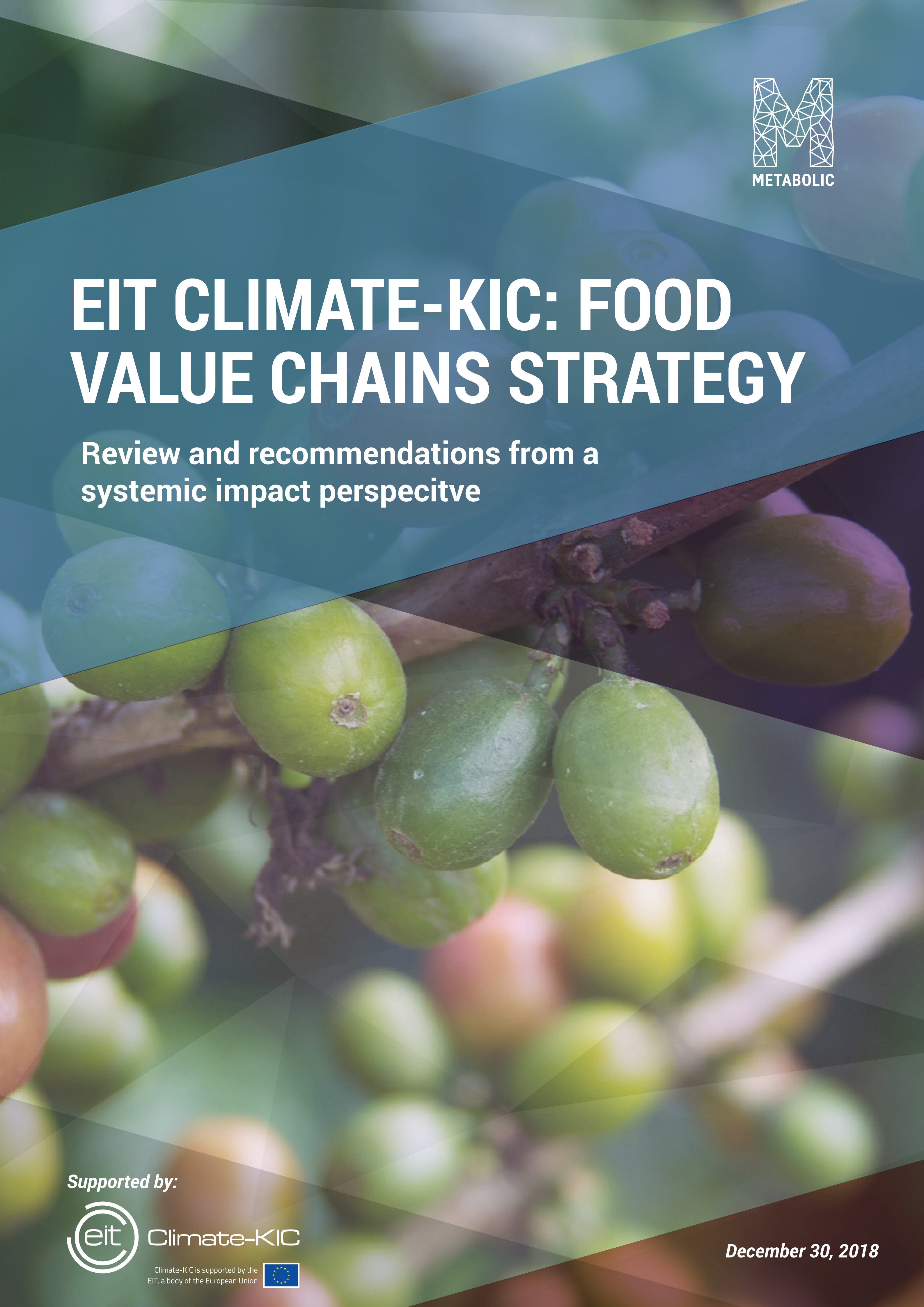

METABOLIC

EIT CLIMATE-KIC: FOOD VALUE CHAINS STRATEGY

Review and recommendations from a systemic impact perspecitve

Supported by:

eit Climate-KIC

Climate-KIC is supported by the EIT, a body of the European Union

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EXECUTIVE SUMMARY

EIT Climate-KIC is Europe's largest public-private innovation initiative focused on climate action. Supported by the European Institute of Innovation and Technology, it works to identify and support innovation activities to help create economically viable products and services addressing climate change mitigation and adaptation. EIT Climate-KIC has four thematic areas of operation, one of which is Sustainable Land Use (SLU).

Metabolic has been asked to review and provide a critical assessment of EIT Climate-KIC's draft strategy for the Food Value Chains focus area. This strategy will be used for selecting, assessing, and funding startups and research projects in this thematic area, positioning it as an essential piece of EIT Climate-KIC's decision-making toolkit.

We have conducted this review with an eye on how EIT Climate-KIC can support the greatest possible strides towards its goals (climate change mitigation and adaptation), keeping in mind the organization's role and resources. In addition, we have considered the systemic implications of the proposed strategy, taking into account how it may interact with other parts of EIT Climate-KIC's operations as well as other critical sustainability objectives beyond those related to climate change.

To summarize our findings, we recommend that EIT Climate-KIC should ideally eliminate the separation between the Climate Smart Agriculture sub-theme and the Food Value Chains sub-theme, creating a single Agrifood theme with six primary topic areas:

- Sustainable and low carbon production
- Food waste reduction
- Sustainable and low carbon consumption
- Policy, finance, and governance
- Data collection and reporting
- Innovation, education, capacity building, and technology transfer

We have proposed these six topical areas based on a preliminary assessment of the highest areas of impact and leverage in the agrifood and land use space. However, as mentioned, we suggest that EIT Climate-KIC follow our recommended implementation plan, and lead from a outcomes-based vision of what sustainable land use should ultimately look like. In the Appendix we provide a preliminary exploration of what a root cause and intervention assessment could yield in terms of priority areas for the first three topic areas listed above, with the caveat that these should be worked out more thoroughly.

A comprehensive vision should then ideally be the basis for a set of holistic metrics that will be used to evaluate all projects, taking climate impact reduction as the leading element, but structurally preventing burden shifting in other areas. We also strongly recommend leading from a Science-Based Targets perspective for the development of these indicators and using a landscape approach for recommending best practices in specific regions. EIT Climate-KIC should also support the development of systemic tools (monitoring frameworks, new finance mechanisms, policy recommendations) that will help drive the emergence of appropriate solutions, which may initially be in short supply.

INTRODUCTION

EIT Climate-KIC is Europe's largest public-private innovation initiative focused on climate action. Supported by the European Institute of Innovation and Technology, it works to identify and support innovation activities to help create economically viable products and services addressing climate change mitigation and adaptation. EIT Climate-KIC has four thematic areas of operation:

- **Urban Transitions**
- **Sustainable Production Systems**
- **Decision Metrics & Finance**
- **Sustainable Land Use**

The overall goal of the Sustainable Land Use (SLU) theme is to "accelerate climate-smart agriculture, sustainable food, and climate-resilient forests." Agriculture, forestry, and other land uses are responsible for 24% of global greenhouse gas emissions, second only to the global energy sector (Climate-KIC SLU presentation), positioning SLU as a clear focal area for climate action. EIT Climate-KIC's SLU theme is further subdivided into two domains (Agrifood and Integrated Landscape), which are each further divided into two focus areas (see the figure below). The focus areas within the Agrifood subdomain are the Climate-Smart Agriculture Booster (CSAb), whose activities are primarily centered on agricultural production, and the Food Value Chains topic, whose focus is primarily on food and its consumption.

PURPOSE OF THIS STUDY

Metabolic has been asked to review and provide a critical assessment of EIT Climate-KIC's draft strategy for the Food Value Chains focus area. This strategy will be used for selecting, assessing, and funding startups

SLU OVERVIEW - 2 DOMAINS, 4 FOCUS AREAS

AGRIFOOD		INTEGRATED LANDSCAPE	
CSAb flagship - Agriculture (Production side focus)	**Food value chains** (Consumption side focus)	**Forestry flagship** (Europe focus)	**Integrated Landscape** (Emerging markets focus)

Capacity Building
• Open Innovation Platform
• Solutions & Policies
• Education & Training
• Regional hubs
 	
Project porfolio
• **Agtech**
  • Precision and digital ag
  • Solitech - land and water use
  • Aquaculture
• **Agrifinance**
  • Data analytics and M&E tools
  • PPP Financing facilities
  • Insurance mechanisms
• **Technical Assistance**
  • Value chain analysis (VCA)
  • Policy analysis
  • Business modelling/co-design
	Food security and systems
	• Building resilient food systems and value chains
	• Improving and harmonizing food policies
	
	Bio/Circular economy development in urban environments (cities)
	• Developing sustainable food metrics
	• Reducing food waste
	• Production of biomaterials and bioenergy from food waste
	
	Foodtech
	• Catalysing food innovations
	• Alternative protein - green and blue
		• Under development - official launc in September?
		
		• **Wood construction and bio/circular economy**
		• **Biomass and forestry management**
		• **Working with cities and surrounding territories**
			• **Finance for deforestation and carbon sequestration** (In partnership with WWF Landscape Finance Forum)
			• **Traceability tools and certification**

and research projects in this thematic area, positioning it as an essential piece of EIT Climate-KIC's decision-making toolkit.

We have conducted this review with an eye on how EIT Climate-KIC can support the greatest possible strides towards its goals (climate change mitigation and adaptation), keeping in mind the organization's role and resources. In addition, we have considered the systemic implications of the proposed strategy, taking into account how it may interact with other parts of EIT Climate-KIC's operations as well as other critical sustainability objectives beyond those related to climate change.

To that end, we begin with a quick overview of some key considerations to take when using a systems approach for strategy development (p.8) and a snapshot of the current nexus of problems in the food system (p.10). Both of these background texts are intended to create a common terminology and an understanding of the principles behind our recommendations.

A SYSTEMS APPROACH

It is now broadly recognized that a "systems approach" is essential for creating robust strategies for societal transition, particularly in the field of sustainable development (Gallopín, 2003). The systems approach is a problem-solving paradigm that, at its core, recognizes the interconnectedness of individual system elements and the importance of the dynamic relationships between them.

The food system is the complete set of people, institutions, activities, processes, and infrastructure involved in producing and consuming food for a given population (Gladek, 2016). Through its many regional interconnections and the trade of essential resources and commodities, our food system has become global in many respects. It is arguably the largest single human system, using the largest fraction of planetary resources and employing over half of the global population.

Historically, efforts to create lasting change in the performance and behavior of systems have been beleaguered by a number of common pitfalls. We describe them briefly here in order to illustrate the importance of the systemic perspective in designing theories of change and to define a set of concepts that inform our commentary on EIT Climate-KIC's Food Value Chains strategy.

UNEXPECTED OUTCOMES

A well-known example of poor decision-making resulting from lack of systemic insight results from the tendency of systems to exhibit "rebound effects." A common assumption in efforts aimed at improving energy-efficiency, for example, has been that if you provide people with a more energy-efficient technology to replace a low-efficiency one, the overall energy use observed in an economy will go down. In every case where this approach has been applied (from the replacement of incandescent light bulbs with more efficient technologies like CFLs and LEDs to increases in the fuel efficiency of cars), the actual result has been an overall increase in energy demand rather than a decrease. Though this may seem paradoxical at first, the reason is that once an essential service like lighting or mobility effectively becomes cheaper, people simply tend to increase their usage of that service. It becomes less expensive to leave the lights on or to drive, and in some cases, more people who previously could not afford that service can now afford it. The result then, ends up being exactly the opposite of what was originally intended.

Rebound effects are only one type of feature seen in complex systems that yield counter-intuitive results compared to what is expected based on the observation of individual elements within the system. These behavioral features of systems are the reason why our efforts at interventions often fail. Perhaps unsurprisingly, this failure to produce systemic change has plagued the international aid and development world for decades, as exemplified in a recent article by long-time development worker, Michael Hobbes:

> "If someone is chronically malnourished, to pick just one example, you should give them some food, right? Duflo and Banerjee describe dozens of projects finding that, when you subsidize or give away food to poor people, they don't actually eat more. Instead, they just replace boring foods with more interesting ones and remain, in the statistics at least, "malnourished."
>
> In Udaipur, India, a survey found that poor people had enough money to increase their food spending by as much as 30 percent, but they chose to spend it on alcohol, tobacco, and festivals instead. Duflo and Banerjee interviewed an out-of-work Indonesian agricultural worker who had been under the food-poverty line for years, but had a TV in his house.
>
> You don't need a Ph.D. to understand the underlying dynamic here: Cheap food is boring. In many developing countries, Duflo and Banerjee found that even the poorest people could afford more than 2,000 calories of staple foods every day. But given the choice between the fourth bowl of rice in one day and the first cigarette, many people opt for the latter."

Therefore, it is critical to take a systems approach to understand (or at least better understand) the real dynamics in a system and anticipating what might happen in response to an intervention whose effects will ripple through the whole structure of a system.

BURDEN SHIFTING

Burden shifting happens when even though an action may satisfy one objective – for example, recovering material value through recycling – it may at the same time create a new problem – for example, generating more CO2 emissions or releasing toxic chemicals into the environment – than the original situation, along a different dimension of impact.

To avoid this problem, we need to explicitly recognize that improvements in resource management can sometimes result in other negative environmental or social impacts. We need to evaluate all of our actions not just on one parameter, but on a complete spectrum. With a holistic set of performance indicators, we can track whether or not circular activities are leading to better results across a broad range of impacts, rather than just optimizing for high value material recovery at the expense of other areas of performance.

EFFECTIVENESS VERSUS EFFICIENCY

Another pitfall refers to the optimization of elements within a system that are actually peripheral and not going to yield the greatest results. We can choose to optimize the efficiency of vehicles, achieving ever increasing gains on fuel efficiency, only to find that unless we change the fundamental design of human habitations, the demand for vehicles remains highly inelastic. In other words, if the design of cities and their adjacent suburban areas is lacking sufficient or high-quality public transportation, we cannot remove the fundamental demand for personal vehicle transport. This situation will therefore lead to the afore-mentioned rebound effect.

Another example is the fact that a well-known electronics producer, Toshiba, has committed to a factor-10 efficiency improvement for all of its products in order to align itself with the broader idea that we need a factor 10 improvement in efficiency in order to bring human resource consumption within planetary boundaries. However, this narrow scoping doesn't take into account the fact that many of these products may be systemically superfluous, or that the major impacts that we need to be reducing lie in other economic sectors. For instance, rather than optimizing the efficiency of an electric peppermill, perhaps this product should not exist at all?

ROOT CAUSES AND LEVERAGE POINTS

To have a genuine impact on the system we wish to change, we also must focus on the underlying root causes that are leading to the undesired impacts that we see. We therefore need to trace back the most significant drivers for each category of impact to their source. Ideally, interventions are targeted as close to the source as possible.

We now turn to a quick overview of the food system in its current state in order to start overlaying some of these systems dynamics concepts on the performance of the food system as a whole, with a particular focus on climate impacts.

THE GLOBAL FOOD SYSTEM: A SNAPSHOT

In the 8 – 10,000 years of practicing agriculture (Harlan & MacNeish, 1994), only a small fraction of the 200,000 years that modern humans are estimated to have existed (Harpending & Eswaran, 2005), food production has altered our environment more dramatically than any other socioeconomic activity. Agriculture now occupies roughly half of the plant-habitable surface of the planet (FAO, 2015b), uses 69% of extracted fresh water (Aquastat, 2014), and, together with the rest of the food chain, is responsible for between 25 - 30% of global greenhouse gas emissions (IPCC, 2014). The expansion of industrial fishing fleets and an increased global appetite for seafood have led to the collapse or total exploitation of 90% of the world's marine fisheries (FAO, 2014b). A growing demand for land-based animal products is the primary driver of tropical deforestation. Through its direct and intermediate impacts, the food system is the largest contributor to the depletion of biodiversity.

Though its environmental impacts are already severe, the food system is poised for a necessary expansion. In 2012, the Food and Agriculture Organization of the United Nations estimated that by 2050 we will need to increase food output by 60% based on a business-as-usual scenario. Since the FAO's 2012 projections, population increases have been further revised upwards and the food demand is likely to need to double by 2050 (United Nations, 2015). This represents a larger increase from today's production levels than we have achieved through advances of the Green Revolution since the 1960s (Searchinger et al., 2013).

THERE ARE SEVERAL CLEAR INDICATORS THAT THE CURRENT FOOD SYSTEM IS FAILING ON MULTIPLE COUNTS:

- Universal food security has not been achieved despite the fact that food production levels are sufficient to feed everyone globally; 10.8% of the global population remains food insecure despite a global surplus in caloric production of over 20% (Marx, 2015; authors' estimates based on FAOSTAT data).
- The global nutrient cycles of nitrogen and phosphorous are broken, not only because of practices in agriculture, but to an equally large extent through the lack of collection of nutrients from municipal waste water systems (Vitousek et al., 1997).
- Production practices are evaluated based primarily on short-term increases in yields, rather than on their ability to sustain long-term productive output based on care for soils, appropriate labour systems, and the need for adaptation to the effects of climate change (Phelps, Carrasco, Webb, Koh, & Pascual, 2013).
- Despite clear indications that allocating arable land use to the production of first generation biofuels is not a good use of resources by almost any measure, policies remain in place to continue this trend (Bastos Lima & Gupta, 2014).
- Around one third of food globally is wasted, indicating large potential gains for reducing impact and saving scarce resources (Gustavsson, Cederberg, & Sonesson, 2011).
- The very structure of global food markets and trade continues to keep individuals trapped in poverty and threatens local food access in developing countries (Serpukhov, 2013)

The current structure of the food system lies at the center of a nexus of global problems, stretching from poverty to environmental degradation. The increase in food production needed to meet the anticipated demands of the near future cannot be achieved by simply extrapolating current trends in production and consumption. A continuation of the recent historical trends of expansion and intensification will undermine the very resource base on which the food system itself depends. The preservation of ecosystems and the future wellbeing of the human population are all centrally dependent on a structural transformation of the food system towards a sustainable and resilient state.

The Planetary Boundaries as a hard limit to growth

The concept of the Planetary Boundaries, introduced by the Stockholm Resilience Centre in 2009, describes nine key Earth systems that must be kept within a certain range to avoid the risk of destabilization that could threaten our planet's habitability. These nine Boundaries define a "ceiling" of total impact that we can reach through our activities without causing catastrophic disruption. Crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes. Out of the nine boundaries, SRC has estimated that we have already transgressed four: climate change, biodiversity loss, phosphorus and nitrogen biogeochemical flows, and land system change.

All of the most severely transgressed boundaries are centrally linked to the activities of the food system. It is imperative that we design pathways for the sustainable transition of the food system with these boundaries in mind. We can no longer rely on arbitrary targets for the improvement of efficiency, which may fall dramatically short of the mark when it comes to the scientific consensus on the impact reduction necessary to stay


АСХАНА
ЖЕМІСТЕР
БАЛЫҚ

within the defined “safe operating space” of our planet. With this understanding, a shift has begun towards target-setting for environmental impact reduction based on scientific assessments of available impact “budgets.” One of these efforts, the Science-Based Targets Initiative (SBTi), has currently engaged almost 500 companies, in establishing or working towards greenhouse gas emissions reduction targets in line with scientific recommendations to maintain global mean temperature rise below 2°C. To date, 151 companies have set targets in line with SBTi’s approach. However, though climate change is an undeniably grave issue, it is not the only environmental impact we need to address on our pathway towards a sustainable future. Other boundaries, such as those defined for biodiversity loss and the disruption of global nutrient cycles, are even more severely transgressed.

The emerging Science Based Targets Network (SBTN) is currently under construction by a large cohort of leading international NGOs. It will serve as an umbrella organization for advancing the adoption of science-based targets for companies, with the goal of ensuring that these boundaries are respected throughout the length of each organization’s global supply chain. The transition to science-based targets is an important upcoming frontier in global environmental management that should be incorporated into planning for a sustainable food system.

POVERTY AS A ROOT CAUSE OF FOOD SYSTEM FAILURE

Though it may often seem like fixing the global food system is a very technical matter, primarily concerning itself with soil carbon, mass balances, and exergetic efficiencies, at its core, food is about people; about our health, our culture, our experience of our lives and our environments. Without a holistic strategy that deeply recognizes the critical role of individuals and societies in the proper functioning of the food system, we will not be able to solve the Gordian knot of challenges that has been described here.

Human well-being is not simply about livelihoods and basic access to resources, but also about having the social conditions to thrive, preserve cultural heritage, and pursue self-actualization. Without addressing this core need, we perpetuate cycles that continue environmental degradation and lead to desperate and short-sighted policies that favor short-term gains and intensification practices over longer-term, sustainable solutions. Moreover, the condition of poverty itself leads directly to much of the environmental degradation that we witness throughout the food system.

The agri-food sector is the world’s largest economic sector and is therefore deeply entwined with poverty. Half the global workforce is employed in agriculture and fisheries, where most of the world’s extreme poverty is also found. Small farmers and fishermen around the world are caught in cycles of poverty, without access to education, employment, economic and social infrastructure, and political representation. Many do not receive adequate compensation, work in unacceptable conditions, or do not have access to sufficient, affordable, or proper-quality food. Poverty is the largest threat to producers of food globally and the largest driver of food insecurity.

Poverty is a pernicious state. Not only is it the primary cause of food insecurity and malnourishment globally, as already highlighted, but it is also one of the main drivers of the low yields and unsustainable agricultural practices that are leading to widespread land degradation in the more impoverished regions of the world. Farmers without access to sufficient resources are unable to improve upon their agricultural production techniques (Tittonell & Giller, 2013). As soil gets increasingly nutrient-depleted and eroded, it becomes ever more unresponsive and challenging to rehabilitate for use. Eventually, this condition necessitates either the shift towards other agricultural land, or the need for greater dietary supplementation through imported food. Increasing reliance on imported food can further impoverish people, expose them to global price shocks, and further reduce investment in local capacity and infrastructure.

These kinds of patterns result in further reinforcing cycles on the level of local governance. Wishing to serve the needs of their impoverished populations, many governments are incentivised to implement permissive policies for the exploitation of natural resources, or encourage the development of lands for the production of cash crops for export, at the expense of local food security. Poverty, thus, can be found at the origins of many of the food system’s most pervasive problems, including land degradation and the associated results of arable land expansion and agricultural land shifting.

Some of the primary strategies for achieving a sustainable, global food system will need to strongly center on tackling this core challenge. Systemic structures that perpetuate poverty need to be dismantled. Sustainable solutions may often be less reliant on technology or on products, but rather more on knowledge and capacity building. They may not always tend towards the highest efficiency or highest yield, but rather reach a Pareto optimum of satisfying numerous societal and ecological needs; ones that are holistically essential for the system to continue existing and improving. As such, these types of solutions are not necessarily equally attractive to private interests as more straightforward technological fixes or rigid policy prescriptions (De Schutter, 2008).

CLIMATE IMPACTS AND THE FOOD SYSTEM

Against the backdrop of the broader issues already described, it is also essential to understand the food system's contribution to greenhouse gas emissions and climate change, the priority focal area for EIT Climate-KIC. The food system (from farm to fork) is responsible for up to 36% of global climate emissions (as mentioned in EIT Climate-KIC's strategy), though the exact percentage is a matter of academic dispute. How these emissions are divided between specific activities is variously calculated in the literature, though the relative impacts of the largest categories are generally agreed upon.

Climate hotspots

Some of the largest greenhouse gas emissions associated with the food system include, in order of greatest individual impact:

- **Emissions from land-use change such as deforestation.** In total, an estimated 12.5% of global emissions can be attributed to land-use change, the majority of which is associated with agriculture (Houghton et al, 2012). A large share can also be attributed to the degradation of soils, mainly through intensive use of land.
- **Direct and indirect emissions from food that ends up in landfills or incinerators** - It is estimated by the Food and Agriculture Organization (2011) that around 1/3rd of all food is wasted. This translates to up to 12% of global emissions which can be attributed to food that is ultimately wasted.
- **Direct emissions from cattle and rice production.** Direct emissions from cattle (enteric fermentation and manure) accounts for nearly 9% of global CO2e emissions by itself, while an additional 1.42% of global CO2e emissions comes from rice production.
- **Emissions due to packaging, transporting, and cooling food along the food chain.** Transportation has been estimated to account for between 6 and 11% of the total CO2e footprint of food and up to 50% of the share for some fruits and vegetables (Wakeland, Cholette & Venkat, 2012). Considering a high total estimate of up to 30% of global emissions originating from the food chain, this would amount to between 1.8 and 3.3% of total global emissions from packaging, transport, and cooling of food.
- **Emissions upstream from fertilizer production or other agricultural inputs such as pesticides and machinery.** Synthetic fertilizers alone are responsible for nearly 2% of global CO2e emissions (FAOSTAT, 2015).

From this quick overview of Climate hotspots, we can see that the vast majority of emissions from agriculture can be attributed to three primary causes: land use change, food waste, and direct emissions from livestock production. This points to a set of key priorities for action if EIT Climate-KIC is to leverage its resources most effectively for de-carbonizing the food system. With a systems perspective in mind, however, it is essential to understand the root causes and drivers of each of these impact areas, as well as the system dynamics at play in order to avoid supporting solutions that lead to rebound effects or other unwanted outcomes.

The need for a global perspective

Though EIT Climate-KIC is naturally focused on the European Union, the previous section points to the fact that many of Europe's largest food system impacts – and their associated climate emissions – are not within the EU's borders. However, even the international impacts outside of Europe's direct control are still strongly influenced by decision-making, policy, and consumer choices within Europe.

As an example, we can consider the single largest contributor to climate change from agriculture, as identified in the previous section: land use change. Europe is one of the only regions globally that has had an increase in forest cover over the last decades. By contrast, according to the United Nations Environment Programme (UNEP), Africa is undergoing deforestation at twice the average global rate, much of which is taking place in highly biodiverse zones. The situation in Africa is much more closely linked to choices made in Europe than it may initially appear.

Africa has been a net importer of food and agricultural products since the mid-1970s, despite its vast agricultural potential. Population growth, low and stagnating agricultural productivity, policy distortions, weak institutions, and poor infrastructure have been cited as the main reasons for this situation (Rakotaorisoa, Iafrate, and Paschali, 2011). While population on the continent grew at an average annual rate of 2.6% between 2000 and 2010, food production grew at less than 0.1% per year.

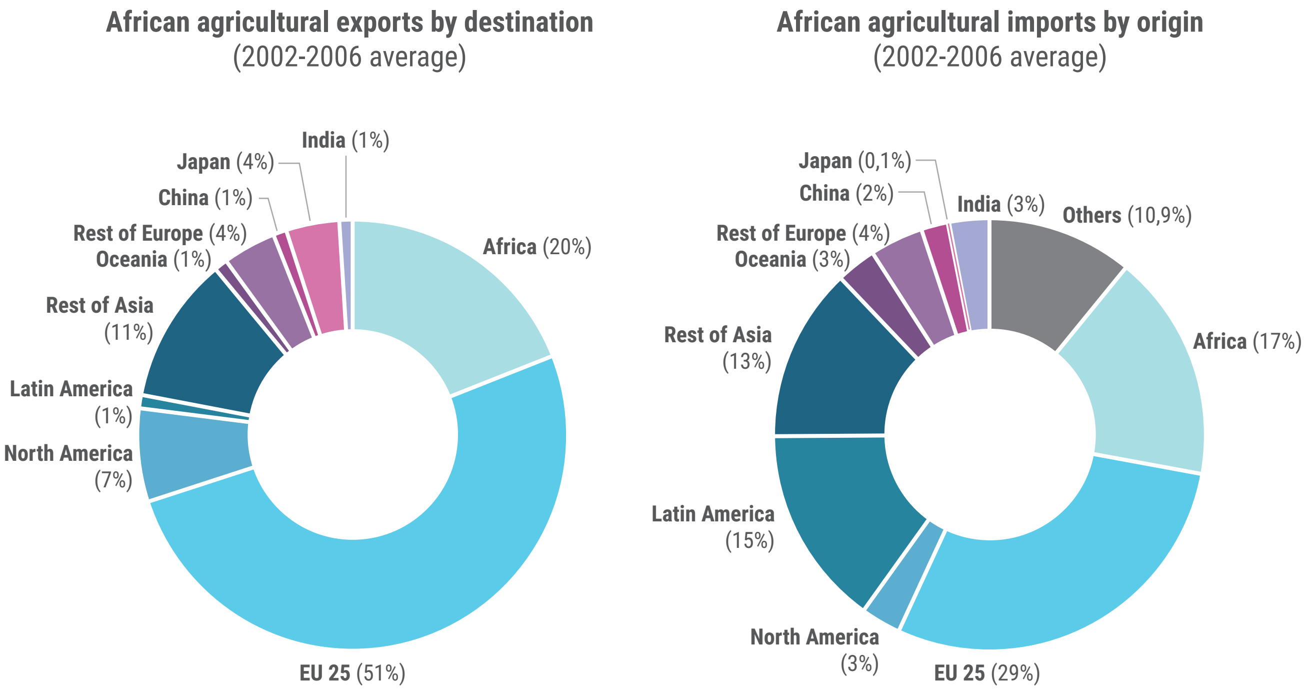
One of the most significant reasons cited for this problem is the effect of trade distortions caused by developed countries' farm and export subsidies as well as high import tariffs on foreign agricultural products (e.g. Tangerman, 1989; Wailes, 2004; Anderson and Masters 2009; and Anderson et al., 2010). The high levels of subsidies provided in OECD countries (around 30% of total production value) have kept the international prices of commodities such as grains, sugar, oil, and livestock below cost-price. Agricultural surpluses of grain and meat have also been routinely dumped on African markets to prevent price stagnation in home markets. This has resulted in situations where African farmers are unable to compete on price with foreign commodities and has created a very unfavorable climate for investment in local agricultural production. This has further resulted in lower capacity and knowledge development on agriculture, perpetuating a cycle of dependency.

The economic situation has forced many African farmers to produce export commodities that are of interest to OECD buyers – such as coffee and cacao – and are not as restricted in export by high protection barriers (commodity tariffs). Overall, tariff escalation has reduced Africa's opportunity to diversify food exports, made export revenue vulnerable to raw commodity price shocks, and reduced African farmers' ability to escape poverty traps. As noted in the earlier section on poverty, the result of this situation is not just an impact on livelihoods, but also on the perpetuation of poor agricultural practices that are leading to land degradation and high rates of forest conversion for the purpose of highly inefficient subsistence agriculture.

In short, the situation in Sub-Saharan Africa is not just a humanitarian issue around livelihoods: it is a pivotal problem to solve when looking towards a sustainable, low-carbon food system in the future. Arguably, some of Europe's largest impact on emissions from the food system is through its trade relationships with Africa. Extrapolating from Figure 2, we can conclude that out of all global regions, the European Union has the most entrenched interests when it comes to the current dynamics in Africa's agricultural and food value chains. It has long been Africa's primary supplier of agricultural commodities and the primary buyer of its agricultural exports. Though on a superficial level, the EU stands to gain through this dynamic by supporting its own farmers' margins, this behavior creates long-term distortions that are ultimately leading to poverty and climate change impacts through deforestation and inefficient land use.

Conclusions from this snapshot

The food system is highly complex and embodies many interacting challenges. For this reason, it is essential not to focus too narrowly on one issue, such as climate change, when devising a sustainable pathway forward. Though securing fair livelihoods for African farmers may initially seem unrelated to climate impacts, as we have shown in the highlighted example in the previous section, it may well be one of Europe's most significant causes of land-use-related emissions, primarily via trade distortions. From a systemic perspective, it is essential to thoroughly understand the largest areas of impact on climate and trace them back to their root causes. Ideally, EIT Climate-KIC's efforts should be focused on targeting the root causes of these impacts as a first priority, and careful consideration should be given to ensuring that innovations are targeted at a broad range of impact areas simultaneously (food security, water scarcity, biodiversity loss, etc.).



African agricultural imports by origin and exports by destination. Reproduced from Rakotoarisoa et al, 2011.

EIT CLIMATE-KIC'S CURRENT FOOD VALUE CHAINS STRATEGY

The graphic below, from one of EIT Climate-KIC's presentations, shows the division of topics among the different focal areas in the SLU theme. The structure of the activities is broad and largely comprehensive, however, we do have some concerns and observations to share regarding this division, considering the strategy from a systemic perspective. Though our objective through this work is to provide commentary specifically on the Food Value Chains component of the strategy, taking a step back to the SLU theme as a whole allows us to also consider how different issues have been divided across the topics. In particular, we want to draw attention to the potential emergence of any conflicting outcomes across the different sub-themes as well as any potential missed opportunities for synergy.

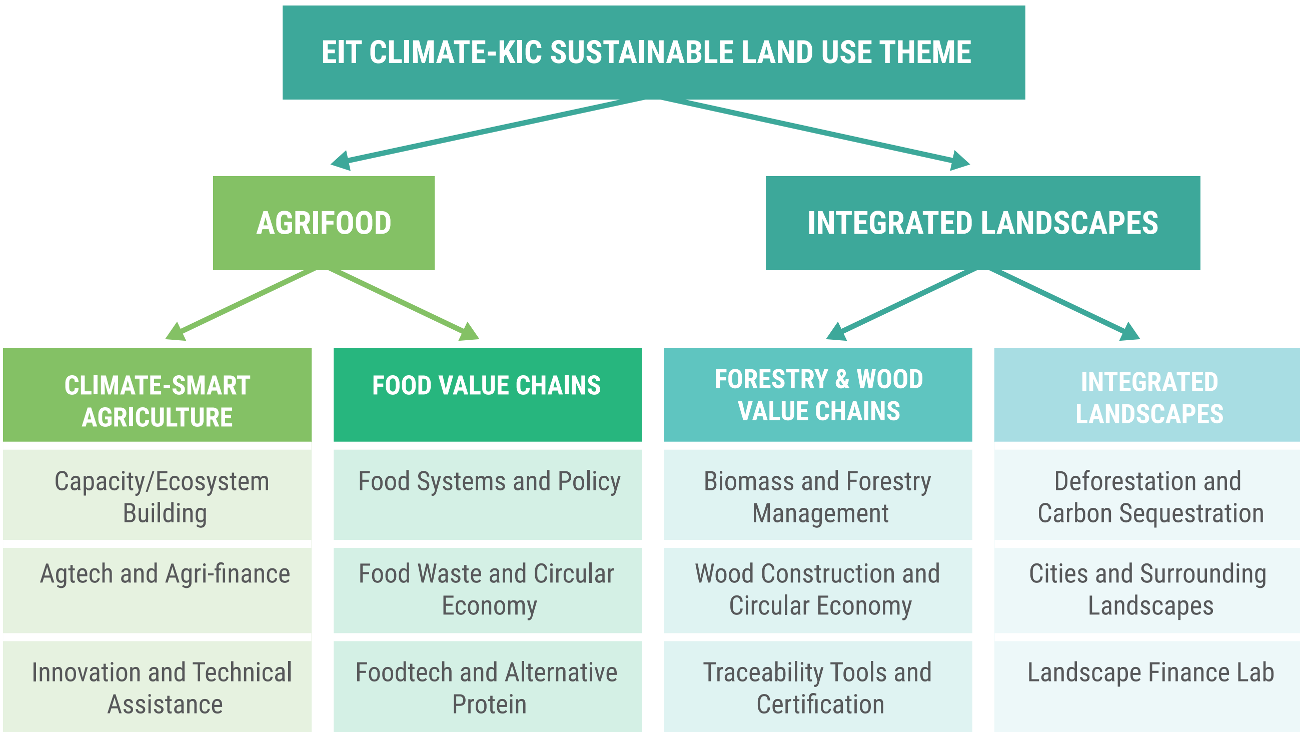
RISK OF "SILO" EFFECT AND FRAGMENTATION

Though it is, in many regards, sensible to divide strategies focused on food consumption from those focused on agricultural production, there are many cross-overs between these two areas; looking at both sides of the problem can often yield more integrated solutions.

As an example, we can consider the issue of cosmetic standards for fruits and vegetables. This is an often-discussed cause of unnecessary food waste in the developed world. Consumers have been trained over the past decades to expect perfect specimens of produce. Bananas that are too long or too straight are routinely disposed of before ever making it to a store if they do not meet these stringent requirements. This problem can be dealt with in multiple ways: farmers can change cultivars or growing practices to increase the percentage of produce that will meet these standards, retailers can relax their purchasing requirements or create sections of their stores that provide discounted "imperfect" products, consumers can be persuaded to change their attitudes, or parallel value chains can be created that make use of these products in processed goods – retaining their use as a food.

Because these solutions span the entire food value chain from production to consumption, it is most useful

SUSTAINABLE LAND USE THEME STRUCURE



to look at them simultaneously and conduct a joint cost-benefit and feasibility assessment. If EIT Climate-KIC were to decide that this is a core problem to deal with (food waste due to cosmetic standards), then ideally the organization would perform such an assessment to have a reasoned scientific basis for which direction should be supported for solutions. Some of these directions will present a greater cost or impacts than others or may be deemed entirely unfeasible. If the different focal topics under the Agrifood topic remain split into production and consumption categories, it becomes more difficult to support an integrated solution pathway to this challenge. This is only one example, but almost every challenge within the food system will have this kind of cross-over solution space that should ideally be dealt with comprehensively.

Looking even more broadly, many of the topics under the "integrated landscapes" heading should also be centrally linked to those under the agricultural production heading. In our recent work with private sector clients, we have seen an enormous, growing interest in the use of biomass for various non-food applications. Because of the constraints of the system, we also know that there is currently not enough arable land to support biomass production for all of these uses while also preserving forest ecosystems. Agricultural production should ideally be considered simultaneously with other land use demands, such as forestry, ecosystems for recreation, and regional water resource allocation. In other words, a landscape approach to planning is essential for achieving sustainable agriculture.

A recent study that we just completed for Alpro, a producer of plant-based dairy alternatives, and a subsidiary of Danone, has yielded some important lessons in this regard. Much of Alpro's almond supply chain consists of smallholder almond farms in Spain. The region is generally arid and experiencing water shortages, yet at the same time, there are highly inappropriate crops, such as rice, being grown in the region, which are using up a majority of the water supply in some watersheds. Another issue is that the area falls in the Mediterranean Woodland and Scrub biome, which is a biodiversity hotspot of which only 9.9% of Natural Intact Vegetation (NIV) remains. For biodiversity objectives, much of the landscape, which is currently being used for farming, should ultimately be rewilded. However, there are some areas, adjacent to national parks, which are better suited for this purpose than others. Taking a landscape lens, the farming cooperative responsible for aggregating the almonds from this region, should ideally create a financial exchange mechanism between its participating farmers to have them trade "productivity credits" in some areas with "biodiversity credits" in other areas: creating an optimized landscape mosaic that creates maximum benefits for both farmers and nature. Likewise, policy measures should ideally be put in place rewarding farmers who are growing suitable crops in the area and penalizing those who are growing resource mis-matched crops.

For these kinds of solutions to be viable, EIT Climate-KIC would ideally bring together the topics under Integrated Landscapes and Agrifood. These landscape approaches require an integrated negotiation between the many different users of land and a balancing of the resources and values this land can supply.

CONSIDERING LOCK-INS, REBOUND EFFECTS, AND BURDEN SHIFTING

Maintaining a siloed approach to addressing food system challenges can also potentially lead to less insight on system dynamics that can ultimately lead to undesirable outcomes like lock-ins, rebound effects, and burden shifting. For example, focusing on food waste primarily under the Food Value Chains theme, in a disconnected fashion from the agricultural production side, can potentially lead to all of the afore-mentioned issues. Solutions that make use of food waste in order to create new, non-food products (such as pigments, specialty chemicals, or pharmaceuticals), can result in a lock-in effect where the waste suddenly has a greater value than the initial product did, which potentially creates strong financial interests to maintain the supply of that material into an alternative chain. Technological investment in new processing chains further entrenches these interests. This could potentially result in market shifts away from food production and further competition for scarce land and water resources.

An over-simplified example that illustrates part of this point is the evolution of the soy value chain as a primary source of animal feed. Initially, soy meal was just a low-value by-product of soy oil production: a dry "cake" material that was originally a waste stream. When it became apparent that this product was ideal for use in animal feed, this rapidly boosted the industrial feedlot model of cattle production. With this new model in place, more and more soy was produced specifically as a cattle feed, to the point where today, soy oil is often seen as a byproduct of the more lucrative "soy cake" used for animal feed.

This is not to say that we should not encourage investment in high value uses of waste products. However, from a systemic perspective, it is essential to consider the possible long-term effects of certain technological developments in this space. As a top priority, food waste across the entire chain should be eliminated rather than diverted. To maintain nutrient cycles, it is also essential for the materials removed from agricultural production to eventually make their way back to the land in order to enrich impoverished soils. So even if they end up as products in a different value chain, we must also ensure the closure of this nutrient cycle.

EIT Climate-KIC needs to ensure strong evaluation mechanisms to assess the potential systemic effects of the programs and projects it supports – also considering how they will interact across the different topic silos. This evaluation mechanism likely needs to be stronger than the current expert assessment in place. Ultimately, there also needs to be a strong vision behind how these scarce biomaterials should optimally be allocated (food, feed, fiber, chemicals, building materials, fuel). This vision should drive how EIT Climate-KIC selects projects to support. By its very nature, this is a cross-cutting issue that affects our overall land use allocation and management, rather than merely being focused on "waste" in isolation.

OUR RECOMMENDATIONS

As we have shown in our brief snapshot of the food system, the largest areas of climate impact are land use change, the generation of food waste, and the production of animal products (and specifically cattle). Though there are many other areas (including some we mentioned in the climate hotspots section) that are also leading to climate impacts, with limited resources, it is potentially wise to primarily focus EIT Climate-KIC's efforts on these three topics. Because solutions to these challenges, by their very nature, require an integrated approach, we recommend grouping them under broader headings of three main hotspot areas of "sustainable and low carbon production," "sustainable and low carbon consumption," and "food waste reduction." A primary focus within the "sustainable and low carbon production" category, should naturally be on creating the most effective solutions to agriculture, thereby increasing yields and reducing land conversion to agriculture in high-priority areas. A supply chain and landscape perspective is necessary in order to address this challenge in the most effective and comprehensive way, which should naturally draw linkages with EIT Climate-KIC's Integrated Landscapes topic area.

In addition, there are cross-cutting areas of influence that we have mentioned throughout the food system snapshot, which should ideally also be dealt with from a higher-level perspective. They, in effect, create the "rules of the game," and control what is possible to achieve within the food system. These include topics such as policy, finance, innovation support mechanisms, and capacity building. Many of the topics covered in this second category relate very strongly to those already described under the Climate Smart Agriculture area.

What we are effectively recommending here is to eliminate the division between "Climate-Smart Agriculture" and "Food Value Chains," creating a single "Agrifood" theme with six sub-topics:

- **Sustainable and low carbon production:** Agricultural practices must become more sustainable across the board, and be executed in ways that don't lead to the loss of arable land. This requires a basis in a comprehensive vision for sustainable agriculture, where certain products are moved primarily to landless systems (such as vertical production near cities), whereas other types of production are either intensified or de-intensified, depending on their location in specific landscapes. It also requires adjustments to policy (such as the removal of trade distortions and perverse subsidies) and the creation of new finance mechanisms that allow for the compensation of farmers in applying more sustainable agriculture at the expense of lower yields.
- **Food waste reduction:** As already stated, for every tonne of food that is wasted, we generate unnecessary carbon emissions. Cutting food waste across the supply chain should be a top priority for emissions reductions. Again, the primary focus should be on the elimination of food waste; only once these wastes can no longer be eliminated should they be put to use in other applications, and care should be taken to avoid techno-economic lock-ins as well as diversion of nutrients out of the food system.
- **Sustainable and low carbon consumption:** One of the most significant drivers of inefficiencies and emissions from the food system is the high amount of animal product consumption. Shifting to lower-carbon diets is an essential focus for decarbonizing the food system and making it more sustainable overall. Beyond just looking at animal products, our research has shown that it is possible to decarbonize diets by shifting to more regionally-appropriate forms of nutrition and seasonal diets.
- **Policy, finance, and governance:** New tools and approaches across the sphere of policy, finance, and governance are needed in order to facilitate transitions in the three categories named above. Internalizing externalities (such as carbon impacts) and creating trading schemes for these impacts, are just one example of such financial mechanisms. As described in the example on African trade imbalances, the EU's policies also have far-reaching consequences on land use worldwide, which should be taken into account in transition strategies for the food system. CAP reform in the EU presents an opportunity to shift the policy landscape.
- **Data collection and reporting:** Without proper data collection and reporting, it is impossible to evaluate whether sufficient progress is being made. EIT Climate-KIC will ideally adhere to and support science-based targets for impact reduction throughout supply chains and on national budget levels, and recommend that projects adopt these more stringent criteria for success. Projects that create new tools and harmonized standards for supply chain data monitoring, such as improved algorithms for remote sensing or blockchain based data tracking, should be another focal area of support.

- **Innovation, education, capacity building, and technology transfer:** The EU has among the world's most advanced and efficient agricultural systems. It also invests more than most nations in agricultural innovation. Maintaining structural support for innovation, but diversifying the objectives of this innovation away from its exclusive focus on traditional intensification, is an important goal for transitioning the food system. The knowledge that is generated within the EU should ideally also be actively transferred to the developing world context, allowing for faster adoption of sustainable technologies worldwide. The EU can potentially be seen as a test bed for the development of essential new approaches to sustainable agriculture.

AN INTEGRATED APPROACH

Though this may not seem to drastically differ from the current set of thematic divisions under the Agrifood theme, what it allows for is to deal with the full extent of the food value chain – from farm to fork – with an integrated perspective. If all six of these thematic areas are considered concurrently, it will allow for the development of optimized solutions across the spectrum of production and consumption, as described in the example on cosmetic standards for produce (page 16).

We have not currently recommended combining the themes under the Integrated Landscapes category with those under the Agrifood category, however, as has already been described, there is a great deal of crossover between some of the topic areas in these two domains. There should ideally be mechanisms in place that allow for this kind of integration. A more detailed reflection on this issue is warranted, but out of the scope of the present assignment.

IMPLEMENTING THESE RECOMMENDATIONS

In order to successfully implement the overarching recommendation that we have made here (merging the Climate Smart Agriculture and Food Value Chains sub-components of EIT Climate-KIC's Agrifood Theme), we recommend following a series of implementation steps. As an external party, we cannot be fully aware of the internal dynamics at work within Climate-KIC (around team organization or funding, for instance), so these recommendations are made from an outsiders' perspective, assuming flexibility of reorganization. However, they can be adapted to the situation at EIT Climate-KIC based on internal knowledge of the teams.

Implementation approach

- **Develop integrated vision of sustainable land use and agriculture.** Something that we feel does not come across strongly from the current definition of EIT Climate-KIC's SLU sub-themes is a vision of the end goal towards which the organization is driving. For instance, if we consider urban agriculture as a possible intervention, many projects in this space will have strong benefits in terms of reducing land use footprint and water demand but will potentially result in higher energy demand and higher food prices. There needs to be an end vision for the SLU theme that serves as a guideline for handling these kinds of trade-offs. Should reducing land use be prioritized relative to energy use increase? Potentially EIT Climate-KIC would like to push for this only in certain circumstances, such as when the land "spared" is in highly forested or biodiverse areas, or when the energy systems supplying the urban food production are fully carbon neutral. A vision is essential for providing the high-level storyline around these conflicts. An example of an integrated food system vision can be found in Metabolic's Global Food System report starting on page 139 (Gladek, 2016).

- **Define performance metrics for SLU outcomes (science-based and holistic).** We have already mentioned the emerging importance of a science-based approach to target setting (page 10), which we recommend EIT Climate-KIC to adopt to the greatest extent possible from both a strategic and impact perspective. Once a vision is defined, each of the end performance areas described in this vision should be associated with absolute performance metrics (such as decrease in CO_2-eq intensity per sector) that should be applied. This is essential to ensure that the projects EIT Climate-KIC is supporting are resulting not just in incremental improvement, but in sufficient change to stay within 2 or 1.5 degrees of total average planetary warming. In addition, because of the risk of burden shifting, we recommend that all projects are evaluated on an integrated set of metrics, not just looking at climate change as a primary driver (see the next section for more on our recommendations in this regard).
- **Do root cause analysis for each area of priority impact.** Once the primary impacts that EIT Climate-KIC aims to address are in clearer focus for all of the core performance areas (for example: preventing any new land use conversion, reaching a certain level of CO_2-eq. intensity per food chain or region), we recommend performing a root cause analysis for each of these impact areas. For example, if one of the goals is CO_2-eq intensity reduction, then a root cause analysis would show where the most intense emissions originate and what are the underlying drivers of these impacts. This would lead back to, for instance, achieving changes in

consumer diets, but also, changing EU policy affecting African trade distortions. We have provided a very high-level breakdown of initial drivers of climate impact on page 14, but this would ideally be further explored and traced back to deeper origins.

- **Define strategies for each set of root causes.** For each of the root causes identified in the previous assessment, we recommend that EIT Climate-KIC develop a set of strategies and intervention mechanisms that can theoretically be used to address these. For example, developing alternative plant-based protein sources will address the impacts originating from the consumption of animal products. The intervention strategies that are identified as most promising should all fit into one of the six sub-themes that we have recommended to adopt for the Agrifood theme. The coarse assessment that we have already performed should already provide a roughly correct framework, but this should be refined to better understand detailed intervention categories. In the Appendix, we provide an example of how such a root cause assessment could lead to priority intervention areas for the first three sub-theme areas we have recommended.
- **Develop new evaluation procedure for projects.** EIT Climate-KIC's current expert-based evaluation procedure is, we believe, insufficiently consistent and systemic, since it is largely based on different subjective priorities held by different experts. In it's current form, we believe it is likely to lead to burden-shifting and also support projects that are insufficiently ambitious in some of their impact reduction effects. We recommend a more quantitative and holistic matrix of indicators for project evaluation, and a consistent team for the implementation of this approach (see next section).

We strongly recommend that EIT Climate-KIC completes this implementation pathway in its development of an impactful and robust long-term strategy. An abbreviated version of this approach could potentially take as little as two months but will need to be based on less quantitative assessments of impact. Ideally, we would recommend following a 6-12-month process to fully follow each of these steps and incorporate peer-review at the appropriate moments. A combined alternative would involve completing the short form of this implementation plan to develop a rough draft strategy that can immediately be acted upon, which can then be deepened over a longer period through different project rounds.

AVOIDING "BURDEN SHIFTING"

While climate change is the main priority for EIT Climate-KIC, it is only one of many environmental threats that pose a risk, as we have already discussed extensively. In Metabolic's own work on food systems, we always take a holistic systems approach to evaluating projects and measuring progress towards sustainability.

In our own framework, we consider all impacts under two apex categories: biospheric integrity and human health and wellbeing. While climate change obviously plays a role in both of these categories, we usually consider this a subcategory of biospheric integrity, as the effects on human health and wellbeing are mainly indirect, through effects on ecosystem functioning. The categories that fall under these two apex categories for the food system include:

BIOSPHERIC INTEGRITY	HEALTH AND WELLBEING
Climate change	Labor and livelihoods
Land systems change	Food security and nutrition
Water management	Food safety and health
Novel entities	Animal welfare
Solid waste	Preservation of culture and heritage
Biogeochemical flows	

Ideally, EIT Climate-KIC is supporting only projects with a positive effect on all impact areas, also beyond climate change. While it is a prerequisite to select projects that have the potential for significant climate change mitigation or adaptation, it is important to also ensure that there are no unacceptable unintended consequences of projects that EIT Climate-KIC supports in other critical impact areas. For this reason, we propose EIT Climate-KIC takes a more systematic and holistic approach to assessing projects across other impact areas. This can be done roughly to understand where tradeoffs might lie, as in the example below.

As already mentioned, we recommend that EIT Climate-KIC develops more advanced metrics and tools for selection of projects to support, based on the expected level of impact reduction to be achieved, rather than relying so heavily on expert review which is bound to be subjective and variable. On the longer-term, EIT Climate-KIC should have a more sophisticated and quantitative method for project selection, though on the shorter term, basic qualitative metrics can already be easily incorporated.

Even some simple ranking metrics could be helpful. We mentioned earlier that a simple table of potential impacts across a holistic set of indicators (not only climate change) can be beneficial, ranking each mechanisms as having a very positive, positive, negative, or very negative effect on each impact category. Table 2 shown below is currently based only on qualitative evaluations on each of these categories. Ultimately, as we have recommended in step two of our implementation plan, we think EIT Climate-KIC should invest the necessary time and effort to develop a set of science-based, quantitative indicators for relevant category based on the vision the organization is working towards.

IMPACT CATEOGRY	EATERNITY	PYCO	VEGANAUT
Climate change	++	+	+
Land systems change	+	+/-	+
Water management	+	+/-	+
Novel entities	+/-	+/-	+/-
Solid waste	+/-	+/-	+/-
Biogeochemical flows	+/-	-	+/-
Labor and livelihoods	+/-	+/-	+/-
Food security and health	+/-	+/-	+/-
Animal welfare	+	+/-	++
Preservation of culture and heritage	+/-	+/-	+/-

CONCLUSIONS AND NEXT STEPS

Summarizing our recommendations, we believe that EIT Climate-KIC should ideally eliminate the separation between the Climate Smart Agriculture sub-theme and the Food Value Chains sub-theme, creating a single Agrifood theme with six primary action areas:

- Sustainable and low carbon production
- Food waste reduction
- Sustainable and low carbon consumption
- Policy, finance, and governance
- Data collection and reporting
- Innovation, education, capacity building, and technology transfer

We have proposed these six topical areas based on a preliminary assessment of the highest areas of impact and leverage in the agrifood and land use space. However, as mentioned, we suggest that EIT Climate-KIC follow our recommended implementation plan, and lead from a outcomes-based vision of what sustainable land use should ultimately look like. In the appendix we provide a preliminary exploration of what a root cause and intervention assessment could yield in terms of priority areas for the first three topic areas listed above, with the caveat that these should be worked out more thoroughly.

A comprehensive vision should then ideally be the basis for a set of holistic metrics that will be used to evaluate all projects, taking climate impact reduction as the leading element, but structurally preventing burden shifting in other areas. We also strongly recommend leading from a Science-Based Targets perspective for the development of these indicators and using a landscape approach for recommending best practices in specific regions. EIT Climate-KIC should also support the development of systemic tools (monitoring frameworks, new finance mechanisms, policy recommendations) that will help drive the emergence of appropriate solutions, which may initially be in short supply.

APPENDIX I: PARTIAL AND EXAMPLE APPROACHES FOR ELABORATING THE AGRIFOOD STRATEGY

In this appendix we explore the first three thematic areas that we proposed in our recommendations in more detail. Following the structure of the Food Value Chains strategy that we received to review, we present the desired outcomes for each theme and the types of mechanisms which can be used to achieve the outcomes. For each mechanism, we also briefly describe an example or two of a type of project which demonstrates the types of mechanisms which could be used to reach desired outcomes. As a disclaimer, we have not thoroughly evaluated these examples against a comprehensive set of impact metrics: they are meant to simply illustrate the type of projects that could be considered. Furthermore, this framework is not vetted or complete: we recommend following the full implementation plan that we described in recommendations section of this report.

In theme 1, sustainable and low carbon production, we suggest focusing on sustainable production of food. This is by far where the largest negative externalities and inefficiencies occur. The production system is responsible for the largest share of emissions and can be vastly improved in order to reduce its climate impacts. The two objectives within this theme are deeply intertwined: on one hand ensuring enhanced sustainability of the production system, and on the other, transitioning towards lower-carbon alternatives. Under this theme we point out that technology and technological advancements should be regarded as a means, rather than an end. While their potential for disruption remains undisputed, they cannot be regarded as a silver bullet to solve the entire problem holistically. A deeper rethinking of the production system is necessary, if substantial climate impacts are to be reduced.

Under theme 2, reducing food waste, we propose focusing on the reduction of food waste, ranging from post-harvest losses to post-consumer and post-retail waste streams. Once more, the objective is twofold: the aim is to reduce the amount of food that becomes waste before it enters the retail market or reaches the consumer, as well as after.

Working towards these objectives requires improved logistics, made possible by better preservation and packaging, which can extend a products shelf-life, as well as value chain optimization, which reduces time and distance. Greater efforts are required to change consumer behaviors and industry standards: nutritionally valuable and perfectly good food products are wasted because of minimal unconformities and imperfections - instead they could be diverted to other uses, preferably following a cascading pathway. In the latter, the highest-value use has priority over lower-value uses, in essence this implies avoiding landfilling at all costs, and cycling a products downwards gradually, so that its nutrients can be recovered as much as possible instead of being lost.

Lastly, under theme 3, sustainable and low carbon consumption, we focus on sustainable food consumption. The global food production system is ultimately shaped by consumer demand. As a consequence, consumers can play a leading role in the reshaping of the system if they wish to do so. Large improvements can be achieved by transitioning to diets that are less carbon intensive. This would imply a reduction in the consumption of animal products, which have by far the largest carbon footprint - and which, at the same time, are responsible for unhealthy diets worldwide. improving diets, by shifting towards vegetal instead of animal foods, could therefore generate benefits not only for the environment, but also for human health.

THEME 1: SUSTAINABLE AND LOW CARBON PRODUCTION

Agricultural production accounts for the greatest share of food-related emissions: up to 10-25% of global emissions, depending on the scope of what is included. Agricultural practices must become more sustainable across the board, and be executed in ways that don't lead to the loss of arable land. Conversion from forests and other natural ecosystems to farmland is one of the greatest sources of emissions. In some parts of the world, intensification of agriculture (extraction of greater yields per hectare) is a desired outcome, but how this is achieved has large implications for the total GHG footprint of production.

Outcomes

Technologies are mechanisms for achieving the outcomes of sustainable and low carbon production, but they are not outcomes in themselves. The outcomes we expect go along with sustainable and low-carbon production include:

- A reduction of land conversion to agriculture (e.g. deforestation). Paired with this, the quality of arable land and water resources should be preserved to prevent a need for converting additional land.
- Yield maximization, achieved by improved agricultural practices, but without negatively impacting biodiversity and fragile ecosystems. Increasing climate resilience of the food system by supporting crop diversity, preventing soil erosion, etc.
- Reducing emissions associated with fertilizer production or mining, as well as preventing excessive use.
- Supporting human wealth and wellbeing, both in terms of food security and in terms of safeguarding exposed livelihoods.

Mechanisms and case examples

Low-carbon/low-impact intensification processes are one means to achieving the desired outcomes. These mainly involve diversifying agricultural production, but could also include technological interventions for increasing yields. Aquaculture is one relevant example and prevents important impacts on ocean biodiversity. However, aquaculture could also have a higher climate impact depending on the inputs and methods used. Supporting mixed land use types (e.g. agroforestry, silvopastoralism) is another important mechanism as it results in a higher yield per area (reduced expansion) and higher carbon sequestration than monoculture.

- **Example case:** mOasis is a non-toxic gel-like soil additive that helps seeds get farther on less water. It works by holding extra water near a plant's roots and releasing it as the soil dries out. A field test from UC Davis found the product results in a 30% yield increase for broccoli using 25% less water.
- **Example case:** Swiim - The patented process behind SWIIM, or Sustainable Water and Innovative Irrigation Management, monitors water budgets and computes data. This allows a large-scale water user, like a farm or a utility company, to better manage usage.

Urban farming means producing food on land that doesn't compete with natural ecosystems and could also include food production in industrial areas. Both low-tech and high-tech urban farming can be important mechanisms for decreasing emissions while increasing food security and reducing pressures on the natural environment. Low-tech urban agriculture can be developed in reclaimed urban spaces or in rooftop gardens. These places may provide benefits other than just agricultural productivity, such as recreational and educational spaces for citizens. High-tech vertical agricultural systems require less space by design and can be deployed in urban environments to maximize production in restricted spaces, however caution should be exercised with these systems as they may increase emissions and other impacts if they require high inputs (of energy, fertilizers, etc).

- **Example case:** Floating Farm is a floating dairy cow production system that is being piloted in the Netherlands. The concept makes use of urban waterways to produce grass and consume urban organic wastes to produce dairy in a floating farm.
- **Example case:** InFarm - Urban farming startup based in Germany is an organization that develops vertical farming tech for grocery stores, restaurants and local distribution centers.

Production technologies can be improved in order to reduce inputs, as well as several negative externalities which often result from conventional agricultural production. A simple mechanism is electrification of farm equipment, though another example of a mechanism could include precision farming, which refers to the deployment of more or less novel and advanced technology applications to improve the use of fertilizers, pesticides, water, or other agricultural treatments through the use of aerial imagery or in-field sensors.

- **Example case:** Vodafone has invested in precision agriculture project which allows farmers to send GPS information collected by fertilizer applying machinery which is translated into a map which farmers can use to spot any wastage and reduce subsequent fertilizer orders accordingly.

Information technologies can enhance the communication as well as the flow of information between agricultural operators all along the value chain. One mechanism could include enabling farmers to retrieve real-time information which may be of use in their decision making process (e.g. local or regional water availability as well as the spread of pests and infestations which may damage crops, etc). Another mechanism could include decision support tools for low-impact sourcing, which enable market operators to obtain a better understanding of available resources in their surrounding environment.

- **Example case:** WeFarm - Wefarm is a free peer-to-peer service that enables farmers to share information via SMS, without the internet and without having to leave their farm. Farmers can ask questions on farming and receive crowd-sourced answers from other farmers around the world in minutes.
- **Example case:** Hara - Smart Farming Platform that enhances the productivity of agricultural companies that works with smallholder farmers. This platform

created by CI Agriculture / Dattabot helps farmers to collect data and analyze the condition of agricultural land related to maintenance activities and crop harvest, including on field potential, farm inputs management, anticipation of pest and disease.

Spatial optimization can be applied to ensure that production techniques best match the specific environmental and climatic conditions of a region, for example by matching crop types more accurately with seasonal changes within regions or selection of production technologies to match regional or even local specificities.

- **Example case:** Kreidenweis, Lautenbach & Koellner (2016) explored CO2e emissions by scenarios of local and international production and found that emissions could be lowest when sourcing from countries with lower-emission production, even when considering additional emissions from longer transportation distances.

Alternative inputs, such as organic and organically certified inputs, can significantly reduce the environmental impact of agricultural production. Additionally, mechanisms that reduce reliance on synthetic or mined fertilizers can be extremely beneficial. Another key mechanism is the development of other new lower-impact foods and additives (e.g. lab-grown meat, grass protein, gelatin alternatives, etc.).

- **Example case: Protix - Creative alternative animal** feed based primarily on black soldier fly larvae. Dutch company currently scaling its activities significantly.
- **Example case:** Biteback - Biteback is an Insect Bio-refinery company aiming to meet an increasing global demand for palm oil by creating a healthier and more sustainable oil alternative.

THEME 2: REDUCING FOOD WASTE

When considering the significant climate impacts attributed to agriculture, it is also important to consider the Food and Agriculture Organization’s estimates that 1/3rd of all food is wasted (FAO, 2011). This means that, if indeed, the food system is responsible for up to 36% of all emissions, then 12% of these emissions are embodied in the food we waste. If we were able to reduce these waste figures, then food production and all of its impacts could be decreased by a commensurate amount. For this reason, food waste should be the second priority theme.

Most food is wasted before it ever reaches the consumer, as shown in the figure below. Even in Europe and North America, where a large amount of post-consumer food waste happens, the largest share of waste still happens during production, processing, and logistics. This means that while a focus on consumer food wastes is still relevant in industrialized nations, prevention of pre-consumer losses are the most relevant globally.
Source: FAO, 2011

Outcomes

The main outcome that needs to be achieved is the reduction of food waste across the entire value chain in order to minimize impacts. Currently, EIT Climate-KIC has too much of a focus on end-of-pipe solutions (what to do with organic waste), rather than addressing root causes for prevention. Some outcomes that could be a focus instead include:

- Reduction of food losses at the agricultural production level through low-carbon methods for pest control
- Improvements in food preservation and packaging to extend shelf life and prevent losses along supply chains.
- Reduction of food losses during transportation and storage, which are often due to a lack of equipment or infrastructure.
- Reduction of food losses at retail, either by identifying alternative products or enacting legislation on food waste prevention.
- Reduction of food waste by consumers at home or in restaurants / catering, as well as reducing packaging waste.
- Improving food waste management by avoiding landfilling and incineration and developing pathways to recover nutrients and/or reduce emissions indirectly by producing high-value products from organic waste.

Mechanisms and case examples

Food preservation and food labeling. Presently there is an increasing market demand for fresh produce and products, while these products may have a substantially lower shelf-life. Ideally, innovative products should both ensure freshness and extend shelf life. One way to extend shelf life is through natural and low-impact additives that are not associated with health impacts and ensure product quality or preservation techniques such as canning, drying, etc. Better food labeling is another option to prevent good food from being thrown away: there is a lot of confusion about “best by” dates on labels.

- **Example case:** Hiperbaric is a company making high-pressure processing (HPP) equipment. HPP is a newly popular technique for sterilizing and extending the shelf life of fresh foods like juices without additives which are unpopular with consumers.

Logistics solutions can prevent food waste by ensuring a faster and more effective delivery of products. These solutions can include packaging options that keep food fresh longer and prevent damage, lower-impact transportation options, or labeling and tracking systems that can facilitate supply chain optimization, including route or ordering optimization systems can optimize delivery routes in way that makes deliveries faster and less energy consuming.

- **Example case:** A natural postharvest protection, Edipeel is an invisible, edible, and tasteless innovation engineered by Apeel Sciences to protect food surfaces. Made from all natural plant extracts recycled from agricultural byproducts, Edipeel serves as a barrier-like skin to protect produce from transpiration, oxidation, and microbial activity.
- **Example case:** Yume, founded in 2014, has an online platform where vendors can offload surplus food before it spoils at deeply discounted prices. Unilever is among the list of suppliers. Yume also helps donate unsold surpluses to charity.

Storage solutions (along the entire supply chain, including in homes) can extend the life of products and their quality. Storage solutions are an expensive necessity for most farmers. A substantial amount of food is lost because farmers don't have means to store food in a way to prevent losses. In addition to on-site storage, cooling systems along the rest of the supply chain for storage are often important to prevent spoilage, but can also result in high emissions.

- **Example case:** A solar-powered, standalone device, Wakati uses hydration to preserve food instead of a cooling system, creating a low-cost, low-energy alternative to refrigeration. Using just one liter of water per week, the Wakati system keeps fresh produce hydrated, enabling farmers in warm climates to effectively store their harvests.
- **Example case:** The Super Bag uses hermetic storage to increase the shelf life of stored grains and seeds. When sealed, the bag reduces oxygen levels from 21 to 5 percent which can reduce the number of live insects without insecticides. The bag also increases the germination life of stored seeds from 6 to 12 months and maintains consistent grain moisture within the bag.

Information technologies can help to identify key areas in which food waste prevention mechanisms can be rolled out and enable consumers to prevent food waste.

- **Example case:** LeanPath provides food waste prevention solutions for commercial kitchens worldwide. The company's smart meters allow kitchen staff to track what food is being thrown away, monitor trends, and make informed decisions to reduce food wastes and costs. LeanPath has been installed in more than 1,000 kitchens in more than 20 countries. In one case, at Boston College, the kitchen reduced food waste by 60 percent.
- **Example case:** Wireless sensors developed by VTT Technical Research Center detect ethanol in food packaging, allowing live data on the food's quality and freshness to be transmitted to retailers via radio frequency identification (RFID) tag technologies. The smart packaging products can help to improve the shelf-life of packaged food products and can help better control and monitor food quality throughout the distribution chain.

Middle-of-pipe solutions can contribute to the reduction of food losses that occur between farm-gate level and retail. Some examples include diverting pre-consumer food wastes to products with different standards (e.g. some produce might not be the correct shape for fresh sales, but could be used in soup), diverted organic waste to high-value uses which keep nutrients in the food system, or preventing food waste through policy by requiring stores give away nearly-expired food or pushing for "ugly produce" to be sold at a discounted price.

- **Example case:** Regrained - Makes Granola bars from spent grains from the beer brewing process and to date has used around 19 tonnes of spent grain in this product.
- **Example case:** Full Harvest - B2B marketplace where growers can connect with food companies to offload surplus or imperfect produce. Full Harvest won the Innovation Award at United Fresh, one of the biggest produce conferences in the U.S.

End-of-pipe solutions can contribute to the reduction of food losses after consumption by the consumer, or after being discarded by retail, though should be a last resort and not a major focal area. Ideally, end-of-pipe solutions keep food waste in the food system, for example by using it as animal feed. Alternatively, deriving products such as specialty chemicals or other high-value products could be explored. Composting or other nutrient recovery techniques can also be employed to prevent fertilizer use production upstream. As a final option, energy recovery can be used, but ideally only when nutrient recovery occurs simultaneously.

- **Example case:** WISErg produces fertilizer, mainly through food waste such as meats and produce sourced from grocery stores and restaurants. Its clients use the company's Harvester, which grinds food waste into a slurry that retains more than 90 percent of the nutrients versus 40 percent from traditional composting. The machine even provides actionable data to WISErg customers, such as the types and amounts of waste being ingested to help guide future purchasing decisions.

THEME 3: SUSTAINABLE AND LOW CARBON CONSUMPTION

Shifting to lower-carbon diets is an essential focus for reducing the footprint of the food system and making it more sustainable overall. One of the most significant drivers of inefficiencies and emissions from the food system is the high amount of animal products consumed. In 2013, an FAO report focused on climate change emissions from the livestock sector, attributed 14.5% of the world's emissions to the livestock supply chain in 2005. Direct emissions from livestock (enteric fermentation and manure) account for 9% of global CO2e emissions, while indirect emissions from feed account for further emissions (around of global cropland is used to produce livestock feed). Beyond animal products, overconsumption and unhealthy diets increase the CO2e footprint of consumption.

Outcomes

Consumers ultimately wield an important power over agricultural production. Improving consumption habits can result in not only lower environmental impacts, but also improved human health. Some specific outcomes regarding consumption that are desirable include:

1. Increasing consumer awareness about the climate impacts of the food choices they make on a daily basis.
2. Reducing the consumption of animal products, which will require the availability of safe, healthy, and desirable alternatives to animal products, especially in developing countries where availability of alternatives is lower.
3. Helping consumers avoid overconsumption and consumption of too many unnecessary foods like sugars, oils, and excess carbohydrates.

Mechanisms and case examples

Plant-based animal product alternatives, such as those found in pulses, can provide equivalent amounts of nutrients and substitute, at least in part, animal products. These products can also be designed to mimic actual animal products to suit the consumer's taste. Developing fake meats, fish, eggs, and dairy alternatives, or other products that are good sources of protein, omega 3s etc, is a good mechanism for reducing the demand for animal products.

- **Example case:** Hampton Creek / Just Foods - has more than 40 entirely plant-based products, including mayonnaise, cookie doughs, cake mixes and dressings, sold at thousands of mainstream stores. The company is also creating an open-source database with information on every plant protein in the world. Hampton Creek is also developing over 400 new products and promises to sell clean meat by late 2018.
- **Example case:** Beyond Meat produces a product called the Beyond Burger, which tastes remarkably like a hamburger patty, but has more iron and protein than a beef burger; a fraction of the saturated fat; and none of the cholesterol, hormones or antibiotics. You can find Beyond Meat products at hundreds of grocery stores in the U.S. The company also produces plant-based ground meat, chicken strips, and sausages.

Meat replacements can also be obtained from either technological advancements or from previously untapped (at least in large parts of the Western world) protein sources. Lab grown meat is one mechanism that has received a lot of attention, while alternative protein products such as those made from insects are also gaining attention.

- **Example case:** Mosa Meats - One of the pioneers of lab-grown meat, MosaMeat in the Netherlands made history in 2013 with its six-figure beef patty. Since then, the company has reportedly brought the price down to $11 per burger. The stem cells come from organic cows, with cells from a single cow capable of producing 175 million quarter-pounders.
- **Example case:** Finless Foods - Brooklyn-based Finless Foods is taking the so-called cellular agriculture riff—culturing meat from animal cells—out to sea. Finless Foods seafood will be free from mercury, plastic and all the crud that goes into aquaculture and fish farming today. The startup takes a small sample of cells from living marine animals to be cultured and structured in a "brewery-like environment in the same shape as a fish fillet." The company hopes to serve up bluefin tuna from the lab by 2019.

Creating consumer awareness about food carbon impacts can have many positive benefits and ultimately empowers consumers by making more informed choices about the consequences of their consumption. Transparency can improve decision making - not all consumers may be affected, but retailers, restaurants, etc. will have an incentive to improve their performance. Involving consumers will also remain an important mechanism. Gamification, i.e. the creation of a game with real-world objectives, is one type of tool to attract consumers to reduce their impacts.

- **Example case:** While EIT Climate-KIC is already supporting Eaternity, an app that allows restaurants to calculate the carbon footprint of dishes, many apps allow consumers to calculate their entire carbon footprint, including from food. The app OroEco allows you to do just that, calculate your footprint from different activities, earn points for eco-friendly products, compare your progress to your friends and other users, and purchase carbon offsets to achieve net zero emissions.
- Pushing for healthier diets can benefit both society and the environment. This can be done through healthy diet programs, for example in public schools, or by developing more healthy food products that are attractive and convenient.
- **Example case:** The Food Dudes has been one of the most successful campaigns to increase consumption of fruit and vegetables among primary school children. The program led to a 60-200% increase in produce consumption and a 10-100% reduction in consumption of unhealthy foods in the U.S., U.K. and Italy where the program ran.
- **Example case:** Nothing But is one of many companies producing snack products made with nothing but dried vegetables and fruits, making it easy for convenience-seeking consumers to eat more plant-based foods.

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