production volumes of each commodity group, per region (million tonnes) taken from Xue, L., & Liu, G. (2019). *Introduction to global food losses and food waste. Saving Food, 1–31.* These volumes were compiled from the FAO Statistical Yearbook 2009, except for the production volumes of oil crops and pulses which were *collected from FAO's FBS, 2007.*

An example of food losses and waste is the food losses of cereal around the world:

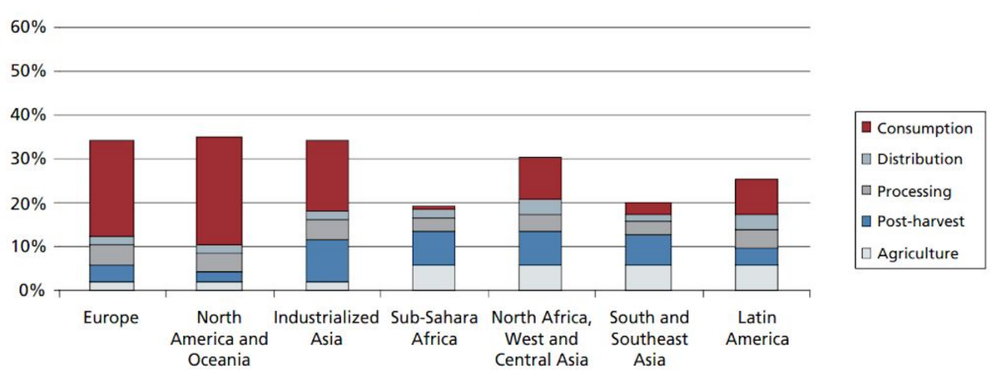


Figure 3. Part (percentage) of the initial production lost/wasted, at different Food Supply

Chain stages, for cereals in different regions. Taken from the 2011 FAO Global Food Losses and Food Waste Report

To see about lost/wasted food values for other food commodities such as roots and tubers, oil crops and pulses, fruits and vegetables etc. see section 3.2 of the 2011 FAO Global food losses and food waste report. To find more educational resources on the global state of food loss and waste visit the FAO's SAVE FOOD: Global Initiative on Food Loss and Waste Reduction page.

3. Causes of food chain losses/waste

In general food can be lost or wasted along the food supply chain from its initial agricultural production down to final consumer/household consumption. This is due to many factors such as financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities in difficult climatic conditions, infrastructure, packaging and marketing systems. In emerging markets food waste occurs primarily between the farm and market due to poor infrastructure, low levels of technology and low investment in the food production systems, while in industrialized countries it is primarily lost at the retailing and consumption levels. Read more in a review about Food waste within food supply chains. Figure 4 illustrates this.

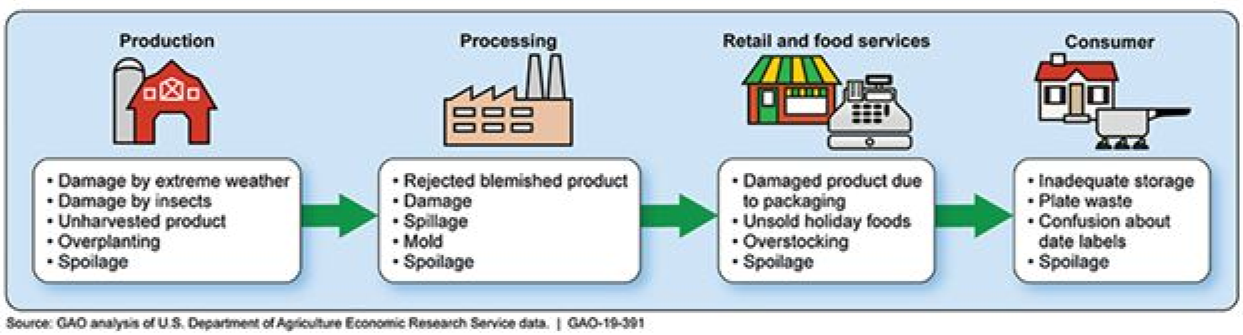


Figure 4. Causes of Food Loss and Waste in the Food Supply-Chain Stages. GAO analysis of U.S. Department of Agriculture Economic Research Service Data.

Find more about waste losses and waste causes identified by the FAO in the 2011 FAO Global food losses and food waste report.

Food wastes are quantified by diverse direct or indirect measurements such weighting, garbage collection, surveys, diaries, records, observation, modelling, food balance, use of proxy or literature data. Each method can have different advantages and disadvantages in time, cost, accuracy, objectivity and reliability. To learn more about these methods see the Commission for Environmental Cooperation Technical Report on Quantifying Food loss and Waste and its impacts here. Also see the Technical Platform on the Measurement and Reduction of Food Loss and Waste.

Experts indicate that…

- Many factors lead to high food loss and food quality degradation in emerging markets: the technology required is not available, energy needed to power equipment is either irregular or unavailable, and food safety regulations are poorly understood or not enforced.
- The **biggest technological challenges** in bringing storage, process, refrigeration and safe transit to off-grid areas depend on the type of food group:
  - Fresh meats, fish and dairy require a consistent cold chain to ensure quality throughout the supply chain. Fresh fruits and vegetables must be cooled after harvest to eliminate field heat and to maximize shelf life and quality.
  - Processed products require mostly safe and sanitary handling.
  - Dried products such as grains require drying to prevent rot(from humidity), mycotoxin growth, insect and rodent damage, and safe storage to maintain quality.
- The **most difficult challenges facing the distribution** of off-grid tech for preserving food are efficient-affordable technologies, storage, inventory management and transportation.
- On average, **how long a product remains is in transit post-harvest for** is product dependent and dependent on the way the food is stored and sold - fresh, frozen, canned.. Etc. For example, strawberries last only a few days while grains such as rice can be stored for years and therefore can remain in transit longer.
- The **most perishable product** depends on the type of food product: non processed-types of fish, meats, require refrigeration, partial cooking or canning. Fruits and vegetables, required controlled atmosphere and cooling to keep fresh longer.
- Food processing, including canning, packaging, drying, vacupacking, and freezing must follow good manufacturing practices including ISO or HACCP.
- Clean water, energy to run machinery and heating/cooling equipment are essential for food storage and processing.
- In order to manage efficient distribution, food traceability and inventory management systems are part of a best practice package.
- Transportation is very expensive therefore isolutions/technologies that can lower the raw material from farm to the distribution/consolidation point, this will highly reduce costs and environmental impacts.

4. Food preservation and processing technologies

Given the technological challenges in food loss and food waste reduction/prevention such as storage, processing, refrigeration and safe transit, technologies for food preservation and processing can be separated into three main groups throughout the food supply chain:

(1) Food Postharvest handling and storage Technologies
These include technologies that improve post harvest techniques and storage and

maintain the quality of food, while waiting for shipping or processing. These include structures such as Zillows to store grains, Big freezers.

(2) Food Processing Technologies
Improving processing techniques include but are not limited to: improving packaging, freezing, freezing-drying/ hermetic sealing and canning procedures/technologies. An example of this is a Mobile Fruit Juice Processing Plant.

(3) Food Distribution Technologies
Food distribution technologies that will contribute to food loss/waste reduction will include improvements in food tagging, traceability, transportation, retailing such as food sensing technologies for food safety, quality, blockchain enabled traceability, real-time supply-chain transparency and traceability, big data and advanced analytics for precision agriculture for input and water use optimization, amongst etc.). Find out more about developing improved food harvest, storage, processing, transportation and retailing processes in the FAO *Toolkit: Reducing the Food Wastage Footprint*. Also see more resources in the USDavid Postharvest technology, Research and information Center.

During any of these stages there will be the need for food preservation technologies. Which can be divided into thermal or non-thermal techniques.

Thermal Food preservation technologies are conventional and emerging preservation techniques that use a combination of temperature and time to eliminate microorganisms from a food product. These technologies include: Pasteurization, Sterilization. Cooling/chilling, Freezing, Ohmic heating, Microwaves, Radio frequency and Synthetic antioxidants to inhibit oxidation in foods.

Non thermal food preservation technologies provide an alternative to the effect on the organoleptic quality and nutritive value of foods, that conventional heat treatments produce while achieving microbial inactivation. These eco-friendly emergent processing methodologies ensure the product's safety as well as maintaining their original quality and include: High pressure processing technology, Ultrasounds and Pulse electric fields.

Read an overview of food preservation technologies here. Find out more about non-thermal preservation/processing technologies here.

Renewable energy and food technologies

Energy is needed across food systems in the production of crops, fish, livestock and forestry products, in postharvest operations, in food storage and processing, in food transport and distribution, and in food preparation. Off-grid renewable energy generation that uses alternative energies such as solar, can provide a sustainable alternative for powering these processes. An example of this is Ecozen, who developed a solar-powered cold storage system for small-scale farmers. Read more in Innovation with a purpose.

5. Innovation snapshot

Examples of off-grid post harvest technologies in the E4C Solutions Library:

ColdHubs is a modular walk-in cold room that is powered using solar energy to provide off-grid storage and preservation of perishable food products. (Cooler)

The SimGas Milk Chiller provides off-grid biogas- powered milk cooling to smallholder dairy farmers without access to electricity. *2018 Kenya ISHOW winner* (Cooler)

The Purdue Improved Cowpea Storage (PICS) Bags is a cost-effective, triple-layer hermetic storage bag which permits farmers to store their grains without the use of insecticide. (Storage)

CTI Ewing Grinder is a hand-operated burr mill capable of making peanut butter, cocoa butter, maize flour, and dozens of other products. (Grail Mill)

The Kinosol Orenda Food Dehydrator is a technology that dries and preserves food for 6 months using a natural convection system that allows airflow without the need of a fan. (Drying)

MFarm is an app and SMS service that provides up-to-date market prices to farmers and connects them with buyers. (ICT)

Read about more innovations in the World Economic Forum report on the role of technology innovation in accelerating food systems transformation.

6. Sustainable considerations

Standards and Regulations pertaining the food supply chain

Food monitoring and testing techniques will be required in all of these groups throughout the food supply chain in order to comply with quality indicators for processed foods, locally as well as internationally. These standards exist to ensure products' safety and quality and avoid health hazards such as food poisoning, botulism amongst many others.

International standards, guidelines and codes of practice for food processing include the "Food Code", those established by the International Organization for Standardization (ISO) , the FAO and WHO and Faolex database. Hazard Analysis Critical Control Point (HACCP).

It is important to note here that **food standards** vary nationally and from country to country and depending on the industry group. Therefore it is important to keep the food quality standards and regulations of the targeted market in mind when developing any type of technology.

An example is the use of antibiotics in meat is much stricter in the European Union than it is in the United States. Also, industry standards are typically higher than government standards. Food industry standards were set before and are stricter at monitoring the food quality because having sick customers can directly affect their companies. Many organizations certify different practices. For example organizations such as Fair trade International and USDA Organic and Organic Certifiers, certifying if ethical and fair deal and organic practises are being followed. Good Manufacturing Practices(GMP) certify for processed foods.

It is important to have in mind that the proliferation of these codes worldwide has brought some challenges. While companies or technologies from developing countries and emerging economies have difficulties complying with stricter regulations, in industrialized countries the increasing costs of certification and accreditation affect profits.

Impact of food wastage on natural resources

Natural resources such as water, land and biodiversity are impacted across the food chain in many ways: their use as resources for the food industry, food wastage disposal into water and land and greenhouse gas emissions into the atmosphere. The effects of food waste on the environment varies geographically and according to the type of food. Read more about this and the challenges of natural resources savings from reduction of food wastage in the FAO Toolkit: Reducing the Food Wastage Footprint, and here. Read an article about Environmental impact of novel thermal and non-thermal preservation technologies in food processing here.

User/Customer considerations of Food waste reduction technology implementation

A variety of issues when implementing any food waste reduction technology must be taken into consideration. A very important aspect is the target customer, how food is currently preserved and what their needs are (whether they need a portable or locally made technology, etc.). The affordability/accessibility of the technology is also determining. This will include how the technology will be demonstrated, adopted, and supported by the targeted user group(s), and whether the benefit of using the technology exceeds the cost of adopting and using the technology (cost benefit) for the user. Another key consideration to take into account are the key stakeholders involved in the value chain of the food product. These can be found in three stages of the food chain: (1) close to the farm, including farmers, farmer cooperatives or food producers that sell directly to users, (2) Procuring food - these involve intermediaries that consolidate, store, transform or distribute food to groceries stores, and (3) at the host sale/retail stage which involves owners or actors managing cold stores, wholesale warehouses involved in organizing, moving products in and out to be shipped as well as ICT technology organizations that provide tracking and traceability systems. See more resources in the USDavid Postharvest technology, Research and information Center.

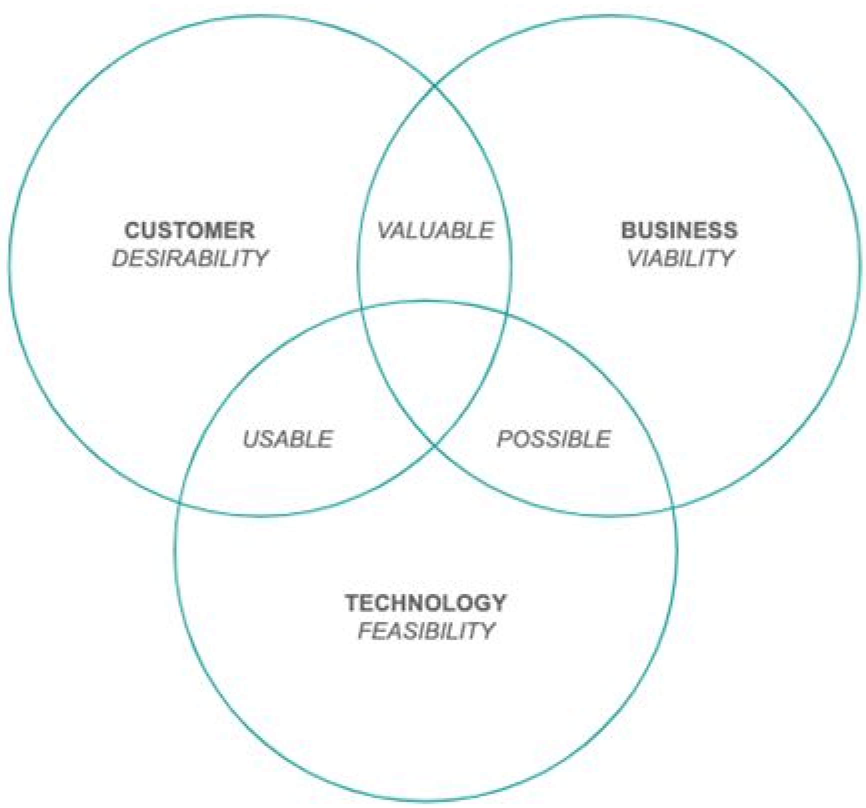
Business and Market Considerations

This will involve considering issues such as where your technology fits in the farm to table value chain, and therefore, your competitor products and their average price point, what stakeholders should be engaged and what partnerships would be needed. A cost -benefit analysis of the benefits versus the cost of production and adoption/distribution of your technology (Investment-return analysis). Also the short-medium or long term plan and timeline for product launch considering all the above. Find more resources in the USDavid Postharvest technology, Research and information Center.

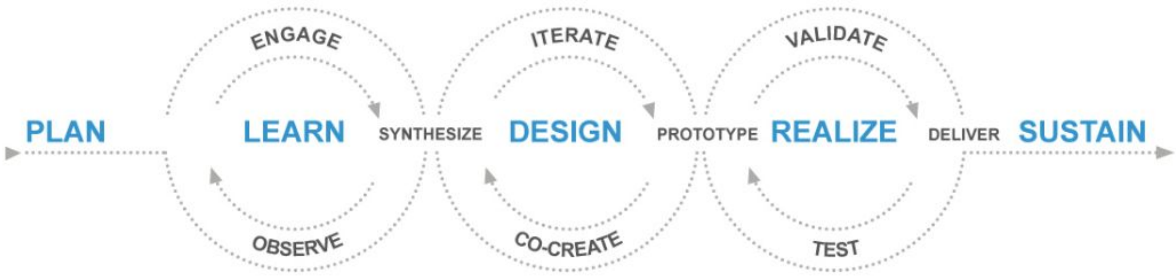
SECTION 2: DESIGN PARAMETERS

1. AN INNOVATIVE APPROACH

A **human centered design approach** to solving problems in underserved communities must take into account the gaps that presently exist between the principal domains that impact most situations - those centered on the *customer*, the *business*, and the *technology*. Without addressing each of these, and the ways that they interact, we risk presenting a solution which does not adequately address all of the issues, and thus will likely not be adopted by the population in a sustainable manner. It probably won't succeed. The Design Objectives below are meant as a guide, to be used to help make sure that key aspects of the zero hunger challenge are being taken into consideration. As you progress in the challenge process, use these as one way to make sure that your proposal stays focused on what is *possible*, what is *usable*, and what is *valuable*. To learn more watch a webinar on Human Centered Design here.



The Solutions Development process developed by E4C (shown below) illustrates the path towards sustainable solutions based on lessons learned from the field. This process is non-linear, in the real world, lines between phases often blur.



Learn more about the Solutions Development Process in E4C's [Introduction to Engineering for Global Development] course.

In order to help you address all of the relevant customer, business, and technology issues you should be thinking about the following questions. While you are not expected to know answers to all of the questions at the start, it can be helpful to answer as many as possible, knowing that your answers may change as you continue to research, design, and prototype throughout the challenge.

2. DESIGN PARAMETERS

For the Plan and Learn phase of the design challenge, you will need to provide answers to the following design parameters, highlighted in **bold**. Considerations in grey will be addressed in subsequent phases.

Customer/User:

1. ***Identify your target customer and determine if they are also your end user.***
2. ***Identify target food products.***
3. ***List your user's needs and decide what is not being met with current solutions.***
4. ***Understand the context/environment in which your product will be used. Make note of how your product will have to perform under specific conditions.***
5. ***Identify what your user's food source will be (food commodity or product). Identify any characteristics or attributes that will require specific handling requirements.***
6. ***Identify opportunities for preserving or enhancing the quality and nutritional value of your food product to better serve your user's needs (See UN SDG Target 2.2)***
7. *Determine your user's harvesting, processing, or transport needs per day. Define an appropriate capacity for your system.*
8. *Discuss how they currently prevent waste (either through market driven solutions or innovative workarounds)*
9. *Define how they make purchasing decisions and what may inhibit them from purchasing a new product.*

10. *Establish what price point is affordable for your customer. Estimate a willingness to pay based on other products they may own or purchase and market standards.*
11. *Determine what an acceptable operating cost would be for your user.*
12. *Determine if your user has the wherewithal (tools, money, expertise) to maintain your product.*
13. *Identify ways to design around ease of maintenance.*
14. *Identify how and where replacement parts will be available for routine maintenance.*
15. *Define where post-harvest food will be delivered and/or used and whether there are specific conditions your system will be required to meet.*
16. *Define how your user might separate spoiled food from preserved food, should the system not be 100% effective.*

Technology:

17. ***Research prior art. Identify standards or other benchmarks that have been set by competitors.***
18. ***Research regulatory standards and define how they might impact your design and development process.***
19. ***Estimate your designs energy consumption (kWh/L) and what that will require in terms of hardware.***
20. ***Identify your preferred food preservation modality (e.g. improving storage or preservation process)***
21. ***Identify ways to preserve post-harvest food during distribution.***
22. *Determine how the environmental conditions that will impact your product's efficiency.*
23. *Determine what material properties are required. Does your user require durability, weight management, or longevity? Consider assembly and manufacturability.*
24. *Describe how your product will be manufactured. Identify what processes you will use and provide justification in terms of sustainability, cost, quality.* *https://www.custompartnet.com/process-selector*
25. *Identify which components could be manufactured locally and which should be outsourced. Internalize how that will impact overall cost, quality and sustainability.*
26. *Decide which technologies you will need to develop yourself and which can be assembled from off the shelf components.*
27. *Address how your design will prevent spoiled food from contaminating fresh post-harvest food.*

Business and/or Implementation:

28. ***Provide a list of other products/solutions that you will be competing with. Identify competitor products and their key features.***
29. ***Determine how you will measure impact for the end user.***
30. ***Identify where in the value chain the proposed technology fits. Determine how it will integrate in an existing system.***

31. ***Identify how you would calculate (or estimate) your product's impact on climate or within a specific market.***
    1. ***Impact could be measured by energy usage, emissions reduction, or water and land usage compared to the current solution in your target market. [NEED LINK TO RESOURCE FOR MEASURING IMPACT]***
32. ***Identify context-specific constraints, including availability/reliability of electricity, affordability of product, and necessary partnerships***
33. *Should you take this concept to market, identify where you lack expertise and how you might close those gaps.*
34. *Research regulatory requirements that may impact the design or distribution of your final product.*
35. *If your design requires chemical consumables, how will you safely procure and discard them after use.*

Phase 1 Key deliverables: Problem Definition and Proposed Concept

Before jumping into developing a solution, it is critical that you outline the exact problem you are trying to solve with the users needs, wants and constraints in mind. This will help you frame, and in the end justify, the reasoning behind your design decisions. Based on your user research and the design parameters you've identified above, contextualize the problem you are intending to solve from the perspective of your user.

Problem Definition:

What is the problem you are intending to solve?

Example Problem statement: *La Guajira is the department with the lowest water coverage amongst rural areas in Colombia (only 4% of its rural population have access to potable water). Due to its deserted landscapes, communities such as the Wayuu indigenous clans get their water from 'Jagueys', ponds that form from rainwater in the rainy season however these have contamination problems due to animals; when 'Jagueys' are dried out during the drought season, communities use wells to access groundwater but this water is mostly brackish. Treated water can be purchased in plastic bags or from water tanks for drinking, crops and livestock but is extremely expensive because it must be brought from long distances (a cost representing sometimes more than half of these people's monthly wages) and yet, in some cases can still taste slightly salty. A few inverse-osmosis water treatment plants have been established in some areas but have had many challenges and have quickly stopped functioning due to operational costs but also because of the lack of maintenance, qualified personnel and successful management.*

Concept Development:

Draft an initial solution concept. Note that you will refine this concept over the course of the challenge. Solutions should address one of the two challenges posted. At the Plan and Learn phase, concepts may be explorative, but should start to answer the following questions:

1. *What is the problem you are intending to solve?*
2. *How is that problem currently being addressed? (Provide a list of other products/solutions that you will be competing with)*
3. *How is your idea different from an Engineering or Human Centered Design standpoint?*
4. *Who is your target user? Describe them and the context that your technology would be used in. What are their current unmet needs or how might your product improve their quality of life?*
5. *Describe your product architecture in 5 sentences. What is the technology at play? What is the relative size of the product? What are the main components and how are they assembled? What are the 3 main features and benefits that this solution provides? What are the potential challenges (design and development) you think you will face?*

In subsequent phases of this challenge, you will need to answer the questions below:

What materials is your product made of? What manufacturing processes will you use to develop each of your products components? What are the potential challenges in design and development you predict you will face?

Sketch how you currently envision your product assembly. Focus on conveying concepts of assembly, part count and functionality.