Recapturing Resources for Circular Food Production: Global Landscape Report

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I. Introduction

A. Challenge / Opportunity Context

Global food production is a central practice to our planet's wellbeing. Human health depends on it and the global economy relies on it. Between 1960 and today, the world population has more than doubled, global food production has more than tripled, and agricultural land use has increased by approximately 15%.[i] As global food production has increased, food loss and waste has increased with it. According to The Harvard School of Public Health, food "loss" occurs before the food reaches the consumer as a result of issues in the production, storage, processing, and distribution phases. Food "waste" refers to food that is fit for consumption but consciously discarded at the retail or consumption phases. The Food and Agriculture Organization of the United Nations (FAO) estimates that a third, by weight, of all food produced in the world was lost or wasted.[ii] This level of inefficiency results in approximately US$940 billion per year in economic losses, according to FAO estimates. The current global food waste would be sufficient to feed two billion people, which is more than twice the number of undernourished people across the globe.[iii]

The connection between food loss and waste and climate change is increasingly recognized by global agrifood experts, as is the link between climate change and agriculture and supply chain resiliency.[iv] Agricultural production produces excessive amounts of greenhouse gases, uses unsustainable amounts of resources, and pollutes the environment. Discarded food is responsible for as much as 8% of global greenhouse gas emissions, according to the US Environmental Protection Agency.[v] If wasted food were a country, it would be the third-largest producer of carbon dioxide in the world, after the USA and China.[vi] In addition to directly contributing to global warming through greenhouse gas emissions, our current, linear food systems contribute to deforestation, rapid biodiversity loss, water scarcity, and damaging aquatic ecosystem services in water-based systems. ***Figure 1*** below illustrates points of food loss and waste along the supply chains.

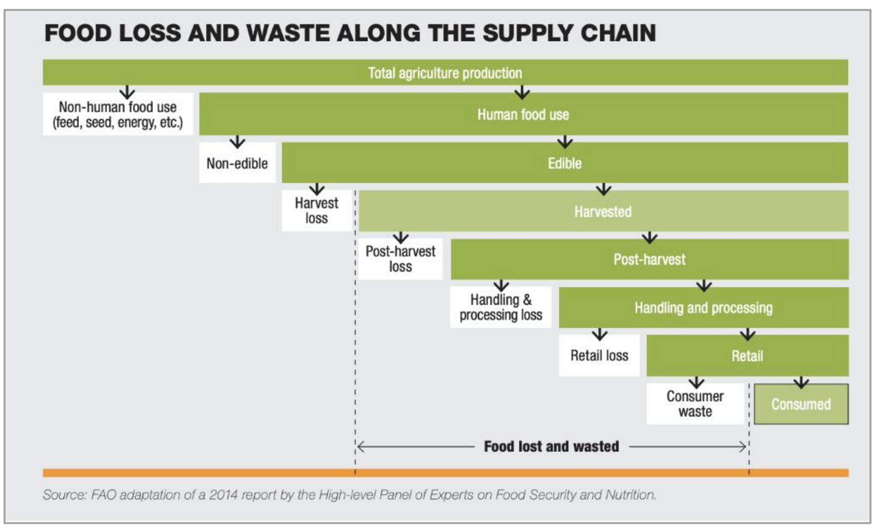

Figure 1. *Food loss and waste along the supply chain, graph sourced from MEED's Investing in Food Security report.*

The reduction of food waste and loss has become a primary focus in efforts to decrease human footprint on the environment continue in global development. One of the UN's Sustainable Development Goals is to halve global food waste and reduce food losses in production and supply by 2030.[vii] If food waste and loss can be sucessfully reduced, there is the potential for all human-caused greenhouse gases decrease by 6%-8%.[viii] Harnessing food waste provides a chance for greater sustainability and economic opportunity. The World Business Council for Sustainable Development found that the circular bioeconomy is a $7.7

trillion opportunity.[ix] Implementing circular food system strategies at actionable opportunities in the food waste and loss sector will allow for the sucessful implementation and scaling of supply chain solutions. A linear supply chain does not have the capacity to adapt to an increasingly fragile ecosystem and political state because it views waste as an "end". Circularity takes the negative externalities of waste into account and works to create a continuous cycle that does not have a harmful end. As noted by Dr. Susan Chomba, Director of Vital Landscapes for Africa at the World Resources Institute (WRI): "Embracing circularity generates multiple benefits for people and the planet. Compared to other methods that only aim to avoid or cut food loss and waste alone, circularity can provide additional benefits such as green job creation, increased value of locally-sourced materials, and revitalizing cottage industries while protecting biodiversity."[x]

There are key gaps in existing research that are stalling the implementation of actionable opportunities for FLW solutions. These gaps and barriers include: underutilization of technology, lack of coordination and collaboration, historical underinvestment in nature and nature-based solutions, lack of finance and assistance to regenerative production methods, and a lack of traceability and transparency in supply chains.[xi] These gaps have the capacity to be filled through greater research on supply chains and impact points of investment. Further research on supply chains has the capacity to raise awareness towards circular supply chain transformations that can in turn develop momentum towards financing for further research, technology, and financial investment.

This landscape report will serve as an overview of the current post-harvest, pre-consumption production chain while additionally identifying high-impact points of intervention for food cycling and valorization. The report will highlight points of food loss waste in 4 unique value chains (rice, cacao, tomatoes, and beef) while elaborating on opportunities to productively repurpose or add value to existing food loss waste streams. When it comes to repurposing, there is an emphasis on systems of circularity to capture waste and revitalize by-products into alternative forms that promote sustainability and increase financial opportunity.

Note: This landscape report has been aimed at assessing the chosen value chains at a broad lens. The findings are not specified to any given global region, country, or community. The information has been collected to serve as a representative overview of selected commodities. PACE has also conducted more in-depth case studies on the *Productive Use of Food Loss and Waste* within the Cacao and Rice Value Chains which elaborates in-depth details and geographical context of the value chains.

II. Scope and Objectives

A. Scope

Food loss and waste will be defined in this paper as the uneaten byproducts and waste generated by food supply chains. "Food loss" typically refers to raw material byproducts and spoilage, whereas "food waste" usually refers to finished edible food that is discarded by food retailers and end consumers. For the purposes of this paper, our research and recommendations will focus on FLW generated during the intermediate stages of food supply chains, after crops are harvested but before food reaches consumers – i.e., post-harvest handling (PHH), processing, storage, and transport. This definition of food loss and waste can be connected to WRI FLW Reporting Standard. This standard includes universally applicable definitions for describing the components of "food loss and waste" in order to provide accounting and reporting requirements that can be used consistently by entities around the world. Additionally, waste upcycling is recurrently referenced in the paper, upcycling is the process of transforming by-products, waste materials, useless, or unwanted products into new materials or products of better quality and environmental value. ***Figure 2*** below is a graphic from WRI's FLW reporting standard that illustrated the definition of FLW that will be followed in this report:

As noted in [PACE's Food Action Agenda](), the term "productive use" of FLW means reimagining wasted materials as valuable resources with productive uses that have the ability to spur innovation for new products and market development. This helps to incentivize stakeholders along food value chains to adapt their business models and generate new revenue streams, while reducing the cost of waste disposal.

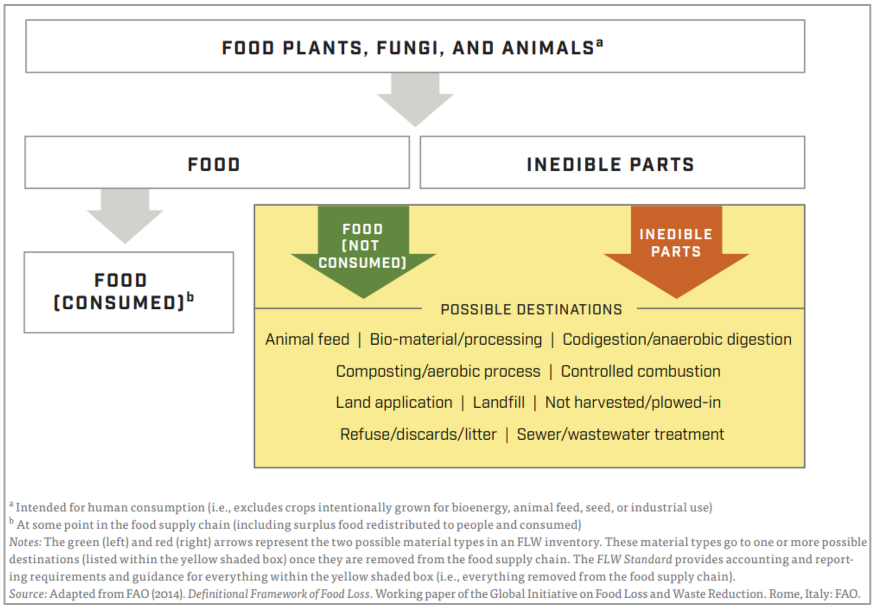

***Figure 2**. Material Types and Possible Destinations under the FLW standard.*

B. Objectives

i. Objectives
   - Present the benefits, feasibility, and scale potential to productively using FLW
   - Identify opportunities and enabling factors to implement FLW solutions in supply chains

ii. Overarching Vision / Strategy
   - Connect these research objectives to WRI's People-Climate-Nature research strategy
   - Our research specifically focuses on case studies and feasibility analysis, to enable action and scale adoption amongst researchers, policymakers, and capital providers

III. Methods

A. Value Chain Analysis Approach

To ensure that our analysis and recommendations are actionable and specific, we have used a value chain analysis approach to provide a representative sample of the varied dynamics and sources of FLW which exists amongst global food supply chains, and how these result in context-specific opportunities and enabling environment requirements to implement FLW solutions. We have analyzed four global value chains – rice, cocoa, tomatoes, and beef. Several productive use examples have been selected for each value chain based on their current potential applicability. The analysis of these value chains are a broad glance at multi-faceted and intricate supply chain systems. Each value chain has context-specific barriers and enabling factors that will differ on a case-by-case basis. The following list contains factors that should be considered in further research to contextualize each unique value chain in any given area:

- Geographical landscape (how is the changing climate affecting the growing season?)
- Political context (corruption, monopolies, trade laws)
- Policy context (existing policy frameworks, or lack thereof)
- Supply chain reporting criteria
- Resource scarcity (access to technology)
- Global market developments

Three case studies have been selected to corresponding value chains as “positive deviants”, meaning they are either examples of harnessing waste by products in a sustainable fashion, or means taken to enable that (such as projects or workshops). These case studies were chosen to potentially spur innovation or create meaningful ways to interact with the FLW landscape. The first two case studies highlight workshops and collaborations that illustrate momentum for the rice and cocoa value chain, the tomato case study focuses on a specific company capturing food waste in the supply chain, and the beef value chain is without a case study due to the findings form the broader beef ecosystem.

The sources used while developing this research are primarily developed from secondary research sources. While developing the background, overview, and definitions of this research there was significant pull from primary research (WRI’s existing circularity sources and PACE’s FLW reporting standard and food action agenda).

B. Research Questions

The following four questions are addressed while following each individual value chain:

1. When and why does FLW occur in this value chain? What are the resulting byproducts or waste streams?
2. What are the possible opportunities to productively repurpose or add value to existing FLW streams? These are categorized as: 1) human consumption, 2) animal consumption, 3) material recycling, 4) nutrient recovery, or 5) energy recovery.
3. What are the key enabling factors and structural barriers that affect the feasibility of acting on these opportunities?
4. Case Studies: are any of these opportunities currently being implemented? What is the solution or innovation that is being used or tested? Can the enabling innovation, policy, and or capital conditions for this pilot be scaled?

IV. Value Chain Findings

A. Rice

I. Overview

Rice is critical to our global economy and agri-food systems, with 3.5 billion consumers and 150 million smallholder farmers relying on the crop for their livelihoods. The global market value of rice in 2021 was $287.45 billion and is expected to reach $334.24 billion by 2028. In 2020, it was recorded that 10% of the world's arable land was dedicated to rice cultivation with 50% of the global population depending on its cultivation.[xii] India was the leading global exporter of rice, harvesting about 45 million hectares of rice. While India was the leading exporter, China is the largest producer of rice globally and is projected to produce

148.99 million tons of rice in 2022-2023. Both countries together make up 50% of the rice grown and consumed globally. See ***Figure 3*** below for a visual representation of global rice production. Rice cultivation is a process that requires vast amounts of water and land, two resources that are increasingly under threat from a changing climate. Rice farming, as with the majority of agricultural crops, is most resource intensive at the cultivation stage. Moreover, rice fields are the main anthropogenic source of methane (25–100 million tons per year), which is responsible for 20% of global warming.

***Figure 3**. Global Rice Production Landscape*

During the process of traditional rice production, there are three primary by-products that are considered waste: rice straw, rice husk or hull, and rice bran. **Rice straw** is produced when harvesting paddy. Rice straw is the vegetative part of the rice plant that is made up by the plant's stem, leaves, and pods and is generated after being cut off during harvest. **Rice husks or hulls** are the outer covering of the rice grain and are produced as a by-product of the rice milling process. **Rice bran** is produced during the second stage in milling, the whitening or polishing process, when the bran layer is removed from the brown rice kernel.

II. By-Product Examples

1. Rice Straw

1a. Rice straw has shown promise for use in **building and construction products**. Natural fibers from agricultural wastes, like rice straw, can be utilized to produce light weight and low-cost polymers for applications in building and construction. Incorporating rice straw presents a cost-effective option for building ceiling panels, bulletin boards, and fiberboard manufacturing.[xiii] Rice straw bales are used as constructive solutions for walls that combine rice straw bales and a variety of coatings. For example, rice straw bale buildings are common in more rural communities in Northern China. There is a push to expand straw-bale construction into main-stream medium-rise buildings in China because it has the potential to make a significant contribution to the reduction of embodied and operational carbon in China.[xiv]

1b. Rice straw material can be utilized to create **paper and packaging products.**[xv] One company in India, Craste, is using rice straws to make boxes. Craste's innovative technology takes rice straw residue left after harvest and saves them from the burn pile by turning them into packaging boxes. Their process is 100% tree-free, requires ⅓ the water of traditional processes, provides a guaranteed income for farmers, and keeps 1460 kg of C02 per tonne of straw out of the atmosphere by preventing crop burning. Craste purchases crop waste from rice farms in Delhi, Gwalior, Ludhiana and Allahbad that would have been burned after harvesting.

1c. Rice straw is a common substrate used for growing a **mushroom** called *Valvariella volvecea*. These mushrooms are grown on rice straw beds and are cultivated throughout East and Southeast Asia by farmers in Vietnam, the Philippines, and Cambodia. The mushroom has a distinct flavor, pleasant taste, and rich protein content which makes it an effective food source in communities with higher poverty rates. This mushroom promotes food security to the community and gives farmers more economic security if a rice crop cycle produces lower yields than expected. The mushroom can grow well in both outdoor and indoor conditions, but outdoor cultivation has more risk with varying weather patterns and can lead to lower yields.[xvi]

2. Rice Bran

2a. The most common use of rice bran "waste" is for **human food consumption**. Rice bran contains high quantities of nutrients like protein, fat, dietary fiber, minerals, and antioxidants. Using rice bran for human consumption positively impacts food security in lower crop yields and escalating populations. After the milling process, the brownish layer of the kernel is removed which produces the bran that can be consumed directly. Rice bran is currently used more frequently as **animal feed**, but there is a move to shift to more human consumption in developing areas.[xvii]

2b. **Rice bran oil** is oil extracted from the hard outer brown layer of rice bran. The oil is well utilized across the world and is used for high temperature cooking due to its low smoke point. Rice bran oil production is relatively sustainable since there is no known significant damage to air, water, land, or soil during production. India has recently ramped up their rice bran oil production as they've tried to overcome an edible oil shortage caused by supply disruptions in 2022. As of June 2022, in India, rice bran oil was trading at 147,000 Indian rupees ($1,879) per tonne compared with sunflower oil at 170,000 rupees.[xviii] While there's little research, it is worth considering rice bran as a sustainable and cost-effective alternative to palm oil in a country like Indonesia that is facing suspensions of palm oil export permits.

3. Rice Husk/Hull

3a. Rice husk ash is a material that can be used as an alternative cementitious material in **concrete**. As a material, rice husk contributes to enhancing the compressive strength of concrete. In the transformation of rice husk to ash (through post-production burning), the cycle eliminates the natural products, leaving silica-rich remains. These silica-rich remains can be utilized in concrete as a limited substitution of cement to enhance its compressive strength.[xix] Rice husk ash has been categorized as a highly reactive material meaning it contains unique chemical compounds that are needed in cement. Rice husk ash industry is set to generate revenue of $1.64 billion by 2025.

3b. Rice husk has also been used as **insulation** for cold storage, walls, and roofs in China for many years. In its raw and unprocessed state, the rice hull constitutes a Class A or Class I (containing fire resistant properties) insulation material. 40% of all materials used in the construction sector are classified as "hazardous". Using rice husk for insulation and construction is a safe, sustainable, and financially beneficial alternative. While there is research on using husks for insulation, there are less examples of countries/companies putting this into practice.

3c. Rice husks can be converted into energy through different processes such as combustion, pyrolysis, or gasification. Of these, pyrolysis (heating of an organic material) is the most promising for rice husks because it has been shown to have high yields in the production of liquids fuel (called bio-oil), gases, and solid (biochar).[xx] Rice husk **biochar** and has been traditionally used in Japan as a soil ameliorant (a substance that aids plant growth primarily by improving the physical condition of the soil). Biochar is primarily used for carbon sequestration. Overall, rice husk biochar is a low-cost and renewable resource that has been found to be highly effective for the remediation of water and soil environments.

III. Structural barriers to value chain

A paper by the International Rice Research Institute said rice was expected to be "the cultivated crop most vulnerable to future changing climates." Asia accounts for about 90% of the world's rice output, and climate unpredictability has significantly affected the continent's crop production. Rains in India's grain belt, a heatwave in China, floods in Bangladesh, and salt seawater infiltrating inland rice production areas in Vietnam is curbing yields in four of the world's top five rice producing countries. As climate change progresses, environmental risks become more extreme, further threatening global supply chains. As a structural barrier to productivity within the rice value chain, this situation forces farmers into adjusting to decreased crop yields. Nonetheless, circular agriculture practices contextualize crop production in the current state of the environment by allowing farmers to transform their systems to take environmental unpredictability into account without sacrificing yields and livelihoods.

With rice being the most consumed crop worldwide and an approachable crop to farm, the global landscape possesses a unique concentration of small holder farms, as established earlier in this text.[xxi] Most farms operate on less than one hectare of land with low productivity. Sixty percent (60%) of rice smallholders are outside the formal markets limiting access to inputs, knowledge, and finance (60%).[xxii]This environment creates both enabling factors and structural barriers to act on opportunities of circularity in the rice supply chain.

Having most of the industry dominated by smallholder farmers demonstrates a huge opportunity for change without necessarily having to upend large rice monopolies or change their practices. While these smallholder farms could likely be receptive to new practices that will increase output and financial revenue, it is an undertaking to create pathways of communication that can reach such a varying array of smallholder farmers, and which vary depending on geography and context. Investment in projects that prioritize capacity building around food loss/waste and circular solutions in rural communities will be crucial to initiate a waste capturing value chain shift. Given that the rice value chain relies on smallholder farms that are often operated within a family, women's empowerment in rural rice growing needs to be prioritized to cultivate efficient supply chains without gender fragmentation. Men and women rice farmers need equal opportunity to be equipped with tools, technologies, best practices, and incentives to farm rice sustainably.

International Rice Research Institute & Can Tho University Workshop

Background: In September 2022, International Rice Research Institute (IRRI), in partnership with the Can Tho University Department of Agriculture and Rural Development, conducted a training workshop on developing and demonstrating a mechanized rice straw composting business model in Can Tho City, Vietnam. Supported by the CGIAR Initiative on Securing the Food Systems of Asian Mega-Deltas for Climate and Livelihood Resilience (AMD) and GIZ-funded Promotion of Sustainable Rice Straw Innovations (PINStraw), the event gathered 60 participants representing farmer groups, government agencies, extension offices, research organizations, and academic institutions to enhance their knowledge and awareness on mechanized rice straw composting through demonstration and training. The event aimed to mainstream rice straw-based green circular economy supporting low emission and organic rice farming. According to a memo on the event from the IRRI, "In his conclusion and way forward, Mr. Le Thanh Tung, Deputy General Director of Vietnam's Department of Crop Production, said that rice production provides farmers with much less profits compared to vegetable and fruit production. However, Mr. Tung believed that the added value, gained from reducing carbon footprint and making the production process more environmental-friendly, will increase the value and marketability of rice from MRD in specialized markets."

How does this workshop demonstrate potential for change? | This workshop reflects the need for collaboration when trying to achieve action in educating. Both IRRI and Can Tho University brought different elements of expertise to the workshop; IRRI had the capacity to organize an event that could reach rice farmers in Vietnam while Can Tho University held the technical expertise to deliver the rice straw composting business model. Although IRRI operates out of The Philippines, this workshop demonstrates ability, need and willingness to scale projects to different locations. This case study is an example of the first step required to promote business circularity in the rice sector; collaboration and awareness raising across sectors, and bringing together farmers, academics, policymakers.

What can we learn from this case study and the potential for scaling? | This workshop is an example of cross sectoral collaboration and can be implemented in other value chains. By bringing together a variety of partners, the workshop was able to bring perspectives to the table that are not typically represented. In addition, the workshop was a step toward developing several demonstration models while also contributing to understand how to remove the 20 million tons of rice straw from the fields of local farmers to contribute to mushroom, cattle feed, and compost productions. This is important as one of the main barriers to the productive utilization of rice straw is how to remove it from fields – a point further elaborated in PACE's deep dive on the productive use of rice FLW. The cooperatives participating in this project will eventually lead the way to cultivating mechanized rice straw composting services and business models. Nonetheless, although the workshop was a good first step in raising awareness on the topic (of which few exist) we do not know of the outcomes of the workshop as they have yet to be publicly reported and captured. In addition, we note the elements of investment (how to fund new technologies) and policy (what enabling policy's are required for innovations to succeed) was missing from the workshop. Both topics are necessary to understand the right conditions needed for the productive use of rice straw. Lastly, workshops like these are a necessary part of incremental change that helps raise awareness among different stakeholder groups and determine needs, however repetition and consistency is required to ensure the efforts ladder up to a structured program of work for the biggest impact.

B. Cocoa

Overview

Cocoa (raw, unprocessed cocoa) is primarily cultivated in equatorial regions in West Africa, Latin America, and Southeast Asia, which are characterized by high temperatures and consistent rainfall. Although cocoa production is concentrated in the Global South due to its tropical growing requirements, more than a third of cocoa beans are processed in Europe. Cocoa is a high-potential value chain for research and action due to its significant rates of food loss (700,000 tons per year)[xxiii], and potential for increased efficiency and equity by way of circular practices. According to the International Cocoa Organization, global cocoa waste generated is estimated to be roughly 700 thousand tons per year. Raw cacao beans are fermented, dried, and processed into cocoa mass, cocoa butter, cocoa powder, chocolate, and other cocoa products.

The primary byproducts of raw cacao pods and beans are the pod husks, pod ash, pulp (also called mucilage or baba), and the cocoa bean shell. **Cocoa pod husks** are the external part of the cacao fruit, representing 75% of the total weight of a pod.[xxiv] Cacao pod husks, when discarded during harvesting, can be sun dried and burned to produce **cocoa pod ash** comprising of 40% potassium hydroxide or potash**.** **Cocoa pulp (mucilage or baba)** is the white substance that coats the cocoa grain (bean). After splitting cacao pods during harvesting, cacao beans and pulp are extracted. From this point, the beans and pulp undergo fermentation, in which yeasts grow on the pulp surrounding the beans. Cacao pulp naturally starts to break down and drain away during the second day of fermentation.[xxv] **Cocoa shells** [xxvi] are the shells of individual cocoa beans, which make up 12-20% of the bean, and are the largest portion of waste generated during chocolate processing. Cocoa shells are typically removed from beans after roasting. Usually, the shells are discarded or sold for use as agricultural mulch. Given the number of uncontaminated organic byproducts generated by the cocoa value chain, it has significant opportunity for capturing and transforming waste.

I. By-Product Examples

1. Cocoa Pod Husks

1a. Cocoa pod husks have been used as an **alternative animal feed source**. In countries like Ghana, where prices of poultry feed are a main limiting factor towards production, there is need to divert and use agricultural wastes in animal feed compositions for livestock.[xxvii] The use of cacao pod husks shows promise, though pods must be appropriately treated to completely remove or reduce theobromine, a compound that has detrimental effects on animals, with the exception of pigs.[xxviii]

1b. Research has proven that **compost** made from cacao pod husks, both healthy and diseased, is effective at improving soil quality as well as inhibiting the common black pod disease. Additionally, biochar produced with cacao pod husks could help to restore soil by building nutrients and improving other soil characteristics that support growth.[xxix] Agricultural extension workers, NGOs, and farmer groups could assist local farmers in adopting these sustainable practices and utilizing common waste.

1c. Cocoa pod husk is well-suited as a biomass source for **electricity production**. The waste ash is rich in potassium, which can be converted in various chemical products, most notably, high-purity potassium carbonate.[xxx] For every ton of cocoa pod husk, ~60 kg of potassium carbonate and ~30 kg of a calcium/magnesium solid are created. Research has been conducted on using cocoa pod husks to generate electrical energy in Uganda, which faces electric power supply obstacles, predominately in rural areas. Using agricultural waste for energy generation is technically most suitable in rural farming areas, where raw material (biomass) is readily available in large quantities and pollution-free (renewable and clean), however the amount generated typically exceeds the amount needed by those living in rural areas. Further research is therefore needed to determine the highest value calculation and ideal proportions.

2. Cocoa Pod Ash

2a. Cocoa pod ash can be used to **manufacture fertilizers**. The potassium found in the ash can be mixed with starch and processed into pellets which can be easily used in fertilizer. Cocoa farmers can macerate the cocoa pod husks as biofertilizer to restore environmentally important soil elements.[xxxi]

2b. Cocoa pod ash is also commonly used in West African countries to produce **African black soap**, sold worldwide. Cocoa pod husks are sun-dried and burned to ash, compromising 40% of potassium or potash. This serves as a catalyst for saponification (the process of converting esters into soaps and alcohols) when added to oils to produce soap.[xxxii] To make the soap, cocoa pods are dried in the sun, then roasted in a clay oven. The clay oven is the only piece of machinery that is needed to create the soap.

3. Cocoa Pulp (Mucilage or Baba)

3a. Cocoa pulp is primarily upcycled for **food and beverage consumption**. Cocoa pulp is sweet and nutritious and is often consumed by cocoa farmers and farming communities. The pulp has been commercialized with various companies specializing in cacao pulp drinks. Pacha de Cacao is an Ecuadoran company that sells natural and vegan cacao juice. The company claims to have a zero-waste policy and works closely with two farms in Ecuador to retrieve pulp.[xxxiii] Cocoa liquor is also a major product made from cocoa pulp, and unlike chocolate cacao liquor, is mainly produced by European companies because the cost of processing is high.

4. Cocoa Bean Shells

4a. Cocoa bean shells have high potential for productive repurposing because of their composition; however, they often cannot be used directly in food production because they may contain components that are harmful for human health. Cocoa shells can carry mycotoxins, microorganisms, polycyclic aromatic hydrocarbons, and heavy metals. **High voltage electrical discharge** presents a novel non-thermal method that has great potential to decontaminate waste materials and to extract valuable compounds from the cocoa shell.[xxxiv] While this is not a specific product that cocoa shells can be turned into, this process could enable farmers to sell detoxified cacao shells to companies interested in upcycling practices.

4b. It is possible to use cocoa bean shell mulch to **suppress weeds** in perennial fruit crops, gardens, urban landscapes, and occasionally in vegetable crops in organic production systems. Cocoa shells have the capacity to reduce weeds organically and retain moisture in garden beds.[xxxv] Biochar made from cocoa shells is also a natural fertilizer. While it is hard to calculate how many farms are utilizing cocoa shells directly on their fields, the use of this byproduct presents opportunities to educate farms that are not utilizing this tactic.

4c. Cocoa bean shells can also be ground to make **cocoa flour** for use in cooking and baking. Cocoa flour is rich in theobromine, dietary fiber, minerals, vitamins, and antioxidants, which make it a healthy, gluten-free option to traditional flour. With an abundance of healthy components, cocoa flour can be considered a functional superfood flour.[xxxvi]

II. Structural Barriers to Value Chains

The cocoa value chain is a difficult one to permeate because of its reliance on cheap labor, child labor, and occasional slave labor at the growing and harvesting level. One barrier tied to addressing labor exploitation is government regulations around deforestation. While regulations prohibiting deforestation are imperative to conserve land, these regulations contribute to little supply chain transparency. Deforestation regulations need to be coupled with supply chain transparency protocol to avoid further visibility problems for cocoa harvesters. It is important to note that the structural barriers of cocoa (and all other value chains) are context specific. Cocoa is known to be riddled with labor issues in the supply chain, but, those labor struggles will look different depending on the region/country/community that is being studied. As an example, Cocoa originated in South America (Venezuela) and was brought to Ghana and Nigeria by Portuguese explorers to create business. This history has informed the differences in operations and labor of the value chains. Another context specific barrier in the cocoa chain within Ghana is the cocoa bean buying monopoly that Ghana holds. Due to the importance of cocoa in Ghana, both in terms of its effect over the lives of cocoa farmers and to the Ghanaian economy, the government of the 1930s took control of the industry. They set up a buying monopoly for all the cocoa produced in Ghana. The government's monopoly was intended to protect the farmers from price fluctuations. This failed to ensure a better price to the farmers, but did receive additional help from the other bodies set up by the government like Cocobod, the countries state owned marketing board that control and regulate cocoa in the country (monopoly).[xxxvii] This cocoa monopoly in Ghana is important context while considering points of intervention in the cocoa supply chain in Ghana.

Low productivity is also considered to be a structural barrier to the cocoa value chain that circular practices can alleviate. Resulting in decreased yield, low productivity from aging cocoa trees grown as a monocrop have led scores of impoverished smallholder cocoa farmers to make illegal incursions into standing forests, where the soil is more fertile. However, it can be improved through the upcycling of cocoa pods by integrating the pods into fertilizer for cocoa trees. The recycling of cocoa by products has the potential to regenerate the soil that houses cocoa trees which will prevent farmers from seeking forests in illegal areas. Understanding how to minimize cocoa production in illegal areas will lead to a more transparent supply chain which will help initiatives improve labor regulations. In addition, this indicates that working with traders and multinationals is a key part of the puzzle to increase the productive use of commonly wasted resources. The negative externalities occurring from the cocoa value chain have the capacity to be improved through circular practices.

Case Study: [From Bean to Bar]

Background: This project is led by Helvetas Vietnam with funding from The European Union. The initiative aims to transition the cocoa and chocolate subsector in Vietnam with regenerative and circular economy approaches at key points in the product's lifecycle. Helvetas' goal is to prove the feasibility of closed-loop and circular production, providing an example for others to follow and informing supportive policies. One intervention includes establishing circular economy business models for companies early in the product life cycle that will create the ecosystem the cocoa sector needs to reach its growth targets while decoupling from negative environmental consequences of conventional cacao production. A second point of intervention includes enabling efficiency of energy and water consumption, bio-based packaging, and environmental management system for chocolate processors by digitalized traceability systems will reduce the environmental impact of cocoa processing and demonstrate a circular economy later in the product life cycle. The project is working with 3,500 cocoa farmers and 500 farm employees and other cocoa-related businesses with a project phase from April 2022 to March 2026. According to Helvetas, "The cocoa sector was selected because it is large and prominent enough to convincingly prove these concepts and achieve meaningful results, but small and cohesive enough to be a pioneering case. Cocoa enterprises are still not aware of the circular economy but are willing to make the necessary changes if they are shown how it can be done productively and profitably. It is therefore essential to have circular economy success cases that convincingly demonstrate how regenerative agriculture and circular economy can be implemented across product lifecycles. A well-documented example, backed by policy, economic and technical research, is a precondition for the adoption of the circular economy by businesses, financial institutions, and policymakers."

How does this workshop demonstrate potential for change: While the Bean to Bar project is ongoing, it demonstrates the potential for success because of a thorough understanding of circularity and a confidence that, if adopted, it has the capacity to transform the cocoa market. Transitioning producers/growers to a more circular business model requires a deep level of trust among local communities to commit to changing the status quo. Understanding the need to win over trust and knowing this is a key barrier to overcome, Helevtas have committed to proving that this business model is effective through transitioning the project funded examples of 3,500 cocoa producers and 500 employees of cocoa farms.

What can we learn from this case study and the potential for scaling: Bean to bar serves are a pioneering example for transitioning a production value chain to a circular model. This solution can most likely be scaled to alternative value chains or countries because the project interventions do not show any specificity to cocoa or Vietnam. Due to the over $2 million costs of this project, the scale of a similar project would need to have a financially equipped large Development donor like The European Union to be replicated at a similar size. However, the true mark of success will not be whether the project can be repeated, but whether the business case is financially viable enough to not require a large donor-funded project, but to create a successful market product. Nonetheless, the European Union is using this project to promote circular economy business models for companies early in the product life cycle. This will create the ecosystem the cocoa sector needs to reach its growth targets while decoupling from negative environmental consequences of conventional cocoa production. Additionally, projects such as this can enable efficiency of energy and water consumption, bio-based packaging, and environmental management systems for chocolate processors by digitalized traceability systems that will reduce the environmental impact of cocoa processing and demonstrate a circular economy later in the product life cycle. Implementing these activities can trigger expansion of circular economy models in the wider Vietnamese agri-food sector. Lastly, there is much learning to be gained from outcomes of the project both in terms of what went well, and which areas require further ideation.

C. Tomatoes

I. *Overview*

Tomatoes are the second most important vegetable crop globally after potatoes.[xxxviii] Although tomatoes are produced in lesser quantities globally than competing vegetable crops like potatoes, they are the world's leading vegetable for processing by weight. Tomatoes are processed into a variety of forms for greater shelf-life and transportation, including canned, dehydrated, paste, puree, pulp, ketchup, sauce, and juice. Global production of tomatoes for both processed and fresh products totaled over 189.1 million metric tons in 2021, increasing steadily over the previous three years.[xxxixi] In 2020, tomato production constituted well over 5 million hectares of production worldwide.[xl] Mexico is the leading global exporter of fresh tomatoes worldwide, followed by the Netherlands, Spain, Morocco, and Canada. China is the top producer of tomatoes, contributing 35% of the global production of this vegetable crop (followed by the U.S. and Italy).[xli]

Tomatoes are a high input-cost crop, and their production already creates risk for smallholder farmers in recouping their costs during the growing season on top of climate change, pest and disease, and market price variation risks. They are also a highly perishable crop, vulnerable to spoilage by microorganisms due to their high-water content. They have very thin skin and are prone to impact bruising, cuts, and punctures during harvest and handling. As a result, the tomato value chain experiences more loss per year than any other fruit or vegetable, with 50 to 75 million tons lost each year.[vi] Research by McKinsey & Company found that only 59-72 of every 100 tomatoes produced in developed countries make it to the store shelf, while only 35-58 make it to the shelf in developing countries.[xlii] Much of the loss in the tomato value chain happens early in the value chain, concentrated at the point of production and harvesting. Even so, large quantities of by-products are also generated and underutilized during tomato processing, accounting for 3-5% of the total weight of the raw tomatoes.[xliii]

Tomato processed by-products consist of peels, seeds, and pulp (pomace). Tomato pomace generally consists of 56% pulp and peels and 44% seeds on a dry basis. However, the composition of tomato pomace is simultaneously dependent on the type of final product and the peeling methods applied in the production line. The tomato pomace generated during the peeling phase of peeled tomato production only consists of peels without seeds. However, in the case of tomato juice and paste production, tomato pomace is a mixture of peels, seeds, and a small amount of pulp.[xliv] Tomato pomace contains several high-added-value compounds, particularly lycopene, proteins, oil, and dietary fibers. Nutrient concentrations and the fiber make up of tomato by products range depending on the variety, geographical location of the cultivation areas, growing stages, ripening, type of processing, extraction conditions, as well as analytical techniques utilized.[xlv] Due to the simplicity and fragility of tomatoes, solutions towards decreased food loss and waste will likely have to be contextualized to specific environments, especially when considering processing for fresh value vs. processed tomatoes.

II. *By-Product Examples*

While waste from tomatoes can be broken up into different items (seeds, peels, overall pomace) the productive uses for tomato by products are typically used together. As listed below, the mechanisms of upcycling waste involve all components of the byproducts.

Heinz and Ford have recently partnered to create sustainable **vehicle manufacturing material** from tomato waste. As the Ford website explains, the companies are looking into options such as using dried tomato skins to make the small storage compartments near the vehicle dashboards and the like. The ultimate victory would be to develop 100% plant-based plastics, according to the Associate Director of packaging and R&D for Heinz.[xlvi]

Rotten tomatoes are feasible for **bioethanol production** if paired with Saccharomyces cerevisiae (a strain of brewing yeast). Utilizing spoiled tomatoes in this way will allow for reduction in waste volume in addition to fueling the generation of a universal organic solvent.[xlvii]

Scientists have recently discovered how to convert waste tomato peels into **petroleum-based filler for sustainable rubber**. Researchers at The Ohio State University in the US have discovered that tomato waste can partially replace the petroleum-based filler that has been used in manufacturing tires. Tests have found rubber made from tomato waste exceeds industrial standards.[xlviii]

On the cutting edge of utilizing tomato waste stands two companies based out of California teaming up to create **sustainable drinking water** out of tomatoes. Los Banos-based Ingomar Packing Company, a tomato processor, has partnered with Botanical Water Technologies to provide a remedy to water drought in California. The process involves capturing the condensate that comes from the tomato before they make the tomato sauce or the tomato paste and putting that condensate through a processing machine that ultimately creates clean drinking water that claims to have no taste of tomatoes.[xlix]

Phenix en Provence is a joint venture between Inaturals® and CAPL, an agricultural cooperative in the Provence Languedoc regions serving French farmers. The mission of this company is "to support **cosmetic and wellbeing brands** that create value within a clean label movement, by supplying high quality French origin ingredients from tomato co-products." The company valorizes the skins, seeds, and tomato hydrolate (distilled herbal waters/essential oils remaining after distillation) of tomato processing at the nearby Panier Provençal factory in southern France. The ingredients they produce include a cosmetic active ingredient, a tomato seed oil rich in Omega-6 fatty acids, and the organic fruit hydrolate derived from water during the tomato sauce concentration process.[l]

Researchers working on the project BIOCOPAC ("Development of bio-based coating from tomato processing wastes intended for metal packaging") have devised a range of alternative **bio-based lacquers** for application on the outside and inside of tinplate cans using tomato by-product waste. This initiative is led by the Experimental Station for the Food Preserving Industry (SSICA) in Italy. The research team has used environmentally friendly techniques to extract cutin from tomato peels. Extracted cutin is then processed into an eco-friendly varnish for food-contact application. This natural lacquer has chemico-physical properties similar to currently used materials in the food industry. Packaging containing this lacquer safeguards consumer health and is recyclable.[li]

III. Structural Barriers to Value Chains

The tomato value chain is a fragile one that possesses unique structural barriers to achieving waste upcycling. High cost of inputs, pest and diseases, postharvest losses and marketing are the major challenges facing tomato production globally.[lii] The majority of these challenges come from the high risk of spoilage, caused by the tomato's high-water content and lack of protective exterior. Value addition in tomatoes is an important aspect in addressing the post-harvest challenges, product diversification, and ultimately profitability. The tomato value chain is particularly sensitive to supply chain issues that stem from a changing climate. Tomatoes are an incredibly water intensive product requiring about 5-6 gallons of water per tomato.[liii] During a time where rain and drought is becoming more erratic and intense, the fragile tomato value chain is under threat. As reported in a Guardian article in February 2023: "The wholesale price of tomatoes, has quadrupled with supply chain issues, as in there isn't enough to go round. Our supply chains are creaking, and we are seeing a forerunner of what could be a huge crisis. There has been a total failure by the government to develop a proper food strategy. "[liv] While these challenges are seen as barriers to the tomato value chain, these issues can serve as a justification for increasing circularity within the supply chain. Capturing and upcycling waste and food loss will add more stability and financial incentive to the value chain. Utilizing tomato waste can be achieved on every scale of processing. Developing projects that are aimed at informing tomato farmers on the various ways they can upcycle spoiled fresh tomatoes or by products from processing is a productive point of intervention for Universities and development organizations.

Case Study: Heinz and Ford Partnership

Background: For the past two years, researchers at Ford Motor Company and H.J. Heinz have been developing an alternative to petroleum-based plastic for cars: tomato-based car parts. Specifically, researchers have been examining the feasibility of using tomato fibers for vehicle manufacturing. For example, the use of dried tomato skins as the wiring brackets or storage bins in Ford vehicles. H.J. Heinz, a company that uses over two million tons of tomatoes per annum to produce its ketchup, has for years been seeking a means to recycle and repurpose an abundance of peels, stems, and seeds. Since 2000, Ford has allocated capital towards an R&D lab specifically focused on developing plastics from renewable sources. In recent years, the automaker has made use of bio-based and recycled nonmetal input materials: for example, recycled cotton fabric for seats and carpeting, soy foam seat cushions and head rests, and console components reinforced by cellulose fiber. The use of tomato waste is a continuation of these efforts. Natural fiber composites, e.g. tomato parts, produce fewer greenhouse gas emissions during the manufacturing process because they are cooked at lower temperatures, and thus are seemingly the perfect marriage of Heinz and Ford's objectives. The tomato initiative is a collaborative commitment to sustainability established in 2012 on behalf of Coca-Cola, Ford, H.J. Heinz, Nike, and Procter & Gamble.

How does this workshop demonstrate potential for change: This collaboration between Ford and Heinz is an example of two large scale companies using each other to capture waste and increase business circularity. Both companies have capitalized on the ability to make each other more sustainable: Heinz has an outlet for waste while Ford has access to waste by products that can be turned into groundbreaking new vehicle manufacturing material. This public collaboration has the potential to inspire other companies to seek out similar partnerships that promote waste utilization.

What can we learn from this case study and the potential for scaling: While Heinz and Ford are two multi-million-dollar companies, the collaboration that this waste solution is built off of can be replicated. This particular case study shows that the most effective way of disposing waste from a value chain doesn’t have to solely rest on the company itself to create a solution. An upcycling solution can mean understanding the uses of your commodities by products while scanning the market to see if there are companies that have the infrastructure and sustainable vision to capitalize on the uses of those by products. With Ford is currently using eight bio-based upcycling materials for car assembly, this case study shows the feasibility of adopting food by products in large scale companies’ assembly lines that may not have not been previously considered. Further research is required to determine how this could be scaled.

D. Beef

I. Overview

The global beef industry, valued at approximately $300 billion as of 2021, continues to demonstrate its lucrative potential within the broader food sector. The industry is projected to grow from USD 414.98 billion in 2022 to USD 604.34 billion by 2029.[lv] The United States produces the most amount of beef, holding 21.7% of the global share with Brazil and China close behind at 17 %and 11% of the global share.[lvi]

Beef production, specifically raising cattle, is known to be harmful to the planet as it is extremely resource-intensive, produces high levels of greenhouse gases such as methane, nitrous oxide, and carbon dioxide. Research shows that ruminant livestock account for between 7% and 18% of global methane emissions from human-related activities.[lvii] Livestock takes up nearly 80% of global agricultural land yet produces less than 20% of the world's supply of calories (as shown in ***Figure 4***). Producers are met with high demand in a production value chain that is land intensive and degrative.

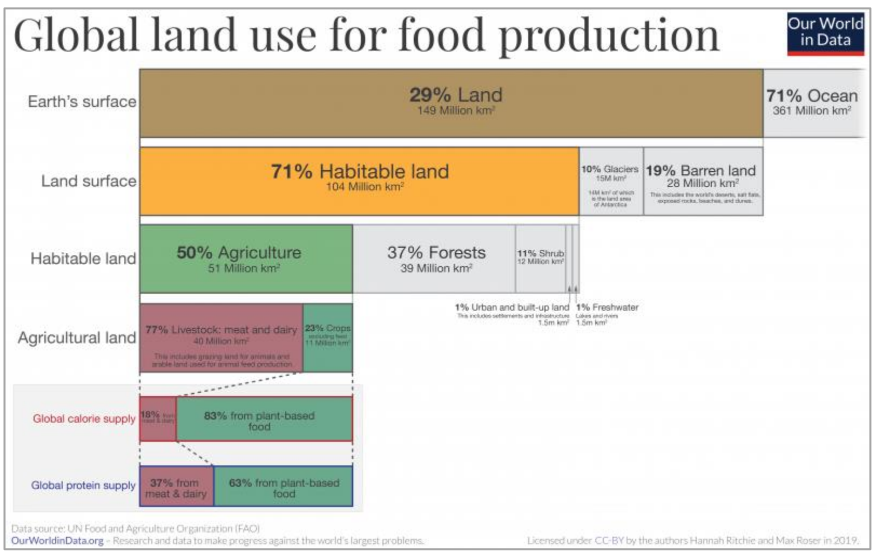

Figure 4. *Global land use for food production; highlighting livestock production.*

Overall, there is a direct correlation between a country's wealth and the amount of beef they consume: getting richer means eating more beef.[lviii] As global wealth grows, our consumption of beef has been on the rise. While meat only comprises 4% of global food loss and waste, it has a higher economic value compared to other food groups. Although the amount of meat wasted is lower than other product groups such as fruits and vegetables, the economic and environmental impacts are significant.[lix] Waste in the livestock industry primarily comes from slaughtering; however, since cattle are such a versatile product, many cultures and countries consume it in different ways. For example, the United States classifies livestock bones as waste, while other countries use bones for stock/soup.

Beef has a unique value chain when it comes to waste and spoilage. Most of the beef consumed by countries with higher GDPs are getting their meat from large producers like Hormel Foods Corporation, JBS S.A., and Minerva Foods SA.[lx]. These companies have the resources to handle and potentially upcycle their waste. By contrast, in economies with less industrial infrastructure, many people get their cows from more locally sourced farmers. Globally, around 500 million pastoralists rely on livestock herding for food, income, and as a store of wealth, collateral, or safety net in times of need. Pastoralists and small-scale communities that keep several cows by a means of feeding their family or community likely don't waste many parts of the cattle because it is so valuable. There is potentially a point to be made for the highest potential impact for capturing food waste is in the large-scale beef production chains because more waste is occurring in this side of production. Locally, livestock production systems have the potential to contribute to the preservation of biodiversity and to carbon sequestration in soils and biomass.[lxi] The research conducted for this value chain has shown a vastly different system when compared to the previous value chains covered in this report. The beef production system has little research on post slaughter pre consumer waste. This is due to a myriad of factors including relatively low rates of waste pre consumption because of the products value, underreporting, and a great emphasis on land management when it comes to beef sustainability.

II. By-Product Examples

The research of beef byproducts is more readily available because beef is seen as a valuable commodity, hence, its value has driven the market to profit from all parts of it. Below is a list of byproducts left after mainstream beef processing and their potential uses.[lxii]The variety of products that are in this list are reflective of how highly utilized beef byproducts are, lending the value chain to existing waste circularity compared to the alternative value chains in this research.

- **Blood:** Imitation eggs, cake mixes, dyes and inks, adhesives, minerals, medicines, laboratory medicines
- **Hide:** gelatin, flavorings, sheetrock, adhesives, candies, leather
- **Hooves & Horns:** adhesives, plastics, pet food, plant food, photo film, shampoo, lamination, wallpaper, plywood
- **Hair:** air filters, brushes, felt, insulation, plaster, textiles
- **Brain:** anti-aging cream and medicine
- **Bones:** refined sugar, charcoal, fertilizer, glass
- **Internal Organs:** instrument strings, tennis racket strings, hormones, enzymes, vitamins
- **Fat:** chewing gum, candles, detergent, fabric softener, deodorant, shaving cream, perfume, cosmetics, lotions, crayons, paint, lubricants, biodiesel, plastics, waterproofing, cement, chalk, matches, fertilizer, antifreeze, insulation, linoleum, rubber, textiles, medicines

III. Structural Barriers to Value Chains

The beef production landscape is an intricate system that sits primarily at the hands of livestock monopolies (Tyson Foods, Cargil, National Beef Packing Company, and JBS).[lxiii] Due to the products significant value and demand, markets in developed economies have already capitalized on the multitude of ways beef waste can be used, as seen in the examples in the section above. Beef shows our food and agriculture systems intrinsic ability to capitalize on food loss and waste. The beef value chain points to the importance of companies and everyday consumers identifying the foods we consume as holistically valuable and containing multiple potentials for profit, consumption, and overall uses. This paradigm shift in seeing our food as containing more value will be needed in order to transition to a more circular agri-food system. This also extends to the need to know the farmers of origin in order to address the whole supply chain.

While comparing beef to the other value chains in this research report, it does not present as many feasible opportunities to currently act on waste circularity due to the fact beef is already a highly valued product and many by products are already productivity used, as illustrated in the previous section. However, the lack of opportunity when it comes to re-purposing commonly wasted resources does not mean there is a lack of necessity around making the beef value chain more sustainable. The landscape is changing as developing countries (particularly in East Africa) become richer and consume more meat. Traditional food value chains in developing countries exhibit the highest post-harvest loss rates but also deliver nutrients to consumers most cheaply.[lxiv] As value chains morph with the rise of a middle class and changing preferences food waste capturing strategies will become increasingly important. The opportunity for circularity in the beef industry can grow as production and consumption grows in developing countries. Locally, livestock production systems have the potential to contribute to the preservation of biodiversity and to carbon sequestration in soils and biomass. According to new research from IDTechEx, "Feeding the world's population in 2050, which is expected to hit 10 billion, will require a 70% increase in global food production that will be detrimental to the environment."[lxv] The points of intervention most dire in making this system more sustainable lies primarily in land management, feed sourcing, and manure processing.[lxvi] An area of circularity that could be worth further research is the upcycling of cattle manure in this sector. Cattle manure is responsible for extraordinary levels of carbon emissions, according to the University of Cambridge, manure and synthetic fertilizers emit the equivalent of 2.6 gigatons of carbon per year – more than global aviation and shipping combined.[lxvii] The opportunity for upcycling manure holds a great deal of impact considering the current level of emissions it is responsible for.

V. Conclusion and Recommendations: from Research to Action

PACE Theory of Change:

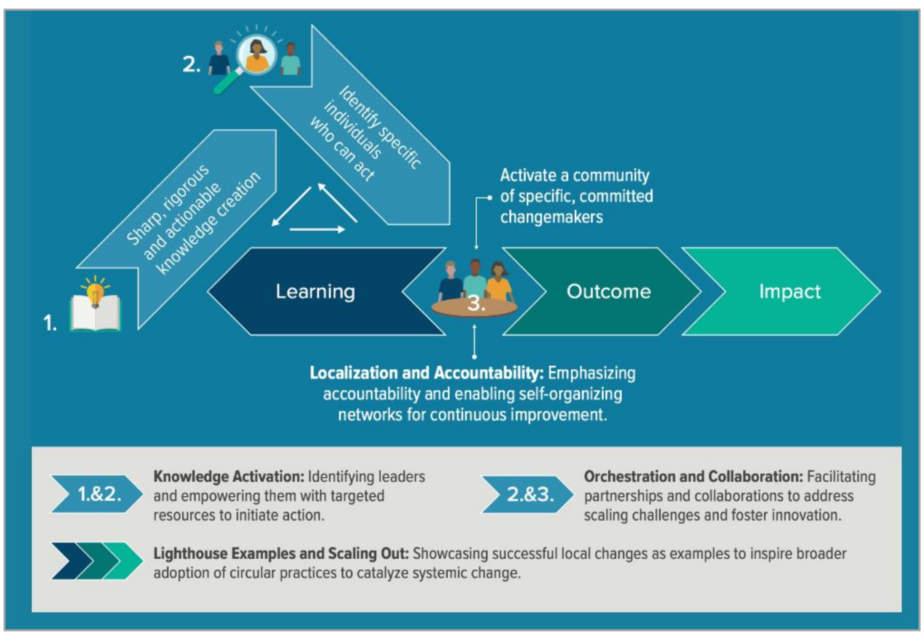

Figure 5. PACE Theory of Change

According to PACE's theory of change shown in figure 5 above, developing solutions to complex environmental issues requires rigorous learning and identification to cultivate well informed and sustaining collaborations or projects. This landscape report sits among a rich research base of scientific and technical literature to draw form, and thus serves as a learning document that gives readers the potential to step into the orchestration and collaboration part of changemaking.

After looking at four value chains at a high level, there are several conclusions that can be drawn from the research in this document. The rice and cocoa value chains have clear mechanisms for upcycling by products due to the dry nature of the waste in these value chains and how technically easily they can be extracted from the main product during harvesting and processing. These value chains produce an abundance of waste product, particularly rice straw. In addition, the smallholder farmers connected to these systems have massive potential for more financial security if by products are capitalized on. Rice's global landscape primarily involves smallholder farmers. **Recommendation:** There is potential for developing circularity workshops for stakeholders within the rice industry (and particularly small holder farmers) in rural India, China, and Vietnam.

The cocoa value chain has significant capacity for food loss and waste prevention. That being said, successful intervention in the cocoa industry will involve an understanding of the underlying inequity and exploitation inherent in the system. **Recommendation:** Develop opportunities and remove existing barriers to empower cocoa farmers/harvesters to utilize waste pod or husk waste and create alternative streams of revenue. These opportunities can be sought out through chocolate companies committed to empowering producers like Tony's Chocolonely or through nonprofit or government sponsored projects. Nonetheless, there needs to be more coordinated, structured and integrated mode of work at a country level looking at development agencies – not project – spend on outcomes / impact.

While the rice and cocoa value chain have clear and high levels of potential in terms of intervention, tomatoes and beef are areas of opportunity that possess more limitations. Tomatoes as a product and value chain are incredibly fragile. Tomatoes have high rates of spoilage due to their make-up and are sitting in a delicate position due to their reliance on high rates of water for production. While this value chain does hold aspects that could cause hesitation in intervention, it still exhibits potential for upcycling. As shown in the byproduct examples, there are many fascinating ways to harness and utilize tomato waste. **Recommendation:** Involvement in capturing waste for the tomato value chain should involve partnerships with corporations that have the technological resources and investment to capture waste in this vulnerable supply chain.

After research, beef's supply chain is arguably the most complex and fast changing. The landscape has two largely divided facets of production between large corporations in nations of higher development supplying beef in the masses compared to smaller more rural communities using individual cattle to feed families. **Recommendation:** In terms of opportunity for current food waste and valorization projects or partnerships, we do not recommend intervention in the beef supply chain at this stage. That being said, there is potential for further research and understanding of the smaller scale production of beef in more rural communities.

In general, this area of food waste can benefit from more attention around the innovation, policy, and capital conditions that can support the scaling up of these by product utilization solutions. The following example below is one example of the public and private sector mobilizing around food waste and circularity in Rwanda.

Circular Food Systems for Rwanda
The **Circular Food Systems for Rwanda Program (CIRF)** started in 2019 with funding from IKEA Foundation, management from World Research Institute, participation from the Government of Rwanda, and technical assistance from a consortium of partners including Resonance. Circular Food Systems for Rwanda Program develops the business resources and enabling policy environment to accelerate the adoption and expansion of regenerative agriculture in East Africa. The CIRF program aims to put the following two principles into practice: a development fund that provides technical assistance to small and medium-sized enterprises (SMEs) in implementing a circular business model or improving upon their current practices. At the same time, the program aims to create an enabling policy environment to catalyse system transformation. This ongoing program illustrates the power that collaboration and targeted expertise has to not only enact sustainable change but also steer public and private sector capital towards expanding solutions for the greater food waste ecosystem.

Intervention in our supply chains to promote food waste cycling/valorization is essential to meet global sustainability targets. Overall, there are a myriad of high potential opportunities for engaging in these value chains to prevent food loss and waste by way of circular practices. Nonetheless, effective stakeholder collaboration between governments, NGOs, businesses, and local communities is crucial to unpack why something is not happening, what needs to change and how do make the change happen.

As a public-private collaboration platform, PACE provides the following practical recommendations for effective stakeholder collaboration. (1) enough **time** to discuss key issues. A one- or two-hour workshop does not allow for sufficient time to dive deep into the key issues required to determine next steps. 2) The right **specificity** of topic. Convening around topics that are too broad will not allow for clear practical recommendations and next steps as discussions typically tend to veer into conceptual. (3) The correct **level** and **variety** of **stakeholders expertise**. Participants must be able to engage with each other on the key issues identified and offer perspectives that others in the group are not typically exposed to. In addition, it is important to ensure that the perspectives include those from policy, innovation and investment coming together on specific topics to better understand the multiple conditions that are required to truly scale solutions.

In conclusion, prioritization of both limiting and enabling factors is imperative to amass effective ways of entering and improving specific value chains. For example, a project aimed at utilizing cocoa bean shells for cocoa flour in the Ivory Coast cannot simply gift communities with the technology needed to manufacture this flour. Full supply chain assessments are required to understand the cultural, social, and economic barriers of potential value chains. Current gaps in the research in this field of food waste can be improved upon to clearer points of intervention and create examples around public and private capital being mobilized or redirected to support these waste efforts. Overall, this field of post-production and pre consumption waste has opportunity for more research and room for creative solutions given there has not been an already established “way of doing things”.

VI. Works Cited

[i] "How We Feed the World Today"
[ii] "Food Loss Waste Reporting Standard"
[iii] "Food Loss and Waste"
[iv] "Food Waste and its Links to Greenhouse Gases and Climate Change"
[v] "Food waste is contributing to climate change. What's being done about it?"
[vi] "Promoting Sustainable Lifestyles"
[vii] "Food Waste Makes Up Half of Global Emissions"
[viii] "Fight climate change by preventing food waste"
[ix] "Circular Economy Action Agenda"
[x] "3 Ways to Tackle Food Loss and Waste in Africa"
[xi] "Circular Economy Action Agenda"
[xii] "Rice Production Chain: Environmental and Social Impact Assessment—A Review"
[xiii] "Utilization of Rice Husk and Straw as By-Products"
[xiv] "Straw bale construction in northern China – Analysis of existing practices and recommendations for future development"
[xv] "Value Chain Analysis of Rice Industry by Products in a Circular Economy Context"
[xvi] "Rice-Straw Mushroom Production"
[xvii] "Rice bran: a novel functional ingredient"
[xviii] "Humble rice bran becomes hot commodity as India scours for edible oils"
[xix] "Effect of Incorporation of Rice Husk Ash Instead of Cement on the Performance of Steel Fibers Reinforced Concrete"
[xx] "Rice Husks for Biochar"
[xxi] "Sustainable Rice Platform"
[xxii] "Sustainable Rice Platform"
[xxiii] "Cocoa bean shell waste as potential raw material for dietary fiber powder"
[xxiv] "Potential Use of Industrial Cocoa Waste in Biofuel Production"
[xxv] "Harvesting Cacao"
[xxvi] "Difficulties with Use of Cocoa Bean Shell in Food Production and High Voltage Electrical Discharge as a Possible Solution"
[xxvii] "https://www.nature.com/articles/s41598-020-69763-9"
[xxviii] "https://www.nature.com/articles/s41598-020-69763-9"
[xxix] "Using Cocoa Pod Husks to Improve"
[xxx] "Cacao by-products and how they can be utilized"
[xxxi] "Use of Theobroma cacao Pod Husk-Derived Biofertilizer is Safe as it Poses neither Ecological nor Human Health Risks"
[xxxii] "Cacao by-products and how they can be utilized"
[xxxiii] "Pacha de Cacao"
[xxxiv] "Difficulties with Use of Cocoa Bean Shell in Food Production and High Voltage Electrical Discharge as a Possible Solution"
[xxxv] "Gardening with Cacao"
[xxxvi] "Urban Cacao"
[xxxvii] "Why Ghana Doesn't Get the Full Value of Cocoa Beans"
[xxxviii] "FAO Land Water Databases"
[xxxix] "Tomato News"
[xl] "FAO"
[xli] "FAO"
[xlii] "McKinsey Industry consumer Packaging"
[xliii] "Science Direct"
[xliv] "A Comprehensive Overview of Tomato Processing By-Product Valorization by Conventional Methods versus Emerging Technologies"

[xlv] "A Comprehensive Overview of Tomato Processing By-Product Valorization by Conventional Methods versus Emerging Technologies"
[xlvi] "YOU SAY TOMATO; WE SAY TOM-AUTO: FORD AND HEINZ COLLABORATE ON SUSTAINABLE MATERIALS FOR VEHICLES"
[xlvii] "Feasibility of Bioethanol Production from Rotten Tomatoes"
[xlviii] "Waste tomatoes can be used to make car tires"
[xlix] "Turning tomatoes into drinking water? 2 CA companies are teaming up to make this happen"
[l] "Phenix en Provence"
[li] "Packaging Made From Tomato By Product Waste"
[lii] "Challenges and Opportunities in Tomato Production Chain and Sustainable Standards Introduction"
[liii] "California's tomato farmers are getting squeezed by water crisis as growing costs continues to rise"
[liv] "Yes, we have no tomatoes: Why shelves are emptying in UK stores"
[lv] "Beef Market Size"
[lvi] "Beef Production"
[lvii] "Cattle Production"
[lviii] "Beef and Production"
[lix] "Food Loss and Waste in the Meat Sector"
[lx] "Top 12 Meat Companies in the World"
[lxi] "Moving Towards Sustainability: The Livestock Sector"
[lxii] "More Than Just Beef"
[lxiii] "The Monopoly on Meat"
[lxiv] "Food Loss and Waste in Sub-Saharan Africa"
[lxv] "The Meat Industry is Unsustainable"
[lxvi] "The Meat Industry – Environmental Issues & Solutions"
[lxvii] Carbon emissions from fertilisers could be reduced by as much as 80% by 2050"Carbon emissions from fertilisers could be reduced by as much as 80% by 2050"