INNOVATING THE FUTURE OF FOOD SYSTEMS

A global scan for the innovations needed to transform food systems in emerging markets by 2035

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Authored by:

Global Knowledge Initiative

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NOTE FROM GKI'S CHIEF OPERATING OFFICER SARA FARLEY

Dear Reader,

If, like me, you are equal parts inspired and overwhelmed by the magnitude of Sustainable Development Goal 2: *End hunger, achieve food security and improved nutrition, and promote sustainable agriculture,* then in January 2017 you received some mixed news. In that month the World Economic Forum released the results of a scenarios planning exercise that offered a glimpse into four possible futures for global food systems. Ranging from dire to promising, the scenarios provoked many questions. Among them: what must we do to stave off the most ill-fated future? What investments should we make? What long shots in research, technology, and innovation should we develop and scale? And how do these scenarios vary depending upon whether you live in a low-, middle-, or high-income country?

These unanswered questions were enticing in their criticality. And so my team at the Global Knowledge Initiative (GKI) initiated a "Scan for Transformational Innovations." Guiding our scan were a set of assumptions we'd developed through previous work in futures and innovation assessment, namely:

- The future isn't a fixed point in time. It is malleable and the very act of exploring it is a first step in shaping it.
- For any challenge substantial enough to be dubbed "pressing", "grand", or "complex" a multitude of innovations—likely straddling process, product, organizational, and market-based—will be required.
- The way in which innovation delivers impact is incredibly context-specific. Understanding systems is key to understanding whether and to what degree innovation will matter.

Guided by these ideas, we began our Transformational Innovation Scan by looking at innovation from two angles. First, we wanted to understand those innovations existing today that hold the most promise to transform food systems in emerging markets in the next five years. Second, we sought to make sense of those forces shaping our world, such as urbanization, wealth disparity, a changing climate, and nutrition and health inequities, to distill how they are transforming the context in which food systems will exist in 2035. We recognized that contending with these forces of change, and transforming food systems to be more environmentally, economically, and socially sustainable, demands unleashing innovation that is as transformational as the forces reshaping it.

To imagine, identify, and evaluate such transformational innovations were the motives behind this research effort. We paid special attention to innovations that address post-harvest loss. GKI currently serves as the Innovation Partner for YieldWise—The Rockefeller Foundation's $130 million 7-year initiative to halve post-harvest food loss (PHL) in the developing world. However, we opened the aperture more broadly, scanning also for innovations germane across global food systems. Filtering these ideas through an expert-driven research process guided the design of our methodology. Through it, we succeeded in ushering 50 global experts through parallel processes to pinpoint likely matches between future scenarios and the innovations that can improve them on dimensions social, environmental, and economic. This report marks the conclusion of our research.

Whether you are an investor, policymaker, philanthropist, business leader, or development practitioner, we hope you'll find value in using the insights offered in this report to unleash innovations best poised to advance our planet toward a more sustainable and inclusive global food system. In doing so, we hope you'll find hope, inspiration, and fuel for your own innovation journey in these pages.

- Sara E Farley, Co-Founder & Chief Operating Officer, GKI

GKI

THIS REPORT WAS WRITTEN BY THE GLOBAL KNOWLEDGE INITIATIVE [GKI] IN ITS ROLE AS THE INNOVATION PARTNER FOR THE ROCKEFELLER FOUNDATION'S YIELDWISE INITIATIVE

About the Global Knowledge Initiative

The Global Knowledge Initiative (GKI) is a non-profit organization based in Washington, D.C. GKI builds purpose-driven networks to deliver innovative solutions to pressing global challenges. It uses an integrated, systems approach to create the environment, mindset, and tools that enable problem-solvers to innovate and collaborate more effectively. As a grantee and Innovation Partner for The Rockefeller Foundation's YieldWise Initiative, GKI works to boost the degree to which innovation is used to improve the efficiency, effectiveness, and, ultimately, the impact of YieldWise.

About the YieldWise Initiative

Launched in 2016, YieldWise is an initiative of The Rockefeller Foundation aimed at demonstrating how the world can halve post-harvest food loss by 2030. By taking a systemic approach to loss reduction, YieldWise aims to improve rural livelihoods, build less vulnerable ecosystems, and increase the availability of nutritious foods. YieldWise currently focuses on demonstrating loss reduction in four value chains in Sub-Saharan Africa: mangoes in Kenya, maize in Tanzania, and tomatoes and cassava in Nigeria.

Photo credit: Lukas Budimaier

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Photo credit: Daniel Burka

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Finally, in addition to this report's authors, GKI's Kathryn Bowman, Glen Burnett, Manmeet Mehta, Cait Goddard, and Shivani Chokshi provided additional editorial and design support.

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PART 1

INTRODUCTION & EXECUTIVE SUMMARY

Photo credit: Left, Sveta Fedarava; Right, Lukas Budimaier

EXECUTIVE SUMMARY

The future of global food systems hinge on how we respond to the challenges of today and prepare for the challenges of tomorrow. In its 2017 Scenarios Analysis on Shaping the Future of Global Food Systems, the World Economic Forum foreshadowed global food systems in 2030 teetering between unsustainable production and consumption and torn between isolationism and collaboration. Called to action by these scenarios, the Global Knowledge Initiative (GKI) and The Rockefeller Foundation endeavored to identify the top immediately investible and emerging innovations that will be catalytic in reducing post-harvest food loss (PHL) and transforming food systems in emerging markets within the next 20 years. Thus, GKI conducted an Innovation Scan from April to October 2017 in its role as the Innovation Partner grantee for The Rockefeller Foundation's YieldWise Initiative, a $130 million initiative to demonstrate 50% reduction in PHL in key value chains by 2030. This report is the culmination of this effort.

THE GOAL OF THIS EFFORT WAS TO DEEPEN OUR COLLECTIVE UNDERSTANDING OF THOSE TRULY TRANSFORMATIONAL INNOVATIONS THAT WILL RESHAPE FOOD SYSTEMS IN EMERGING MARKETS FROM NOW TO 2035.

Through this Innovation Scan, we engaged global experts in the fields of agribusiness, academia, investment, innovation, international development, and Futures Foresight to examine the above challenge from two angles:

1. **What are the most promising innovations that exist today, or are just over the horizon, that merit investment?**
2. **How can next-generation innovations bridge the gap between the present state of the food system and the future system to which we aspire?**

Our findings to the first question live in Section 2: Investible Innovations (pg. 20), and our findings to the second live in Section 3 Emerging Innovations (pg. 77).

WHO SHOULD READ THIS REPORT?

Investors can use these findings to indentify those challenges or innovative solutions most likely to meet an existing or likely market demand, and which have untapped commercial potential.

Policymakers can use these findings to assess how high-priority innovations can be enabled through good governance, new regulations, targeted funding, infrastructure development, and cross-sectoral alignment.

Innovators can research, design, create, and test their own ideas that build upon the innovative solutions in this report.

Business Leaders can use these findings to expand into new markets and serve new consumers with new products that meet unaddressed needs.

Investible Innovations for Impact Today

In Section 2 (pg. 20), we present profiles of the top 22 investible innovations that should be further investigated, developed, and championed *today* to build resilient and prospering food systems in emerging markets over the next five years. This selection of innovations emerged through a rigorous process of divergence and convergence with an expert panel. Together, these experts helped to illuminate the transformational potential of each innovation, including the existing market opportunities, comparative advantage, critical risks, and performance across an array of evaluation criteria, explained in more detail on the next page and in Section 2 on pg. 31-32.

The top 22 investible innovations for today can be found in the table below. Some innovations, such as evaporative cooling systems, offer quick wins. These low-hanging fruit are solutions that value chain actors can adopt quickly with minimal training and low up-front costs. Other innovations, such as modular factories, are believed to have the most potential to reduce PHL in the long run. Still other innovations yield benefits that primarily accrue to smallholder farmers, or would have the most positive environmental impact, or would face substantial systems barriers, such as data and transport infrastructure, before delivering impact. See pg. 33-76 for detailed profiles for all 22 Investible Innovations.

INVESTIBLE INNOVATIONS FOR TODAY

1. Cooperative packaging solutions
2. Modular factories
3. Near-farm mobile processing
4. Mobile packhouses & pre-cooling
5. Dehydration for smallholders
6. Battery technologies
7. On-farm solar preservation
8. Crates adapted for SHF supply chains
9. Micro cold transport
10. Adaptable reefer containers
11. Cold chain as a service
12. Micro-warehousing and shipping
13. Evaporative cooling systems
14. Biodegradable coatings
15. Microbes for agriculture
16. Early warning system for diseases & pests
17. Improved traceability technologies
18. Specialty marketing for PHL-prone crops
19. Farm-to-fork virtual marketplace
20. First-loss capital guarantee for PHL reduction
21. Mobile education centers
22. Behavioral economics for agriculture

QUICK WINS

- Evaporative cooling systems
- Cooperative packaging solutions
- Crates adapted to smallholder supply chains
- Biodegradable coatings
- First-loss capital guarantee for PHL reduction

GREATEST POTENTIAL TO REDUCE PHL

- Modular factories
- Near-farm mobile processing
- Dehydration for smallholders
- Micro-warehousing & shipping
- Specialty marketing for PHL-prone crops

BENEFITS ACCRUE TO SMALLHOLDERS

- Adaptable reefer containers
- Behavioral economics for agriculture
- Mobile pre-cooling & packhouses
- Specialty marketing for PHL-prone crops
- Mobile education centers

ENVIRONMENTAL SUSTAINABILITY

- Battery technologies
- On-farm solar preservation
- Evaporative cooling
- Early warning systems for plant disease and pests
- Microbes for agriculture

MOST SUBSTANTIAL SYSTEMS BARRIERS

- Cold chain as a service
- Early warning systems for plant diseases and pests
- Improved traceability technologies
- Farm-to-fork virtual marketplace
- Mobile education centers

EXECUTIVE SUMMARY

To gain confidence in each innovation's estimated potential, our expert panel converged from 100 evaluation criteria to a suite of 8 to serve as an objective, intuitive, and comprehensive tool with which to better assess the potential of an innovation to achieve the goals of this effort. In the innovation profiles on pg. 33-76, we include an estimate of how each innovation performs on each criterion, as projected by our expert panel. Absent rigorous field tests or primary research, these are just that – estimates.

EVALUATION CRITERIA

Affordability	The income range of individuals and institutions who could afford the innovation
Usability	The amount of training required for the end-user to effectively use the innovation
Scalability	The point in the diffusion process at which the innovation could be scaled within 5 years
Smallholder benefits	The percentage of benefits that would likely accrue to smallholder farmers
PHL reduction potential	The innovation's potential to reduce current levels of post-harvest loss
Sustainability	The length of time that external support would be required before the innovation is accepted, adopted, and provides benefits
Energy considerations	The type of energy access required to deploy and operate the innovation
Environmental impact	The innovation's likely impact, either positive or negative, on the environment

Supporting Emerging Innovations Now for Impact in 2035

INVITATIONS FOR INNOVATION
NEEDED TO TRANSFORM FOOD SYSTEMS BY 2035

1. How might we engineer production systems impervious to crop failure and spoilage?
2. How might we reimagine the relationship between consumers and producers?
3. How might we create closed-loop agricultural systems?
4. How might we assure that all food everywhere is priced to account for its true cost?
5. How might we create farm-free foods?
6. How might we open, share, and use data across the supply chain to eliminate information asymmetries?
7. How might we transform conventional agriculture into regenerative agriculture?
8. How might we scale hyper-adaptive, localized polyculture?
9. How might we build and scale a model of self-sufficient city-based agriculture?
10. How might we reposition rural areas as places of opportunity?

We also asked our expert panel to imagine how innovation could alter the course of the future as offered in WEF's four scenarios from its 2017 Scenarios Analysis. In some instances, our experts described specific applications for emerging innovations that could fundamentally rewrite the way our food systems work. Quantum computing, blockchain, Internet for All, and synthetic biology are but a few of the innovations indicated as promising in the pursuit of such transformation. Other times, experts offered ideas about the opportunities that exist for transformational innovation to reshape agricultural systems altogether. We view these opportunities as *Invitations for Innovation*. In Section 3 (pg. 77), we issue 10 such invitations, each of which is meant to capture the imagination of investors, policymakers, innovators, researchers, and you to inspire bold efforts to reshape food systems in emerging markets.

CALL TO ACTION

Photo credit: NASA

The year is 1973 and it's the height of the Cold War. The world's two superpowers, the United States and USSR, are locked in a global game of chess. Avoiding straightforward conflict, they opt instead to engage in proxy wars and the deployment of strategic missile installations. Meanwhile, another battle rages in space. As the two super powers continue to vie for supremacy in both arenas, the Pentagon hatches a plan.

Flash forward to five years later, a balmy day in Southern California in February 1978. At the Vandenberg Airforce Base, an Atlas series rocket, a converted intercontinental ballistic missile, is being prepped for launch by the United States. Its payload is an unmanned navigation satellite, equipped with dual solar arrays, nickel-cadmium batteries, an S-band Space-Ground Link System for the Air Force to control the satellite, and an L-band communication system for navigation information. Once the Atlas delivers its payload, the satellite, the first of ten Navstar Block I satellites that will successfully launch over the next 7 and a half years will enter a medium Earth orbit at a distance of roughly 22,200 km from Earth. In orbit, it will circle the planet every 12 hours, relaying geolocation information back to Earth.

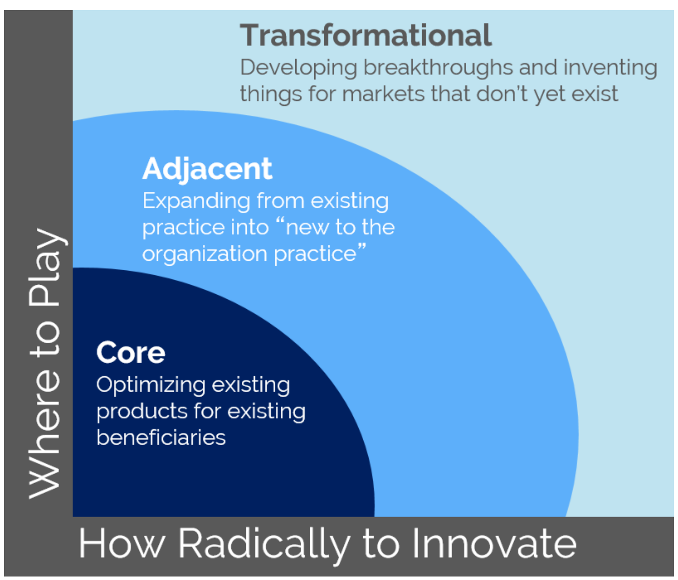
It is now September 2, 1983. The Republic of Korea is mourning. The day prior, Korean Air Lines Flight 007 flew to Seoul from New York City via Anchorage, Alaska. While on the final leg of the flight from Anchorage to Seoul, the pilots deviate from the original path, unaware they are entering prohibited Soviet Airspace. After firing warning shots, an Su-15 interceptor shoots down the aircraft. All 269 civilians aboard, including passengers, pilots, and crew, perish. In two weeks U.S. President Reagan will announce that a new Pentagon-developed technology—the Global Positioning System, or GPS—will be made available for civilian use free of charge to help prevent similar tragedies.

WHAT IS TRANSFORMATIONAL INNOVATION?

Now fast forward to the present day. A computer small enough to fit in your purse or pocket is constantly communicating with the successors of the original Navstar Block I satellites—the Block IIF. Using GPS, today's smartphones can guide you around a new town, or help you to find new places in a familiar one. Shop owners use it to track shipments; miners to position their equipment; and farmers to optimize field activity through precision agriculture practices like field mapping.

With innumerable applications that span agriculture, logistics, transport, military, recreation, aviation, extractives, and more, GPS is truly a **transformational innovation**, one that not only introduces a substantial improvement to current practice, but also provides entry into new markets, sectors, and application spaces. Also called *breakthrough* or *disruptive*, transformational innovations are the innovations that, when successful, make headlines. In their 2012 Harvard Business Review article, Bansi Nagii and Geoff Tuff explain how transformational innovation differs from "core innovation" (the current, standard area of innovation for a company) and "adjacent innovation" (that area of innovation just beyond current practice that entails serving existing customers and markets with a new product, process, or organizational offering).

TRANSFORMATIONAL INNOVATION



Unique for its ability to reimagine not only how a problem is solved but the nature of the problem itself, **transformational innovation** is the audacious, bold innovation target that most innovation misses.

So why in this report do we concern ourselves with transformational innovation, and in the agricultural sector no less?

In its 2017 Scenarios Analysis on Shaping the Future of Global Food Systems, the World Economic Forum foreshadowed a hotter, more crowded planet, one teetering between unsustainable production and consumption and torn between isolationism and collaboration. In some depictions of the future, various global actors heed the call to upend unsustainable patterns of production and consumption; while in others, apathy and inequity combine to seal a perilous fate for large portions of the planet.

THE ONLY CERTAINTY THE FUTURE OFFERS IS AN IMPERATIVE TO INNOVATE.

Looking across the WEF scenarios, one message is clear: to adapt to any of the possible futures, we have no choice but to succeed at transformational innovation.

This imperative raises two questions. First, how might we improve at detecting transformational innovation as it emerges? Consider the case of GPS. During the history of GPS' design and deployment, when did someone realize that it could transform far more than ballistic missile tracking? Second, how might we frame opportunities for transformational innovation in such a way as to encourage action by innovators capable of unleashing it?

Inspired by these questions, GKI and The Rockefeller Foundation undertook an ambitious effort to identify the top immediately investible and futuristic innovations that will be catalytic in reducing post-harvest food loss (PHL) from now through 2035. We convened global experts at the foundation's Bellagio Center, known for sparking creative thinking. There, GKI led this group of global thought leaders to pinpoint dozens of investible innovations to tackle the PHL challenge, including many technologies and process innovations that we can point to right now, such as crop-monitoring drones and advanced cooling technology. However, other innovation areas are so early-stage that we couldn't say for certain whether they offer solutions or not. In such instances, we can merely identify indications of needed change (e.g., urban migration and competition for land use) and research areas ripe for application (e.g., quantum computing and synthetic biology). It is there, in those emerging pockets of innovation and ideas for research, that we hope to provoke a reaction (and action) from global innovators and investors seeking to usher in the next Big Thing in agriculture.

But framing an opportunity to innovate so that it guides the efforts of would-be solvers can be harder that it sounds. Science biography writer David Bodanis writes of the power and difficulty in articulating a "mid-level abstraction"—a well-framed challenge specific enough to guide action but lofty enough to inspire. Those research centers, mangers, and companies that achieve well-articulated mid-level abstractions have higher rates of breakthrough success, and Nobel Prize-winning discoveries, according to Bodanis. For GKI, in spearheading the expert-driven process that yielded this report, among the most powerful insights sourced from experts were a compilation of Invitations for Innovation, or, mid-level abstractions (see Section 3: Emerging Innovations, pg. 82-102).

HOW MIGHT WE TURN CHALLENGES INTO OPPORTUNITIES?

There are more people living on earth in this moment than any previous moment in human history. This report is being published in 2017, but, barring an unforeseen global catastrophe, if someone picks up this report at any point over the next thirty years that statement will still be true.

The World Health Organization estimates that, of our current population of roughly 7.5 billion people, there are 800 million who suffer from hunger and 2 billion who suffer from nutrient deficiencies, the vast majority of whom live in emerging markets in East Asia and the Pacific, Latin America and the Caribbean, the Middle East and North Africa, South Asia, and Sub-Saharan Africa. With so many people suffering from hunger and nutrient deficiencies in low- and middle-income countries, a staggering amount of the world's food nonetheless goes uneaten. Estimates vary, but in Sub-Saharan Africa somewhere between 30-60% of food that is grown never reaches the plates of consumers. Much of this loss happens between when the food is harvested and when it reaches the market, a challenge known as post-harvest food loss (PHL).

Inefficiencies inherent in smallholder supply chains, which characterize much of the food production in low-income countries, offer a partial explanation for PHL. Small load sizes, lack of access to electricity, and poor rural transport infrastructure further contribute to inefficiency, which leads to losses in the form of food, and contributes to the problems described above. Further, when food is lost, it has implications for the livelihoods of smallholders, who lose out on income generating opportunities when they use limited resources to grow food that does not make it to market.

When looked at as a whole, transforming the systems in which smallholders operate may seem a daunting task. But, by asking pointed questions such as *How might we increase smallholder access to post-harvest loss-reducing products and services?,* we can turn these challenges into opportunities to innovate.

Ultimately, uncertainty about the future should not be an impediment to innovation today. While we cannot know for certain what the future holds, we can use the tools and resources available to consider its possibilities. One such resource is the aforementioned World Economic Forum report whose authors engaged in a Scenarios Planning exercise to produce their analysis. The resultant four scenarios serve as a useful starting point for considering how food systems may evolve over the next 20 years. However, the scenarios only paint the picture of *what could be,* not *how to make it so*. This report, and its underpinning research process, endeavors to take the WEF scenarios analysis a step further by seeking solutions that will help us build food systems in low-income countries that yield the outcomes we want—reductions in post-harvest loss, greater environmental sustainability, improved health and nutrition, and benefits to smallholder farmers.

WHO STANDS TO BENEFIT FROM THIS REPORT?

More than anything, we hope that this report will spur *action*. Action to find new solutions inspired by the conclusions. Action to find new partners to develop, test, and champion those solutions. And action to take the findings, analyze them differently, and turn them into something wholly new. Below are some ideas for how this report could be of use to the investor, policymaker, innovator, or business leader.

Investors

For any innovation or innovator to achieve impact, support is needed along the journey from idea to impact. Investors, funders, and donors are invited to use our findings to guide their quest for those challenges or innovative solutions that are most likely to (1) meet an existing or likely market demand, (2) have untapped commercial potential, (3) achieve scale across multiple contexts, and (4) make a real difference in the lives of people in low-income countries and emerging markets.

Policymakers

Policymakers and advocates play an essential role in fostering the enabling environment to support innovation. Policymakers are invited to use our findings to assess how high-priority innovations could be enabled through good governance, new standards and regulations, targeted funding, infrastructure development, and cross-sectoral alignment. In particular, the enabling environment features corresponding with the innovations in Section 2 on pg. 33-76 offer a jumping off point for policy prioritization.

Innovators

Innovators and researchers are invited to use our findings to research, design, create, and test their own ideas that build upon the innovative solutions in this report. In particular, Section 3 on pg. 82-102 offer explicit invitations to innovate that correspond with various forces of change that demand new research, innovation, and invention. With reference to emerging innovations, these invitations point to the white space where your efforts are vitally needed.

Business Leaders

Alignment and support from the private sector is a prerequisite for any innovation to achieve scale in emerging markets. Private sector leaders are invited to use these findings as inspiration for expansion into new markets to serve new consumers with new products. We also hope that the business community will join the development community in crafting an agenda for innovation in alignment with triple bottom line goals.

RESEARCH PROCESS

Photo credit: Riley McCullough

As the Innovation Partner grantee for The Rockefeller Foundation's YieldWise Initiative, GKI often applies a periscope approach to scan for global forces and innovative solutions to universal challenges that stymie the efforts of YieldWise and the agricultural sector more generally. This was our intent for the current effort, a global Innovation Scan seeking to deepen our collective understanding of those truly transformational innovations that will reshape agriculture between the present and 2035.

GKI employed a philosophy rooted in our organizational core to conduct this Innovation Scan: Collaborative Innovation. To us, Collaborative Innovation is the act of combining efforts and sharing complementary resources to create, test, and implement innovative ideas together. We believe that when changemakers collaborate with partners across organizations, sectors, and cultures, they are better able to unleash innovations with the potential for big impact.

Therefore, to identify and understand which innovations have potential to reduce PHL and transform food systems, we collaborated with global thought leaders at every step in our Innovation Scan.

RESEARCH PROCESS

GKI first convened a diverse group of global experts at The Rockefeller Foundation's Bellagio Center in April 2017. Over the course of three days, participants discussed prevailing opinions on the critical challenges related to post-harvest loss (PHL); examined scores of pervasive, nascent, and yet-to-be-imagined innovations poised to help us address these challenges; and, ultimately, constructed pathways of innovations with the potential to reduce PHL and achieve The Rockefeller Foundation's goals of nutritional security, sustainable ecosystems, and secure rural livelihoods.

We emerged from Bellagio with a clearer understanding of the role that innovation can play in addressing PHL and, better yet, a list of dozens of prospective innovations brimming with potential to address the challenge.

But we didn't yet know which innovations had the *most* potential to reduce PHL. Nor did we know which could have the most significant impact on food and nutrition security, environmental sustainability, and the lives of smallholder farmers. Nor did we know how current food systems would need to change to enable these and more cutting-edge innovations to *be* transformational. These were the central areas of inquiry for our continued investigation.

We next invited prolonged engagement with 40 experts to gradually converge upon those innovations with the highest potential to reduce post-harvest loss and improve food systems in emerging markets from now through 2035. We used a modified Delphi Technique at this stage because of the approach's unique ability to both forecast the likelihood and outcome of future events and shepherd a group with diverse perspectives toward consensus. The Delphi Technique, developed by RAND in the 1950s to estimate the impact of technology on warfare, guides a panel of experts through an iterative, multi-stage survey process, with each successive round designed to solicit reactions to the responses from previous rounds, ultimately leading to convergence on top ideas.

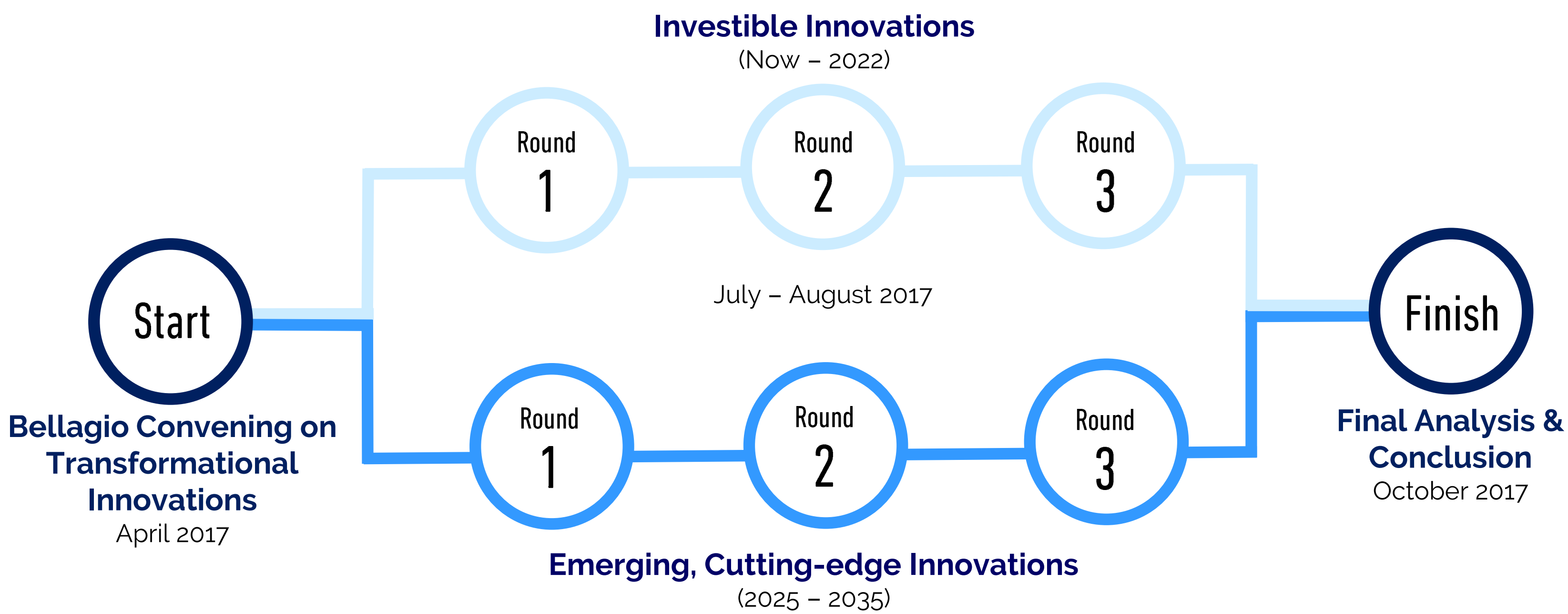
Through our Delphi process, we engaged experts in the fields of agribusiness, academia, investment, innovation, international development, and Futures Foresight to examine our thesis questions from two angles, listed below. Our experts divided into two cohorts to examine each question exclusively.

1. **What are the most promising innovations that exist today, or are just over the horizon, that merit investment?**
2. **How can next-generation innovations bridge the gap between the present state of the food system and the future system to which we aspire?**

OUR DELPHI SURVEY ENGAGED 40 GLOBAL EXPERTS TO SIMULTANEOUSLY EXAMINE INVESTIBLE INNOVATIONS AND SOURCE EMERGING, CUTTING-EDGE INNOVATIONS

Each expert cohort engaged in three successive response rounds, as shown below in the process diagram. After each round, GKI analyzed and summarized responses, and reported the results back to the cohort so that they could react to and refine their opinions through a subsequent round. Through three survey rounds, we walked away with a sounder understanding of the agricultural challenges ripe for innovation; the areas of innovation most poised to address these challenges; and the specific innovations that should be championed today, tomorrow, and through 2035 if we are to achieve an agricultural future as imagined by The Rockefeller Foundation and so many of us.

More information on the specifics and, more importantly, the findings from each round can be found in Section 2: Investible Innovations on pg. 20 and Section 3: Emerging Innovations on pg. 77.



PART 2

INVESTIBLE INNOVATIONS

INNOVATION FOR THE NEXT 5 YEARS

Photo credit: Mike Enerio

Transformational innovation is often the groundbreaking technology or business model that turns conventional thinking on its head. But sometimes, core and adjacent innovations—innovations that seem more incremental in nature—are capable of ushering in large-scale, positive change, sustained over the long-term as well.

In this section, we present profiles on high-priority investible innovations, whether they be transformational, adjacent or core, with potential to reduce PHL in smallholder value chains and contribute to the improvement of food systems more broadly in emerging markets over the next five years. This selection of innovations emerged through a rigorous process of divergence and convergence that involved some of the world's leading minds from a diverse range of sectors (see our Research Process on pg. 17-19). Together, this panel of experts helped to illuminate the transformational potential of a top list of innovations, including each innovation's existing market opportunities, comparative advantage, critical risks, and performance across an array of criteria.

You will find profiles of the top 22 investible innovations beginning on pg. 33. Prior to that, we walk through the process that helped surface these innovations and eliminated those innovations that would ultimately require more than five years of support to achieve widespread impact in smallholder value chains.

For these and other more cutting-edge innovations, we conducted a separate inquiry with research questions aimed at detecting innovations poised to have impact across a longer time horizon: from now through 2035 and beyond. It is these innovations that have even greater transformational potential: the potential to usher in a different future for food systems, or help us adapt to one should it emerge. Turn to pg. 77 for the findings from this parallel Innovation Scan on Emerging Innovations.

INNOVATION PROSPECTING

GKI embarked upon this journey with an initial list of 65 prospective innovations, shown below. Many surfaced at GKI's convening on Transformational Innovations at The Rockefeller Foundation's Bellagio Center in April 2017. Others emerged during our first engagement with experts in the Delphi survey. We believed that each innovation presented a unique value proposition for smallholder agriculture in emerging markets, but we did not know which could have the most potential to reduce PHL. Nor did we know which could have the most significant impacts for food security, nutrition, environmental sustainability, and smallholder livelihoods. These were the questions we took to our panel.

AWARENESS & CAPACITY BUILDING	BUSINESS MODEL	DATA	ENERGY	LIFE SCIENCES & ENGINEERING	PACKAGING & PROCESSING	STORAGE & TRANSPORT
Behavioral economics for agriculture	Community/kickstarter-supported agriculture	Aflatoxin detection and reduction technologies	2nd generation biofuels from edible biomass	1-MCP technology	Automated sorting and packaging	Adaptable reefer containers
Fee-based extension services	Farm-to-fork virtual marketplace	Blockchain logistics	Battery technologies	Antimicrobial fogging	Cellulose crating and packaging materials	Biosequestration of carbon in crop storage
Global PHL accounting protocol	Farming as a service	Distribution system mapping	On-farm solar preservation	Biodegradable coatings	Cooperative packaging solutions	Crates adapted for smallholder supply chains
Legislative support for farmer cooperatives	First-loss capital guarantee for PHL reduction	Early warning systems for plant disease and pests	Smart grids for agriculture	Bio-waste consumer goods	Dehydration for smallholders	Cold chain as a service
Mobile education centers	Multinational corporation anchor buyers	Fiber optic biosensors		Genetically engineered loss-resistant crops	Ethylene absorption technologies	Drone delivery of fresh produce
Open-source platform for PHL innovations	Private sector innovation and incubation hub	Government satellites for agriculture		Kilobots	Irradiation for smallholder value chains	Evaporative cooling systems
Public awareness campaigns to reduce PHL	Specialty marketing for PHL-prone crops	Hyperspectral imaging		Microbes for agriculture	Mobile packhouses	Micro-warehousing and shipping
		Improved traceability technologies		Nanomaterials for PHL reduction	Modular factories	Micro cold transport
		Low-cost moisture meters		Plant-based protein alternatives	Near-farm mobile processing	Mobile pre-cooling
		Millimeter wave sensors		Silk fibroin coating	Smart packaging	Retrofitted cold storage for smallholder value chains
		Mobile ethylene monitoring				Uber for produce delivery
		Open-source supply chain planning				Unmanned first-mile transport
		Open-source PHL mapping				
		Post-harvest data to improve access to finance				
		Smart sensors				

WHICH AMONG THE 65 INNOVATIONS SHOULD WE INVEST IN TODAY TO HAVE THE BIGGEST IMPACT IN 5 YEARS?

Over the course of three months, our expert panel scrutinized the 65 innovations on this list. They answered tough questions about each innovation's surmised utility, market potential, comparative advantage, risks, capital and operating costs, systemic barriers, time to scale, time to achieve impact, need for additional R&D, and a dozen other important considerations. In the end, and in the absence of costly and time-consuming field tests, we relied on the power of collective intelligence to illuminate which innovations have the highest potential to reduce PHL and improve food systems in emerging markets over the next 5 years.

The expert panel collectively narrowed this list to 22 innovations. These 22, listed on the following pages, are believed to be the innovations that should be further investigated, developed, and championed *today* to build resilient and prospering food systems in emerging markets over the next five years. You'll notice that many of these innovations are simply innovative spins on existing products, processes, and business models, such as *mobile* packhouses, *micro*-warehouses and first-loss guarantees *for PHL reduction*. Packhouses, warehouses, and first-loss guarantees are not novel in their own right, but their newly imagined adaptation to smallholder agriculture is.

You'll also notice that many of these innovations slant toward applications in fresh fruits and vegetable (FFV) value chains. This was our original priority when we began this Innovation Scan, due to the particularly high rates of PHL for FFVs, and the implications it has on the availability of vital micronutrients. It was not until later in the Innovation Scan that we began to consider applications of these solutions in other value chains. Despite this, the insights of our expert panel suggest that many of the innovations offer the potential to reduce PHL across multiple value chains, not only FFVs, but also roots & tubers, grains, and animal proteins. What is important for innovators and investors to consider is how the innovations must be *adapted* to achieve impact.

Photo credit: Asantha Abeysoo

WHICH INNOVATIONS ARE NOT PRIMED FOR IMPACT WITHIN THE NEXT FIVE YEARS?

Perhaps just as interesting are those innovations that ultimately weren't prioritized. While these might look promising at first glance, upon deeper investigation they were largely eschewed. Not because they were not deemed important, but because it may be unrealistic to expect these innovations to reach the scale needed for impact over the next five years. For instance, our experts think that more technologically advanced innovations related to data collection and monitoring, life sciences, and engineering, *will* be needed over the longer term. However, they are not yet practical for smallholder agriculture and value chains in a low-income contexts.

In short, several key reasons led our panel to reject an innovation. Among the most common reasons were: (1) too long of a timeline for implementation or to reach scale; (2) the need for considerable R&D before utility in emerging markets could be assessed; and (3) too heavy a dependence on political or popular support for near-term implementation. To get a better sense of what our experts said, some of their comments are offered to the right.

But while these innovations were not elevated to the top investment picks for the purposes of this Innovation Scan, it does not mean they are not workable solutions for PHL reduction. Rather, they present invitations for the right innovators and stakeholders to collaborate and bring their impact in a more concerted effort, in full recognition of the challenges that may lay ahead.

BIOWASTE CONSUMER GOODS

"Perhaps not within 5 years but certainly within a decade. Animal protein is simply unsustainable."

SMART SENSORS

"This innovation will likely be key… but for now there are too many barriers to its success."

DRONE DELIVERY OF FRESH PRODUCE

"The current state on the ground is not ready."

OPEN SOURCE SUPPLY CHAIN PLANNING

"How do you provide such information to farmers?"

MULTINATIONAL CORPORATIONS AS ANCHOR BUYERS

"The risks here potentially outweigh the benefits."

SMART PACKAGING

"We need to get basic packaging right before jumping to 'smart' packaging!"

GENETICALLY ENGINEERED LOSS RESISTANT CROPS

"It is still a sensitive subject with no political clarity."

NANOMATERIALS FOR PHL REDUCTION

"There is no doubt that nanotechnology will play a greater role in modern life in 10 years."

LEGISLATIVE SUPPORT FOR FARMER CO-OPS

"This is complex. Not workable in the short term."

22 INNOVATIONS ARE BELIEVED TO BE THE TOP INNOVATIONS NEEDED TO BUILD RESILIENT AND PROSPERING FOOD SYSTEMS IN EMERGING MARKETS OVER THE NEXT FIVE YEARS.

In the end, our experts believed that the 22 innovations highlighted below should be further investigated, developed, and championed *today* to build resilient and prospering food systems in emerging markets over the next five years.

AWARENESS & CAPACITY BUILDING	BUSINESS MODEL	DATA	ENERGY	LIFE SCIENCES & ENGINEERING	PACKAGING & PROCESSING	STORAGE & TRANSPORT
Behavioral economics for agriculture	Community/kickstarter-supported agriculture	Aflatoxin detection and reduction technologies	2nd generation biofuels from edible biomass	1-MCP technology	Automated sorting and packaging	Adaptable reefer containers
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		Millimeter wave sensors		Silk fibroin coating	Smart packaging	Retrofitted cold storage for smallholder value chains
		Mobile ethylene monitoring				Uber for produce delivery
		Open-source supply chain planning				Unmanned first-mile transport
		Open-source PHL mapping				
		Post-harvest data to improve access to finance				
		Smart sensors				

22 INVESTIBLE INNOVATIONS

Packaging & Processing
Cooperative packaging solutions
Modular factories
Near-farm mobile processing
Mobile packhouses & pre-cooling
Dehydration for smallholders

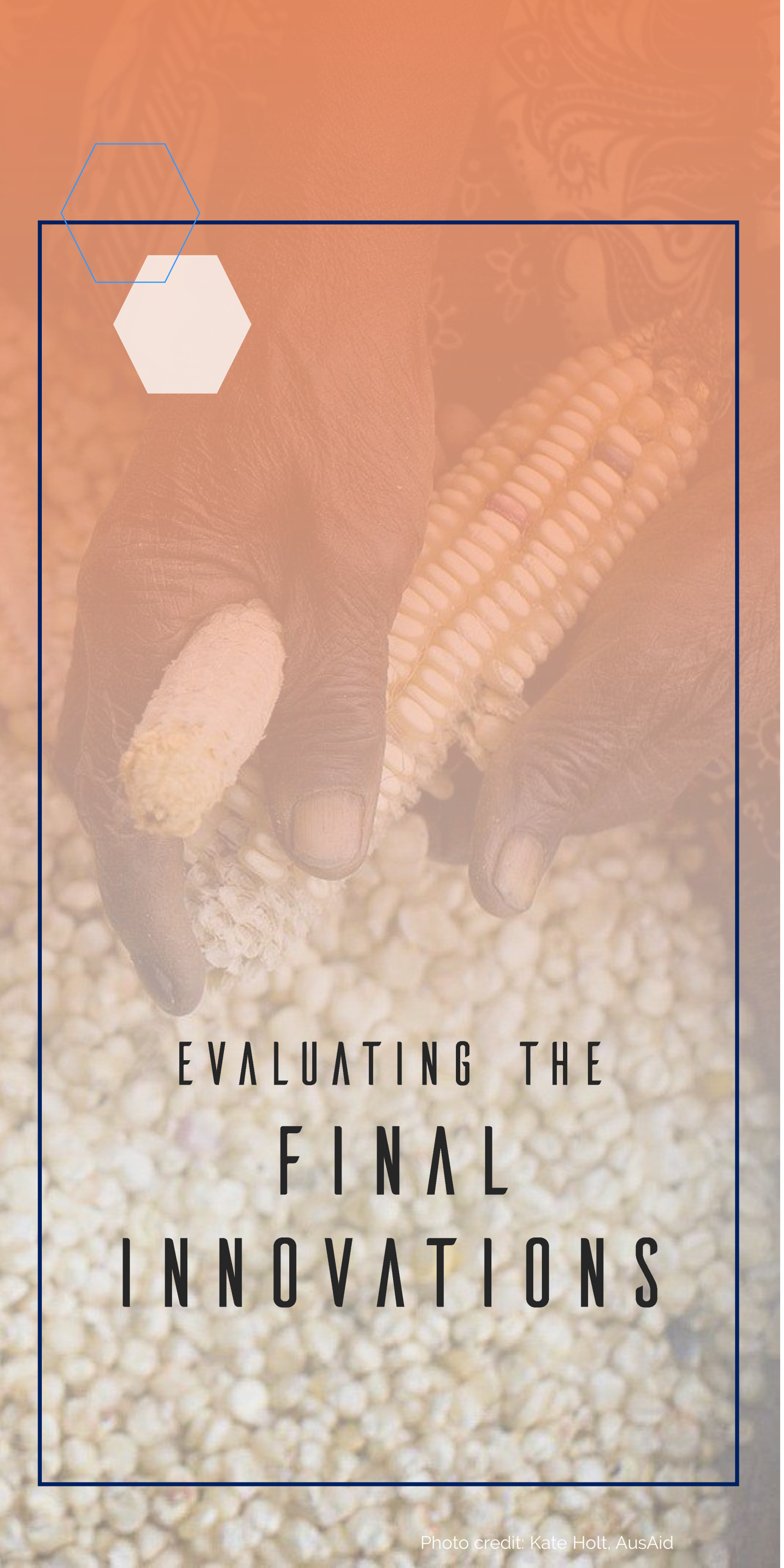
Energy
Battery technologies
On-farm solar preservation

Storage & Transport
Crates adapted for smallholder supply chains
Micro cold transport
Adaptable reefer containers
Cold chain as a service
Micro-warehousing and shipping
Evaporative cooling systems

Life Sciences
Biodegradable coatings
Microbes for agriculture

Data Collection & Monitoring
Early warning systems for plant disease and pests
Improved traceability technologies

Enabling Innovations
Specialty marketing for PHL-prone crops
Farm-to-fork virtual marketplace
First-loss capital guarantee for PHL reduction
Mobile education centers
Behavioral economics for agriculture



EVALUATING THE FINAL INNOVATIONS

Photo credit: Kate Holt, AusAid

Ours is not the first report to offer a list of priority innovations for agriculture, food systems, or emerging markets. But while profiling a list of innovations is one step, the crux of the effort is how to decide which ones to prioritize.

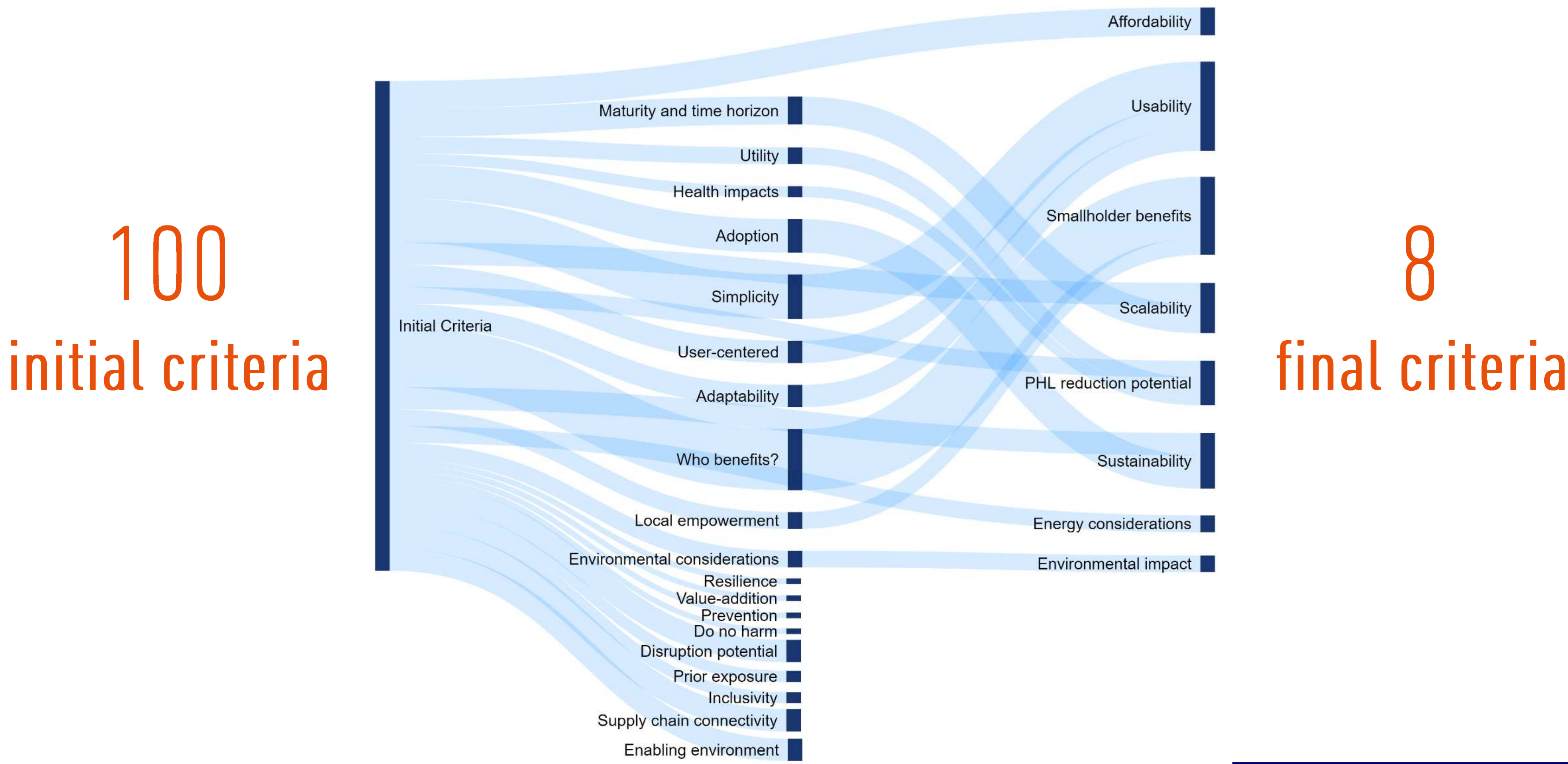
With the diverse range of perspectives represented in this study, we thought the opportunity was ripe to harness the power of collective intelligence for yet another objective—to converge upon a set of criteria most pertinent to evaluating the potential of an innovation to reduce post-harvest loss in smallholder value chains, prior to it being invested in or deployed.

In doing so we asked our panel to identify criteria that they use, either implicitly or explicitly, to evaluate innovations. The result was a bountiful 100 recommended metrics for evaluation. While many of these might be what you could call "the usual suspects", such as affordability and feasibility, others were innovative in their own right. To evaluate each innovations, our experts posed questions such as:

- Can the innovation be easily installed or repaired?
- Is the innovation simple enough to be tried with little investment?
- Can it be deployed at a scale that would accommodate short, high-volume crop harvests in several geographic regions?
- Will the innovation require continuous external support?
- Does it improve smallholder farmers' stability and resilience?
- Does the innovation present a new opportunity for local and national private sector growth in emerging markets?
- Does it drive development of an integrated, complete supply chain?
- Does the innovation prevent a problem before it occurs, or does it provide a remedy after the fact?

FROM 100 INITIAL CRITERIA TO 8 FINAL FILTERS FOR EVALUATING INNOVATIONS

With so many recommendations, it was imperative that the list be narrowed down. We had to evaluate the evaluation criteria. To do so we first asked whether a single criterion was objective, useful, and easy-to-apply. Second, we asked our experts to use their initial recommendations to build a suite of criteria that could serve as an innovation assessment tool of sorts, and be used to fully describe and evaluate the potential of an innovation before it elicits investment. As we narrowed down the criteria from 100 to 8, it became clear that many of the considerations our panel offered were not criteria but something else entirely—systems enablers or barriers—so we decided to consider them separately (defined on pg. 32).



TOP EVALUATION CRITERIA

Below you will find the final suite of evaluation criteria. We believe these eight criteria offer decision-makers an objective, intuitive, and comprehensive tool with which to evaluate the potential of an innovation to achieve desired impacts.

1 AFFORDABILITY

A cost that doesn't impose an unreasonable financial burden on the user. Affordability takes into consideration the financial resources needed to create, promote, and distribute the innovation; the financial resources needed to purchase, participate in, or use the innovation; non-monetary transaction costs; and, the user's income and competing uses of funds.

2 USABILITY

For the innovation to achieve impact, it needs to be adopted and used by the intended value chain actors. Usability therefore takes into account the innovation's simplicity and ease of use; the degree to which it was designed for end-users; and, the effectiveness of the innovation at accomplishing its intended task.

3 SMALLHOLDER BENEFITS

Benefits that can accrue to smallholder farmers are primarily noted in the form of income growth, but could take other forms, such as improved access to infrastructure, markets, information, and access to decision-makers, each of which could have spillover effects for rural communities.

4 SCALABILITY

An innovation's ability to achieve widespread adoption and positive impact. Unlike earlier stages of an innovation's lifecycle, an innovation faces new challenges when scaling, such as increased pressure to control costs, confront competition, exploit efficiencies, and manage a more diverse and sophisticated group of investors and stakeholders.

5 PHL REDUCTION POTENTIAL

The extent to which an innovation prevents or reduces the incidence and volume of post-harvest loss (PHL) in targeted value chain(s).

6 SUSTAINABILITY

The extent to which an innovation is accepted, adopted, maintains functionality, and continues to provide benefits over its projected lifespan and impact time-horizon, irrespective of external support.

7 ENERGY CONSIDERATIONS

The extent to which an innovation interacts with energy systems, including required inputs, potential outputs that could be used for other purposes, the recycling of otherwise wasted resources, and the creation of linkages with energy markets.

8 ENVIRONMENTAL IMPACT

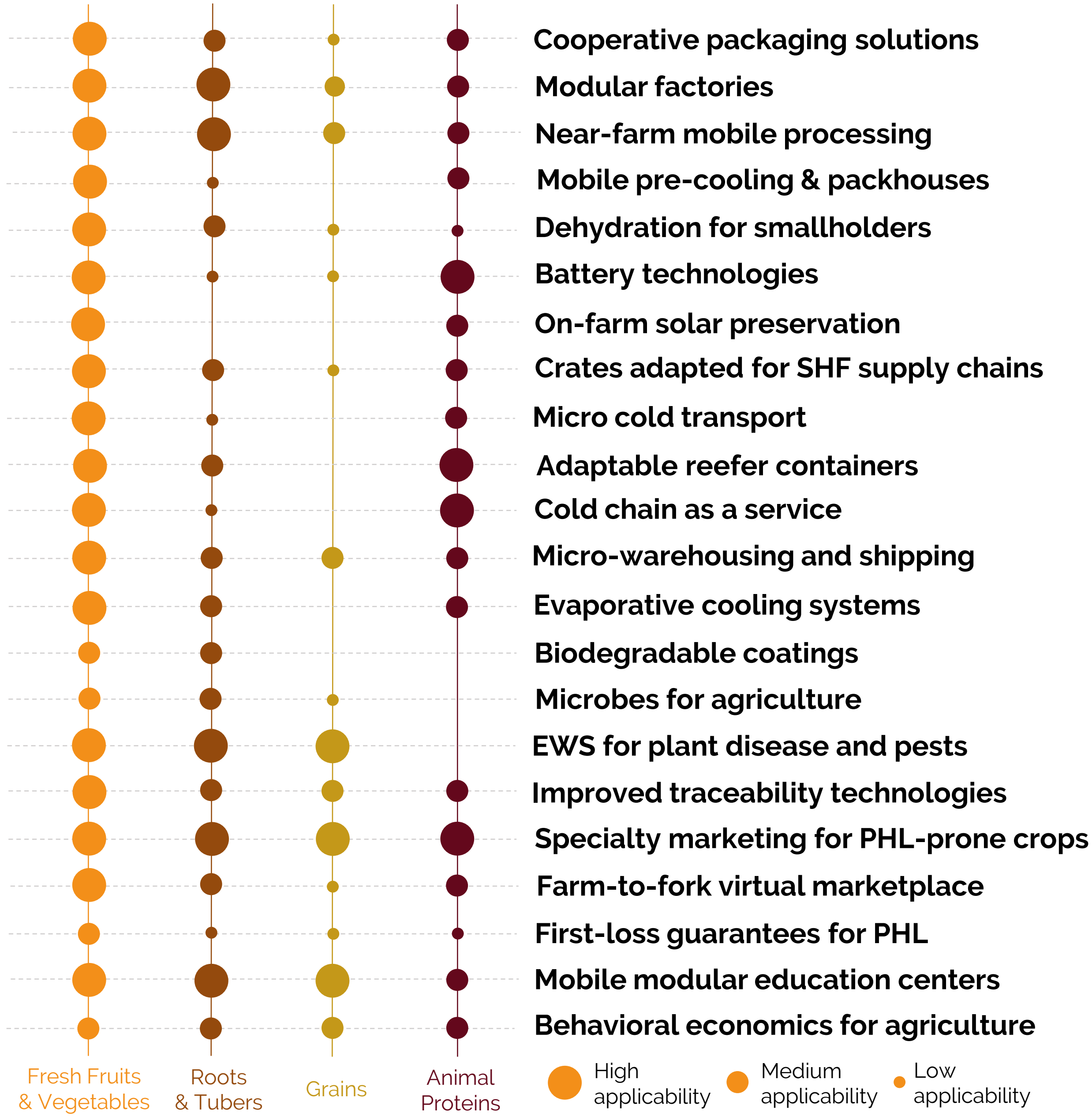
The potential impact—positive or negative–caused to the surrounding environment or natural resource base due to the use of an innovation over its projected lifespan. Typical agricultural impacts on the environment include soil erosion and pollution, land conversion, biodiversity loss, and water use and pollution.

THE DEGREE TO WHICH AN INNOVATION CAN BRING BENEFITS TO MULTIPLE CROP TYPES OFFERS AN INDICATION OF SCALABILITY

Finally, we recognize that the transformational potential of each innovation is tied to the context in which it's implemented. Thus, we asked our experts to give us a sense of potential applications of the top 22 innovations across geographic regions and product types: fresh fruits and vegetables, roots and tubers, grains (cereals and legumes), and animal proteins.

In the adjacent chart, we indicate whether an innovation has high, medium, or low applicability for each crop type. As noted prior, a vast majority of the innovations have potential in fresh fruit and vegetable (FFV) value chains, as this was our original priority for YieldWise, but we also wanted to explore cross-applicability in other key value chains.

Our panel also believed that, in general, an innovation with potential for FFVs in South Asia, say, would likely have utility in FFV value chains in East Asia and the Pacific, Latin America and the Caribbean, and Sub-Saharan African. That isn't to say that smallholder contexts are homogenous across geographies, but rather that it is more likely that a solution can be adapted to have applications across multiple geographies.



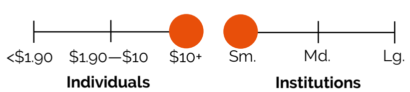
INNOVATION PROFILES

On the following pages you will find profiles of the top 22 investible innovations identified through this Innovation Scan. In these profiles we aim to present a clear and concise picture of the market opportunity, comparative advantage, and systemic enablers and barriers important to each innovation, as well as examples of nascent innovations or innovators filling the space. We also display an estimate of how each innovation performs on our criteria suite, as projected by our expert panel.

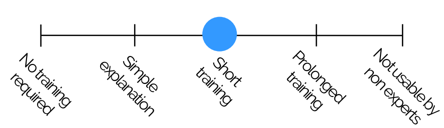
CRITERIA

Each innovation was evaluated against the final 8 criteria. Guidance on how we depicted the estimated score for each criterion follows.

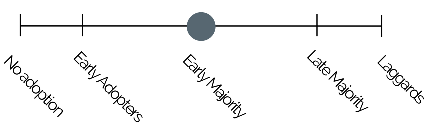
Affordability refers to the per day income range of *individuals* and *institutions* that would be able to afford the innovation. For those innovations that require ownership by one and use by another, it is often the case than an institution could afford to own the innovation, while an individual would rent it, participate in, or purchase services provided by the institution.



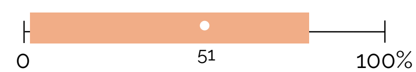
Usability refers to the amount of training or explanation required for the end-user to effectively utilize the innovation. Some innovations would require prolonged training for a skilled operator of the innovation, while in other instances only a simple explanation or no training would be required.



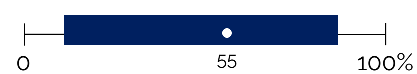
Scalability refers to the point in the diffusion process at which the innovation could be in 5 years with sufficient support.



Smallholder benefits refers to the percentage of the innovation's benefits that would likely accrue to smallholder farmers. The colored bar represents the range of responses, while the white dot represents the average across responses.



PHL reduction potential refers to the innovation's potential to reduce current levels of PHL [in crops and areas of the supply chain in which it is applied]. The colored bar represents the range of responses, while the white dot represents the average across responses. A 55% average implies that current PHL levels would be reduced by 55%.



Sustainability refers to the length of time that external support will be required before the innovation is accepted, adopted, maintains functionality, and provides benefits.

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy considerations refers to the type of energy access required to deploy and operate the innovation. Energy types include:

None required

Requires grid access

Requires non-renewables (e.g. fossil fuels)

Powered by renewables

Environmental impact refers to the innovation's likely impact, either positive or negative, on the environment. Negative impacts are generally a direct consequence (e.g., widespread use of reefers would result in transport runoff polluting water) while positive impacts are generally a result of a substitution effect (e.g., if microbes replace chemical pesticides this would reduce pollution). Environmental impacts include:

Soil erosion or pollution

Water usage or pollution

Greenhouse gas emissions

Land conversion & biodiversity

SYSTEMS ENABLERS & BARRIERS

In addition to criteria, we asked the expert panel about the systems factors that would be essential to the successful application of each innovation. Systems factors include aspects of the enabling environment as listed below. We present this information using a color coded scheme (shown at the bottom of this page) to indicate each factor's importance, along with a brief explanation.

Transport Infrastructure such as roads, bridges, ports, etc.

Energy Infrastructure availed through grid or off-grid sources

Human Resources of sufficient and trained individuals

R&D whether from universities, public, or private institutions

Governance such as regulations, policies, institutions, etc.

ICT Infrastructure such as cell towers, internet access, etc.

Private Sector Landscape such as ease of doing business, taxes, business norms, etc.

Collaboration between major stakeholder groups with an interest in use and impact

Sociocultural features like values, attitudes, and demography

PEACH: NEEDED BUT NOT ESSENTIAL

LIGHT BLUE: NOT NEEDED

NAVY BLUE: IMPOSSIBLE WITHOUT

Color Code for Systems Enablers

COOPERATIVE PACKAGING SOLUTIONS

Photo credit: Elaine Casap via Unsplash

OVERVIEW

Farmer cooperatives provide many vital services to smallholder farmers, such as aggregation and financing. But cooperatives do not often provide packaging services, which can be an important value-add to products, as they reduce the potential for crops to incur damage, generally extend shelf life, and command premiums at points of sale. Rather, packaging typically takes place on an industrial scale, with large buyers and processors closer to the point-of-sale reaping the benefits. Models in which goods are packaged closer to the farm would help reduce loss and generate additional income for smallholder farmers.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers
- Animal Proteins

WHAT: A cooperative-owned and managed packaging operation that provides simple packaging services, such as sorting, cleaning, wrapping, packing, and labeling, to a community of smallholder farmers. The cooperative would provide the labor, equipment, location, and knowledge to package foods in line with quality requirements and market demand, either for local sale consumption or for export.

EXAMPLES: The Cooperative Central Gaúcha Ltda is a Brazilian dairy cooperative created to integrate multiple agribusiness activities and generate competitive advantages for its member dairy producers. One of the ways it does this is through processing and packaging solutions focused on creating powdered milk products suitable for export markets.

OTHER CONSIDERATIONS: Different pricing structures could cater to different cooperatives, depending on the level of coherence and engagement across a cooperative's member base. For example, fee-based packaging services could be more appropriate for members who engage selectively or only during a single harvest. Alternatively, membership dues could be a more appropriate model for a cooperative with members who dedicate most of their resources to producing a single product, such as powdered milk.

SYSTEM ENABLERS & BARRIERS

ICT
ICT is not needed for this to be successful

ENERGY
Energy is needed to utilize packaging technology

PRIVATE SECTOR
Requires a market for packaged goods, including retailers and consumers

COLLABORATION
Depends on ability to align start-up costs with a strong cooperative manager

R&D
Not needed, as packaging solutions already exist

TRANSPORTATION
Packaging at the cooperative level reduces rural farmers' reliance on infrastructure

GOVERNANCE
Would benefit from packaged goods standards and food safety inspectors

HUMAN RESOURCES
Need to train cooperative members in food handling and quality control

SOCIOCULTURAL
Requires a market for packaged goods, either locally, domestically, or internationally

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ (Individuals)
Sm. | Md. | Lg. (Institutions)

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non-experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 — 63 — 100%

PHL Reduction Potential

0 — 64 — 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

Packaging processes could use energy from non-renewables or renewables.

Environmental Impacts

This innovation has no clear positive or negative environmental impacts.

MODULAR FACTORIES

Photo credit: Ben Barber, USAID via Pixnio

OVERVIEW

Building post-harvest infrastructure closer to farms is not a new idea, as farmers have long faced difficulty transporting their goods to distant warehouses and processing plants. But factories face challenges in rural areas: they require a steady, reliable stream of inputs to sustain operations –inputs smallholder farmers may not always be inclined or able to provide, given the nature of harvests. It may be that value chains in emerging and frontier markets would benefit from a different model. By allowing for the assembly and disassembly of small factories, a modular approach may offer a solution that provides lower-cost, on-demand storage, packaging, and processing services to rural areas during periods of need.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers

WHAT: A combination of prefabricated components that can be easily assembled into a functional factory. For post-harvest purposes this could include cold storage warehouses, automated packaging, and/or processing services.

EXAMPLES: UK-based InspiraFarms has commercialized several models designed to provide agribusinesses and farmers in Central and East Africa access to on- or near-farm pre-cooling, cold storage, and processing. Compared to traditional warehouses and plants, these modular factories are lower cost and can be assembled anywhere. InspiraFarms factories can be scaled to accommodate larger volumes by adding additional modules; solar panels are available for all models; and financing options are available for those who can pass a credit assessment.

OTHER CONSIDERATIONS: A business model that shares revenue equitably with smallholder producers would help ensure a supply of higher quality inputs. Factories of different sizes, particularly micro-factories, would likely be more affordable and accessible in low-income countries.

SYSTEM ENABLERS & BARRIERS

ICT
ICT infrastructure is not needed for the success of this innovation

ENERGY
Processing and cold storage technologies are typically energy intensive

PRIVATE SECTOR
Private investment would be needed to purchase and transport factories

COLLABORATION
Multi-stakeholder approach to benefit sharing could help to bring farmers into the model

R&D
There is an opportunity to develop a market for new tools and training

TRANSPORTATION
Transport infrastructure is needed to move factories and supply inputs

GOVERNANCE
Policies to increase private investment would help scale this innovation

HUMAN RESOURCES
Skilled workers are needed to set up and operate the factories

SOCIOCULTURAL
Local acceptance of both business model and processed goods is critical

CRITERIA

Affordability

<$1.90 $1.90—$10 $10+
Individuals
Sm. Md. Lg.
Institutions

Usability

No training required
Simple explanation
Short training
Prolonged training
Not usable by non-experts

Scalability

No Adoption
Early Adopters
Early Majority
Late Majority
Laggards

Smallholder Benefits

0 15 100%

PHL Reduction Potential

0 85 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

This innovation requires grid access, non-renewable sources, or renewable sources.

Environmental Impacts

This innovation could increase water use and pollution, and greenhouse gas emissions.

NEAR-FARM
MOBILE PROCESSING

Photo credit: Klima Schutz Proje

OVERVIEW

Processing transforms raw food ingredients into other forms, and in doing so can be used to extend shelf life, improve quality, and ease transportation challenges, especially in the notoriously thorny "first-mile" in emerging markets. For smallholders, access to processing can mean access to greater income and new markets. However, most processing units are industrial scale, which smallholders have difficulty accessing. The stringent quality, quantity, and timing requirements can be hard for a farmer to meet, especially when he or she has to make the arduous journey to a center of commerce using poorly maintained rural roads. But what if processing was brought to the farmer? Near-farm mobile processing seeks to do just that.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers

PROCESSING & PACKAGING

WHAT: A mobile processing unit that travels around rural areas offering fee-based processing services to farmers. Units could provide a range of processing services, including juicing, dehydration, canning, and freezing. The result would be a high-quality value-added product, such as jellies, pickles, juices, flours, or frozen fruits and vegetables, which could be sold in either local or distant markets.

EXAMPLES: In the US, Kentucky State University pioneered the first mobile processing unit for poultry in 2001. The unit is designed to provide services for slaughtering, cleaning, and packaging chickens, turkey, fish, and rabbits. More recently, in 2015, the University unveiled a mobile unit for processing fruits and vegetables. Equipped with a kitchen, evaporative dryer, and blast freezer, operators are capable of processing a wide range of horticulture crops into jams, jellies, pickles, salsa, and bags of frozen fruits and vegetables.

In 2012 the UK-based company Alvan Blanch created a mobile processing plant to reach African farmers. The mobile unit is equipped with juicing, evaporative cooling, and packaging technologies, helping farmers create juice, jam, or pastes out of their produce.

OTHER CONSIDERATIONS: A successful deployment of near-farm mobile processing units would serve multiple crop types and have the capacity to serve many farmers at once during seasonal gluts.

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non-experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 64 | 100%

PHL Reduction Potential

0 | 81 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

This innovation requires grid access and/or non-renewable sources.

Environmental Impacts

This innovation could increase water use, but reduce land conversion and associated losses to biodiversity.

SYSTEM ENABLERS & BARRIERS

ICT
ICT can be used to communicate with farmers and better schedule the unit's routes

ENERGY
Processing technology is typically energy intensive

PRIVATE SECTOR
A strong private sector would help the processed products reach export markets

COLLABORATION
The rate of adoption will be higher if the units are designed with end-users in mind

R&D
Processing technologies need to be adapted for near-farm applications

TRANSPORTATION
Success hinges on reliable transport infrastructure to reach farmers

GOVERNANCE
Regulatory regime needs to balance food safety and private sector competitiveness

HUMAN RESOURCES
The processing unit would need to be operated by a skilled service provider

SOCIOCULTURAL
The local market and food culture would need to support processed foods

MOBILE PRE-COOLING & PACKHOUSES

Photo credit: David Melchor Diaz

OVERVIEW

The way foods are stored can have a significant impact on their shelf life. For perishables, pre-cooling is used to reduce temperature, which helps reduce respiration rates and retain moisture without affecting the quality of the product. But on-farm pre-cooling technology is capital intensive and beyond the reach of most smallholders. This creates a viscous cycle in which smallholders cannot afford to invest in pre-cooling for their products, leading to lower quality and greater levels of loss, which in turn results in less income, thus impairing their ability to invest in pre-cooling storage technology. For smallholders who face challenges getting their produce to markets before spoilage or without damage, mobile aggregation and pre-cooling could provide access to these services without major cash outlays.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Animal Proteins

WHAT: A mobile unit that acts as a produce aggregator, offering farmers access to pre-cooling, transport, cold storage, and possibly even sale of crops to local or distant markets. Instead of having farmers bring their crops to a storage warehouse, a mobile unit would come to the farm, eliminating transportation barriers for rural, smallholder farmers.

EXAMPLES: In India, Pick 'N Serve is demonstrating the financial viability of a pre-cooling and packhouse model targeted at bananas. Traveling in a band of 4 trucks, Pick 'N Serve unloads a small cooling facility on-site , which altogether takes about 1 ½ hours. Once the bananas are cool they are transferred to a reefer storage container nearby, where they are held until being transported to local markets, large retailers, or ports for export.

The US-based company ColdPICK uses a similar model, bringing pre-cooling chambers to farms. There, harvested crops can be loaded into a chamber where it will be cooled and palletized—a form of standardized storage and transport in the US cold chain. Once palletized, the crops can be easily loaded onto trucks for transport to a local warehouse.

OTHER CONSIDERATIONS: Multiple mobile units will likely be needed to service an area at the same time to provide sufficient capacity to cool multiple farmers' crops during a harvest period. Additionally, this innovation could be seen as an interim solution that could be gradually phased out with the influx of more permanent, larger-scale solutions for farmers.

SYSTEM ENABLERS & BARRIERS

ICT
ICT can be used to communicate with farmers and better schedule the unit's route

ENERGY
Will require energy to cool, but this could be from a generator or renewable source

PRIVATE SECTOR
The model relies on complex logistics, which could benefit from existing knowledge

COLLABORATION
A PPP model could help this innovation be more affordable and adopted at scale

R&D
Packhouse and pre-cooling technology already exists, the challenge is scaling it down

TRANSPORTATION
Success hinges on reliable transport infrastructure to reach farmers

GOVERNANCE
Governments could use policies to increase access and adoption

HUMAN RESOURCES
Rural entrepreneurs would need to be recruited and trained

SOCIOCULTURAL
Farmers must be committed to delivering their crop on time and as promised

CRITERIA

Affordability
<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.
Individuals | Institutions

Usability
No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability
No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits
0 | 65 | 100%

PHL Reduction Potential
0 | 57 | 100%

Sustainability
This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy
This innovation either requires grid access or transportable non-renewable or renewable energy sources.

Environmental Impacts
This innovation could increase water use and greenhouse gas emissions, but reduce land conversion and associated losses to biodiversity.

DEHYDRATION FOR SMALLHOLDERS

Photo credit: Ultimate Super Foods

OVERVIEW

Drying is the oldest preservation technique used for agricultural products. It proves an excellent way to preserve nutritional content, even during months of storage. Smallholders generally dry their excess or damaged crops, as well as fish and meats, in small batches in the open sun on mats, rock surfaces, or mud roofs, which exposes the product to contaminants and can lead to uneven drying or scorching. But opportunities exist to introduce dehydration technologies and processes that improve the efficiency and the output quality of smallholder farmers' drying efforts, without the need for large capital outlays.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables

WHAT: Dehydration technologies apply a reliable and concentrated heat source to horticulture crops, fish, and meat to reduce moisture content and produce a shelf-stable, nutritious dried product. Dehydration technologies vary from simple to sophisticated; from sun- to solar- to mechanized-drying. Small-scale solar dryers have been adapted to numerous local contexts by local researchers and innovators. Whereas emerging advanced methods, which include modified atmosphere, microwave, and osmotic drying, have not yet been adapted. There is an opportunity to imagine how both solar dryers and more advanced technologies could be adapted to fit the scale, resource requirements, and needs of farmers in low-income countries.

EXAMPLES: India-based Project SCD developed the Small-Scale Solar Conduction Dryer (SCD), the world's first solar dryer that uses all modes of heat transfer: conduction, convection, and radiation. It claims the same efficiency as standard solar dryers, but at 50% the cost, and maintains 45% more nutrients. Project SCD's design was the 2013 Dell Social Innovation Award Grand Prize winner. Project SCD also works to establish the supply chain for dried tomatoes, working with farmer groups, processing companies, and financers.

OTHER CONSIDERATIONS: Moving up the spectrum toward higher-tech solutions means more controlled drying conditions, and, thus, higher quality products, but also higher capital expenditure requirements. Depending on the season and geography, some methods may not be applicable to certain contexts.

SYSTEM ENABLERS & BARRIERS

ICT
ICT is not needed for this to be successful

ENERGY
Need for energy infrastructure is dependent on drying method.

PRIVATE SECTOR
There is a need to develop a local or export market for the dried products

COLLABORATION
Would be useful to work with local farmers to select the most appropriate technology

R&D
There are many models available but must determine which best fits the local context

TRANSPORTATION
Would be needed if dehydration is taking place at an aggregation center

GOVERNANCE
Product safety regulations would be needed for more advanced technologies

HUMAN RESOURCES
More complex technologies would benefit from trainers on new methods of dehydration

SOCIOCULTURAL
Requires consumer demand for and acceptance of dehydrated products

CRITERIA

Affordability
<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.
Individuals | Institutions

Usability
No training required | Simple explanation | Short training | Prolonged training | Not usable by non-experts

Scalability
No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits
0 | 61 | 100%

PHL Reduction Potential
0 | 74 | 100%

Sustainability
This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy
Depending on the method, dehydration could use a variety of energy sources.

Environmental Impacts
By reducing on-farm PHL, it would reduce the need for land conversion.

Photo credit: MK2010 via Wikimedia

BATTERY TECHNOLOGIES

OVERVIEW

In low-income countries, unreliable energy access is an impediment to a modern agricultural sector. The development of the requisite electric grid would require massive infrastructure investment — likely beyond the immediate reach of many countries. Renewable energy offers one solution, but its production often varies with supply, such as solar generation spiking and plummeting with the presence of sunlight. If renewable energy is going to support energy-intensive operations such as cold storage and processing in remote, off-grid areas, energy will need to be reliably available. Advances in energy storage technologies, such as batteries that store sufficient solar energy to power on-farm cold storage units, could bring on-demand energy access to rural areas.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Animal Proteins

WHAT: Battery technologies that are able to hold a large enough charge, for long enough, and at low enough cost to support farmers and value chain actors in smallholder food systems. Batteries would need to be connected to a generation technology, such as solar panels, which could be offered as a package deal along with installation.

EXAMPLES: Tesla is the most well known innovator in battery technologies. The company's Powerwall, which is intended to be paired with off-grid solar generation, is capable of storing 14 kilowatt hours (kWh) of energy for times when solar energy is not available. By contrast, a typical refrigerator uses about 5 kWh per day, while an energy efficient model can use as little as 1.5 kWh.

Aquion Energy is another company researching next generation battery technology, with a focus on developing sodium-ion batteries to support energy storage for small businesses and homes. Their goal is to develop the cleanest, safest, lowest cost-per-kWh battery technology in the world, and have recently shifted their focus from the US to China and other emerging markets.

OTHER CONSIDERATIONS: The success of this innovation has implications far beyond PHL reduction. However, one key consideration for introducing battery technology to smallholder food systems is finding the right balance between the level of charge needed and the cost at which it can be made available.

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 57 | 100%

PHL Reduction Potential

0 | 57 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

This innovation would work best being paired with a renewable source of energy.

Environmental Impacts

This innovation could reduce greenhouse gas emissions.

SYSTEM ENABLERS & BARRIERS

ICT
ICT infrastructure is not needed for the success of this innovation

ENERGY
This innovation only works if paired with an energy source

PRIVATE SECTOR
A strong private sector can support adoption by offering financing packages

COLLABORATION
Coordination between solar and battery providers can help increase uptake of both

R&D
Technical innovations in batteries are needed to bring costs down

TRANSPORTATION
PHL reduction potential is dependent on a connected supply chain

GOVERNANCE
Adoption could be supported by policies to develop a network of charging stations

HUMAN RESOURCES
Installation and maintenance could increase employment opportunities in rural areas

SOCIOCULTURAL
Sociocultural considerations have not been identified

ON-FARM SOLAR PRESERVATION

Photo credit: Biel Morro via Unsplash

OVERVIEW

Reducing PHL begins on the farm; the period immediately after harvest is critical for preserving the quality of crops, especially fresh fruits and vegetables. However, many of the best solutions—pre-cooling and cold storage—require energy access, which is severely lacking in rural areas across the world. But perhaps not for long. Advances in solar technologies, such as crystalline silicone and perovskites, have prompted costs to drop precipitously in recent years. As costs continue to fall there exists a significant opportunity to expand the benefits of solar energy to smallholder agricultural systems. Farmers could then adopt better on-farm cooling, storage, and processing practices, thus increasing shelf life, reducing loss, and generating more income.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Animal Proteins

WHAT: A crop storage technology, such as pre-cooling, cold storage, or evaporative cooling, that generates the energy it needs through an attached advanced solar technology. The size of the solar panel would depend on the type of storage the technology provides, with more energy intensive storage options, like cold storage, requiring more energy generation capacity.

EXAMPLES: Wakati is a stand-alone storage unit that consists of three pieces: a tent, a small solar panel, and a 'climate unit' that requires 1 liter of water per week. Together these elements create a microclimate inside the tent that can be used to store 200-1000 kg of fresh fruits and vegetables. While it does not cool the produce, it does help to reduce spoilage rates by maintaining humidity, controlling the release of ripening hormones like ethylene, and sterilizing mold growth. Wakati has recently made their technology open-source to expand the reach of PHL-reducing on-farm storage solutions.

OTHER CONSIDERATIONS: A successful application of this innovation would be low-cost and not dependent on infrastructure. While the micro-climate solution developed by Wakati is one approach, other solutions could use solar power to enable on-farm pre-cooling or cold storage.

SYSTEM ENABLERS & BARRIERS

ICT
ICT infrastructure is not needed for the success of this innovation

ENERGY
This innovation is an energy solution, further energy infrastructure is not needed

PRIVATE SECTOR
A strong private sector could support adoption by offering financing packages

COLLABORATION
A multi-stakeholder approach could help improve technology adoption by farmers

R&D
Technical innovations in solar energy are needed to further reduce costs

TRANSPORTATION
PHL reduction potential is dependent on a connected supply chain

GOVERNANCE
Trade policies could help increase imports of solar panels

HUMAN RESOURCES
Installation, use, and maintenance require skilled workers and/or trained farmers

SOCIOCULTURAL
Sociocultural considerations have not been identified

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 64 | 100%

PHL Reduction Potential

0 | 57 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

This innovation could generate surplus energy for other domestic or commercial uses.

Environmental Impacts

This innovation could reduce greenhouse gas emissions as well as land conversion and associated losses to biodiversity.

Photo credit: Clem Onojeghuo

CRATES ADAPTED FOR SMALLHOLDER SUPPLY CHAINS

OVERVIEW

Great care is needed to ensure that fragile fruits and vegetables aren't damaged during handling and transport. In many emerging markets, the use of traditional storage, such as baskets atop donkeys or bicycles, often leads to smashed produce, especially on rough rural roads. Sturdier Reusable Plastic Crates (RPCs) are a simple solution for improving handling and transport, but adoption has been limited. One reason is because RPC designs are optimized for truck transport, which is not the primary mode of transport for smallholder farmers. Crates better adapted to smallholder value chains could be optimized to fit both trucks and the smaller modes of transport used by farmers, such as bicycles, motorbikes, carts, and pack animals.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers
- Animal Proteins

WHAT: A reusable crate that is designed to fit multiple modes of transport, servicing both agribusinesses that rely on trucks and smallholder farmers who often use bicycles, motorbikes, carts, or pack animals to reach an aggregation point or local market. An adaptable design could allow for the crate to be folded or unfolded to conform to different specifications preferred by different users. This would allow for a crate to fit both local and global transportation systems (e.g. standardized crates).

EXAMPLES: In East Africa, the company Mazzi pioneered a plastic milk jug that is optimized for smallholders. The jugs include a leak-proof lid and are designed to be stacked prior to being loaded into a basket for transport by bicycle.

While Mazzi is focused on first-mile transport storage, the India-based company ColdEx has developed a last-mile solution that performs in a similar vein: a refrigerated box that is optimized for delivery via scooter transport—the most common method of delivery for residents of Indian cities.

OTHER CONSIDERATIONS: This innovation could allow for almost all of its benefits to be generated in, by, and for a local community, including crate design, manufacturing, and sale. This could create new opportunities for individuals employed in traditional industries, such as basket weaving.

SYSTEM ENABLERS & BARRIERS

ICT
This innovation does not rely on ICT infrastructure

ENERGY
This innovation does not directly require energy infrastructure

PRIVATE SECTOR
Crate development could be led by the local private sector

COLLABORATION
Crates should be designed in partnership with the communities who will use them

R&D
Research into new ways to adapt crates could increase their usefulness

TRANSPORTATION
These crates will be adapted to local transport infrastructure

GOVERNANCE
Government support could increase initial adoption rates

HUMAN RESOURCES
Locally skilled workers could support design and manufacturing

SOCIOCULTURAL
Bias toward the cheapest option might deter adoption if benefits are not demonstrated

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 49 | 100%

PHL Reduction Potential

0 | 52 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

No energy is needed for this innovation to be used by the target population.

Environmental Impacts

The disposal of crates could lead to pollution; if possible crates should be made of bioplastics or biodegradable plastics.

MICRO COLD TRANSPORT

Photo credit: Rogerio Bromfman

OVERVIEW

A functioning agricultural cold chain depends on numerous supply chain actors to connect and transfer their perishable products, all while maintaining those products at stable temperatures. In high-income countries, refrigerated truck transport is the most common means of transporting perishable products over land. In low-income countries, cold chain transport often doesn't serve agricultural value chain actors in the first mile—from the farm to the first aggregation point or local market. Smallholder farmers are often unable to take advantage of cold transport services because of poor rural infrastructure, small loads, and/or price barriers. Micro cold transport could deliver a cold chain solution that is better adapted to smallholder value chains in low-income countries.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Animal Proteins

STORAGE & TRANSPORT

WHAT: A reliable, low-energy, durable micro cold transport unit that is adapted for transporting smaller harvests of perishable crops over rough rural terrain, optimizing it for smallholder value chains in low-income countries. Ideally, the micro cold transport unit would be designed to fit common forms of first-mile transportation, such as bicycles and motorbikes, and be powered by renewable energy.

EXAMPLES: In Uganda, where bicycles and motorbikes are commonly used to get around, Fruti-Cycle is pioneering a biogas-powered tricycle cold storage unit with a capacity of 300 kg. The combination of biogas power and pedaling keeps products in cold storage for up to 100 km. The unit, with a $50,000 initial cost, may be more appealing to a local entrepreneur, but it is projected to provide a 15.6% return on investment in the second year.

OTHER CONSIDERATIONS: While diesel is one option for powering a micro cold transport unit, it would ideally be powered by renewable energy, which could dually charge on-farm cooling as well as the mobile cold transport unit. Another key consideration is the cost to manufacture and distribute the unit, which directly impacts which business model would work best. Depending on price, smallholder farmers, farmer cooperatives, or local entrepreneurs could own the micro cold transport unit.

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non-experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 45 | 100%

PHL Reduction Potential

0 | 35 | 100%

Sustainability

This innovation requires **No** external support to sustain impact over the long-term.

Energy

This innovation could use energy from non-renewables, like diesel, or renewables, like biofuels, to power the vehicle and storage unit.

Environmental Impacts

Environmental impacts of this innovation would depend on the fuel source used.

SYSTEM ENABLERS & BARRIERS

ICT
ICT is not needed for this to be successful

ENERGY
A renewable or non-renewable energy source is needed to power the cold transport unit

PRIVATE SECTOR
This innovation is an entirely private sector endeavor

COLLABORATION
Coordination needed to create a network of owners, operators, and users

R&D
Needed to create reliable, low-energy, durable micro cold transport units

TRANSPORTATION
Its comparative advantage is its ability to use current transport infrastructure

GOVERNANCE
No governance concerns for this innovation

HUMAN RESOURCES
Semi-skilled workers needed to operate and repair the cold transport units

SOCIOCULTURAL
This innovation provides a youth employment opportunity

ADAPTABLE REEFER CONTAINERS

Photo credit: David Melchor Diaz

OVERVIEW

Reefer containers, or refrigerated intermodal transport units, are the most common means of shipping perishable products in the world. Their widespread use contributes to the seamlessness of the global shipping industry. However, the use of reefers for agricultural goods in emerging markets remains spotty. In India, for example, only 4 million metric tonnes (MT) of perishable produce, of ~100 million MT produced annually, is transported via reefer, leading to loss of over 40%. For transporters, the reefers' large volume is often at odds with the small volumes produced by smallholder farmers or purchased by small retailers and agribusinesses. Distributors will thus make partially full shipments or transport multiple crops in a single container, most stored at suboptimal temperatures.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers
- Animal Proteins

WHAT: A compartmentalized reefer container that allows for multiple crop types to be stored and transported in their optimal environments, and brings flexible cold chain services to a wider market. Depending on the load, the compartments may be adapted by size, environmental condition, and other storage requirements.

EXAMPLE: India-based ColdEx has seen commercial success with multi-temperature trucks. The trucks consist of two reefer units and three doors which, together, create a flexible layout that can be arranged into a number of compartment configurations. The driver can then specify temperatures for each area, including refrigerated, frozen, and ambient.

OTHER CONSIDERATIONS: To generate a return on investment for the reefer containers, farmers and aggregators must be able to afford the service, which in turn depends on the amount of usage and how often efficiencies of scale can be achieved in a given geography. Further, roads infrastructure is a requirement for reefer trucks to reach aggregation points by land. Alternatively, in some instances either rail or port infrastructure is needed for reefers to access other markets.

SYSTEM ENABLERS & BARRIERS

ICT
ICT is not needed for this to be successful

ENERGY
Fueling stations are needed for trucks

PRIVATE SECTOR
This service would likely be provided by the private sector

COLLABORATION
Coordinating multiple pickups and aggregation would improve efficiency

R&D
Technology exists but must be adapted to new contexts

TRANSPORTATION
Rural roads are essential to reach intended users as are ships, ports, and railroads

GOVERNANCE
Local regulations could inhibit or enhance technology uptake

HUMAN RESOURCES
Skilled operators would be needed to prevent cross-contamination of foods

SOCIOCULTURAL
Farmers must trust new companies that serve their market

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non-experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 58 | 100%

PHL Reduction Potential

0 | 58 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

This innovation requires gas or diesel to transport and refrigerate.

Environmental Impacts

Could increase GHG emissions for transport, water use for cooling, and water and soil pollution via increased runoff.

COLD CHAIN AS A SERVICE

Photo credit: Leandro Saumuel Zeller

OVERVIEW

Keeping crops cool is the most effective way to reduce spoilage for fresh fruits and vegetables. But cold chain, which includes refrigerated transport and storage systems, has proven difficult to implement and scale in many low-income countries. Access to stable energy supply, coupled with the high capital requirements of industrial scale cold storage, have been two of the main barriers. Even where cold chain is available, it is often out of reach for smallholders, as its design more naturally caters to large-volume producers. One way to overcome this accessibility challenge would be to offer cold storage and transport as a service to the vast market of smallholders.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Animal Proteins

WHAT: A cold chain service provider that serves the market of smallholder farmers in low-income countries, offering a range of cold chain services, such as pre-cooling, refrigerated transport, and refrigerated storage. Service providers could use a range of business models, such as subscription or pay-as-you-go, depending on customer demand.

EXAMPLES: Coldhubs is a Nigeria-based company that utilizes solar panels to provide off-grid cold storage to farmers using a pay-as-you-store business model. The farmers are provided with reusable plastic crates into which they can transfer their produce, and are charged a flat daily rate per crate.

In South India, LEAF provides integrated and customized cold chain solutions by combining cold chain as a service with an aggregation business model. They integrate logistics, storage, and processing services to bring goods from farm to market, uniquely utilizing a combination of GPS and logistics software to optimize truck routes for efficiency.

OTHER CONSIDERATIONS: This innovation will be most successful when supported by logistics that improve the financial return of the business model, and will achieve the greatest impact when it is able to cater to a variety of volumes, particularly smaller volumes, and made affordable for smallholders. Additionally, service providers must consider the reliability and availability of electricity or renewable energy to power cold chain technologies available in specific contexts.

SYSTEM ENABLERS & BARRIERS

ICT
ICT can be used to communicate with farmers and provide on-demand cold chain services

ENERGY
Cold chain requires energy which could come from a variety of sources

PRIVATE SECTOR
Market conditions need to render this financially viable for firms and farmers

COLLABORATION
Partnership with local authorities would help to improve usage

R&D
Innovation would benefit from R&D to scale down cold chain and provide at lower cost

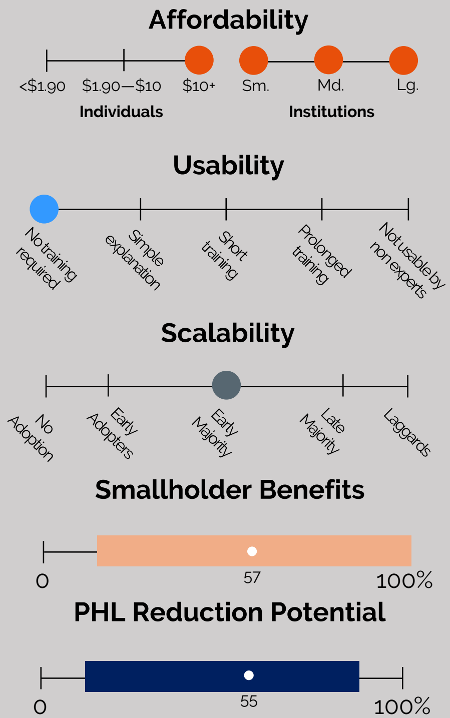
TRANSPORTATION
Being able to bring the service to farmers is critical for impact

GOVERNANCE
Governments could support adoption by helping to create a favorable business environment

HUMAN RESOURCES
The service provider would need to be a skilled worker

SOCIOCULTURAL
This innovation would need to fit with local cultural norms around food storage

CRITERIA



Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

This innovation requires grid access or transportable non-renewable or renewable energy sources.

Environmental Impacts

This innovation could increase water use and greenhouse gas emissions.

MICRO-WAREHOUSING & SHIPPING

Photo credit: Igor Ovsyannykov

OVERVIEW

If one were to name the seven wonders of globalization, the modern global shipping and logistics industry might be among them. Facilitating the movement of vast quantities of goods at record speeds, it plays a key role in linking producers to markets. But it is largely inaccessible to actors in smallholder value chains, who face infrastructure and financial constraints that prohibit access to warehousing services. Smallholders also face additional entry-barriers, like volume, quality, and standardization requirements. Right-sizing storage and shipping options for smallholder value chains represents a significant opportunity for both agribusinesses and farmers.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Grains
- Roots & Tubers
- Animal Proteins

WHAT: Micro-scale storage and shipping options made available to smallholders at a reasonable cost. By engaging smallholder farmers directly, micro-warehousing and shipping providers would also provide farmers with the logistics solutions needed to help smallholders access larger-scale processors, distributors, and retailers.

EXAMPLES: In India, Ergos works with farmers at the village level to build micro-warehouses for grain storage. They charge farmers a manageable USD 0.10-0.15 per 100 kg of grain, per month of storage.

Another Indian company, PLUSS, designed a shipping solution for pharmaceuticals that can be assembled in 5 minutes and provides temperature-controlled storage for up to 96 hours. These types of solutions could be adapted to agricultural supply chains, which would improve storage and shipping options for smallholder farmers.

OTHER CONSIDERATIONS: Designs will need to be made specifically for different regions. Irrespective of geography, poorly designed solutions could lead to cross-contamination and foodborne illnesses for end-consumers.

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 70 | 100%

PHL Reduction Potential

0 | 90 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

This innovation requires grid access, or non-renewable or renewable energy sources.

Environmental Impacts

This innovation could increase greenhouse gas emissions.

SYSTEM ENABLERS & BARRIERS

ICT
ICT can be used to communicate shipping information with farmers

ENERGY
Some variations of this innovation require energy infrastructure

PRIVATE SECTOR
Needs supporting market conditions and infrastructure to be financially viable

COLLABORATION
Needs a plan or strategy to engage farmer groups

R&D
R&D would help to right-size the storage and shipping solutions

TRANSPORTATION
Shipping also requires inland transport infrastructure

GOVERNANCE
Governments could incentivize actors in the shipping industry

HUMAN RESOURCES
Skilled operators of storage units and vehicles are required

SOCIOCULTURAL
This innovation would need to fit cultural norms around food storage

EVAPORATIVE COOLING SYSTEMS

Photo credit: Devin Rajaram

OVERVIEW

Inadequate access to energy resources is a major barrier for farmers adopting better storage practices. While expanding energy access is imperative for opening up access to new technologies and process for smallholder farmers, it is not a given that, of the options to use their limited energy resources on, a farmer would prioritize crop storage. It follows then, that a variety of solutions, including some that do not require energy, are needed to fully address the post harvest loss challenge. This is where evaporative cooling offers a compelling solution. By utilizing the same principles as perspiration, evaporative cooling is capable of storing crops at lower-temperatures, without electricity, and at a lower-cost.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers
- Animal Proteins

WHAT: Crop storage solutions that use the evaporation of water to cool the storage container and preserve crops. Evaporation occurs in the container when air, which is not saturated with water vapor, passes over a wet surface, helping to remove heat in the form of energy transfer.

EXAMPLES: Evaptainer emerged from a research project at the Massachusetts Institute of Technology (MIT) that challenged students to create something that could help improve the lives of 1 billion people. The students' technology was the EV-8 — a 60 liter cooling container that activates a 15-20 ˚C cooling effect when the user fills the internal reservoir with water.

In India, the Zero Energy Cooling Chamber (ZECC) has been used to store tomatoes, potatoes, leafy greens, bananas, mushrooms, and other crops with great success by individual farmers. The chamber can be made of local materials—bricks and sand—for roughly USD 60. It requires water twice a day to produce a cooling effect of 10-15 ˚C.

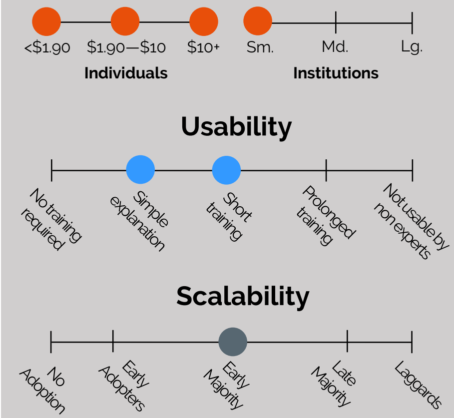
OTHER CONSIDERATIONS: An application of this innovation would be operational in climates with varying levels of humidity, bring benefits directly to farmers, and reduce the water input requirements to the maximum extent possible.

CRITERIA

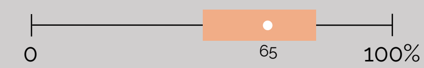
Affordability

Usability

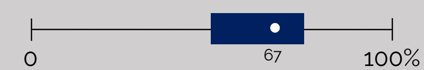
Scalability



Smallholder Benefits



PHL Reduction Potential



Sustainability

This innovation require as little as **No** external support, and as much as **1 – 5 years** to sustain impact over the long-term.

Energy

This innovation does not require electricity.

Environmental Impacts

This innovation could reduce soil pollution, greenhouse gas emissions, and land conversion and associated losses to biodiversity.

SYSTEM ENABLERS & BARRIERS

ICT
This innovation does not require ICT infrastructure

ENERGY
This innovation does not require energy

PRIVATE SECTOR
This innovation can be successful independent of the private sector

COLLABORATION
The more the solutions are developed with end-users the higher potential uptake

R&D
Innovation adoption could be supported by market research to target priority areas/users

TRANSPORTATION
Ultimate PHL reduction potential depends on what happens after on-farm storage

GOVERNANCE
Water regulations and governance would be useful to improve availability

HUMAN RESOURCES
Larger systems would require some training to build/use

SOCIOCULTURAL
This innovation would likely fit cultural norms around food storage

Photo credit: Lior Mazliah via Unsplash

BIODEGRADABLE COATINGS

OVERVIEW

While cold storage and transport is currently acknowledged as the gold standard for preserving fresh fruits and vegetables, it may be that other approaches are more suitable in contexts where introducing cold chain is far from feasible. Coatings are an affordable technology that have been used for a long time in horticultural supply chains to reduce the rate of decomposition and extend shelf life. If these technologies can be made available to smallholders, they could present a manageable and low-cost way to reduce PHL.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers

WHAT: A water-, oil-, or wax-based solution applied to the surface of crops that effectively slows the rate of decomposition and maintains nutritional integrity.

EXAMPLES: Apeel Sciences is a California-based company that specializes in developing crop protecting technologies using agricultural by-products and waste. Their Edipeel technology is an invisible, tasteless, edible, and all-natural coating that can be applied to the surface of fresh fruits and vegetables to extend shelf life. Apeel offers packaged formulas specific to a particular crop, including bananas, tomatoes, and mangoes.

Pace International has developed a variety of post-harvest solutions, such as BioSpectra 100 SC, a natural fungicide used to deter and slow the rate of growth of a broad spectrum of post-harvest diseases common in citrus fruits.

OTHER CONSIDERATIONS: While coatings are generally simple to use, successful applications must be accompanied by good food safety and hygiene practices, otherwise the risk of cross contamination is very high, with one product being able to infect the whole load. As many coatings are applied using a water-based solution, this requires clean, potable water for both washing and application.

SYSTEM ENABLERS & BARRIERS

ICT
Not needed for this innovation

ENERGY
Not needed for this innovation

PRIVATE SECTOR
Larger producers would be more likely to invest which could help to increase adoption

COLLABORATION
Support to resolve food safety challenges could increase adoption

R&D
Current technology exists but needs to be scaled to smallholder food systems

TRANSPORTATION
Not needed outside of existing supply chain infrastructure

GOVERNANCE
Food safety standards are needed to mitigate risk of cross contamination

HUMAN RESOURCES
Need trainers and distributors of coating technologies

SOCIOCULTURAL
Farmers and local consumers may be averse to coating food in a foreign substance

CRITERIA

Affordability
<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.
Individuals | Institutions

Usability
No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability
No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

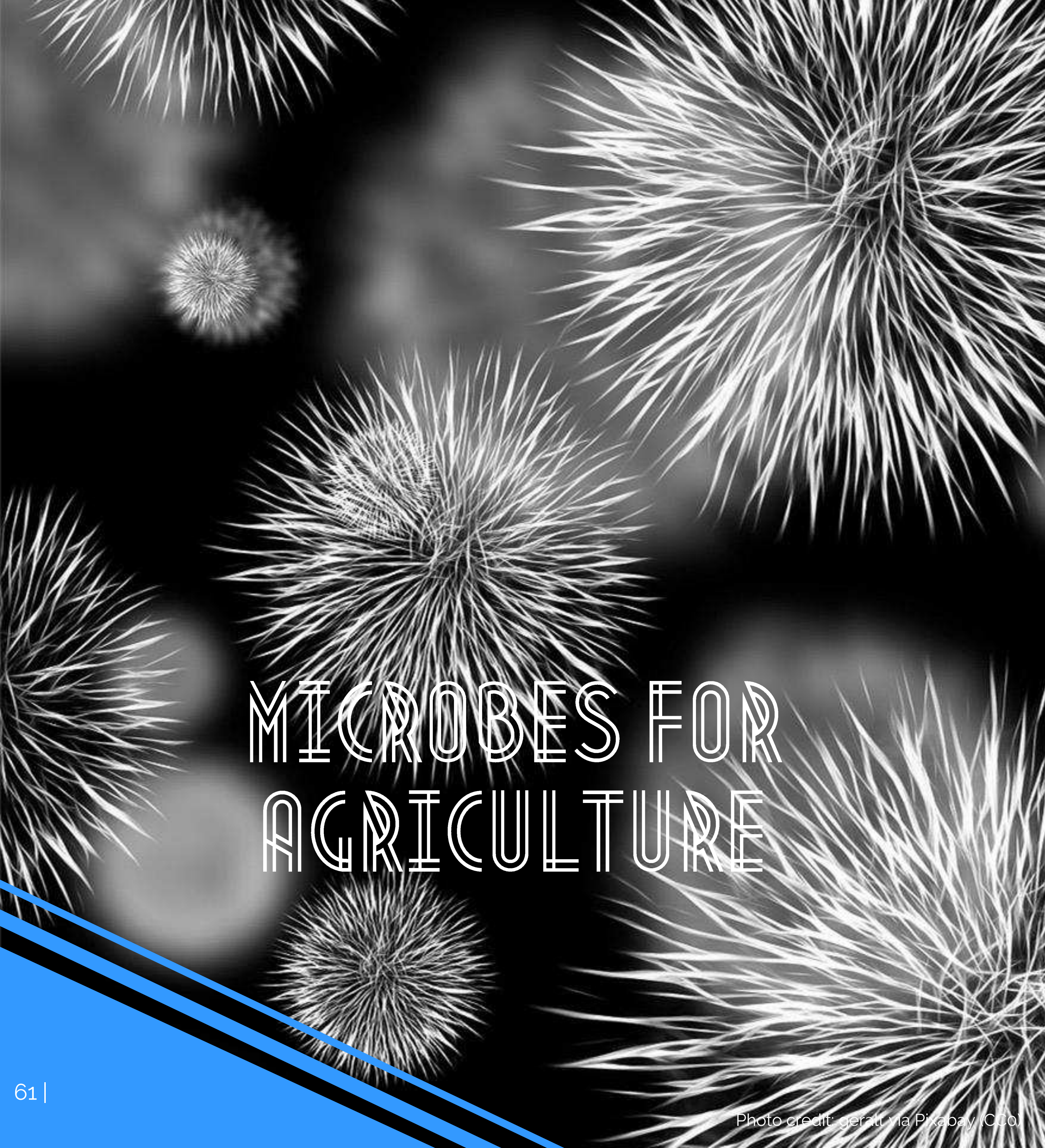
Smallholder Benefits
0 | 32 | 100%

PHL Reduction Potential
0 | 51 | 100%

Sustainability
This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy
This innovation would not require energy.

Environmental Impacts
Water use would increase due to the need to wash produce, and further if the solution were water-based.



MICROBES FOR AGRICULTURE

Photo credit: geralt via Pixabay (CC0)

OVERVIEW

With every new piece of research into microbes (a catch-all term for any micro-organism, such as bacteria, fungi, and amoebas), science reveals more about how these unseen organisms shape our world—from the inside of our bodies to the surface of our foods. If we can harness the microbiome's power, the possibilities are limitless; if there is another Green Revolution for agriculture, microbes will be a part of it. Research already shows how microbes can be used to increase the uptake of nutrients from soil to stimulate growth, thus reducing the need for chemical fertilizers. As research continues, post-harvest applications such as easy-to-apply, water-soluble microbial solutions, could be developed to support food safety and extend shelf life across the supply chain.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers

WHAT: An application of micro-organisms to crops with the purpose of reducing PHL. While the goal of the application is to reduce PHL, the microbes could be distributed much earlier in pre-harvest processes, including on-seed, to later prevent spoilage and extend shelf life from farm to market.

EXAMPLES: In the last 5 years, entrepreneurs have developed numerous microbial applications for *pre-harvest* agriculture. US-based Marrone Bio Innovations, for example, sells microbial insecticides and biofungicides, the latter of which work with a plant's natural defense system to help suppress disease pathogens. Other companies, such as NewLeaf Symbiotics and Indigo Agriculture, are working to identify microbes that act like fertilizers to stimulate plant growth. Still other companies, like Monsanto, Bayer, and DuPont are testing thousands of bacteria, isolated from soil from around the world, to find additional, new uses in agriculture. People are also finding *post-harvest* applications for microbes. VRM Biologik is a Singapore-based company experimenting with how to use microbes to turn unused food into reusable materials that then can be reapplied to crops to promote growth. In the future, microbial sprays and coatings could be used for other post-harvest applications as well.

OTHER CONSIDERATIONS: Understanding the microbiome is key to understanding how spoilage and disease can be prevented, controlled, and managed. There is a flurry of empirical research currently being conducted on agricultural applications for microbes. For microbes to impact food systems, the results of this research will need to be disseminated, discussed, and accepted by producers, industry actors, and regulators.

SYSTEM ENABLERS & BARRIERS

ICT
Not needed for this innovation

ENERGY
Not needed for this innovation

PRIVATE SECTOR
Could support distribution and sales of product

COLLABORATION
Technology uptake enhanced by coordination between developers and farmers

R&D
Research and field trials are needed

TRANSPORTATION
Improved distribution channels would be helpful

GOVERNANCE
Requires science-based regulatory policies to properly weigh risks and benefits

HUMAN RESOURCES
This innovation can be adopted and adapted to local context by local entrepreneurs

SOCIOCULTURAL
Consumer acceptance is likely to become an issue

CRITERIA

Affordability

<$190 | $190—$10 | $10+ (Individuals)
Sm. | Md. | Lg. (Institutions)

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 — 67 — 100%

PHL Reduction Potential

0 — 28 — 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

This innovation would not require energy.

Environmental Impacts

Possible reductions in soil pollution and water-use due to beneficial effects of microbes on soil fertility.

EARLY WARNING SYSTEMS FOR PLANT DISEASE AND PESTS

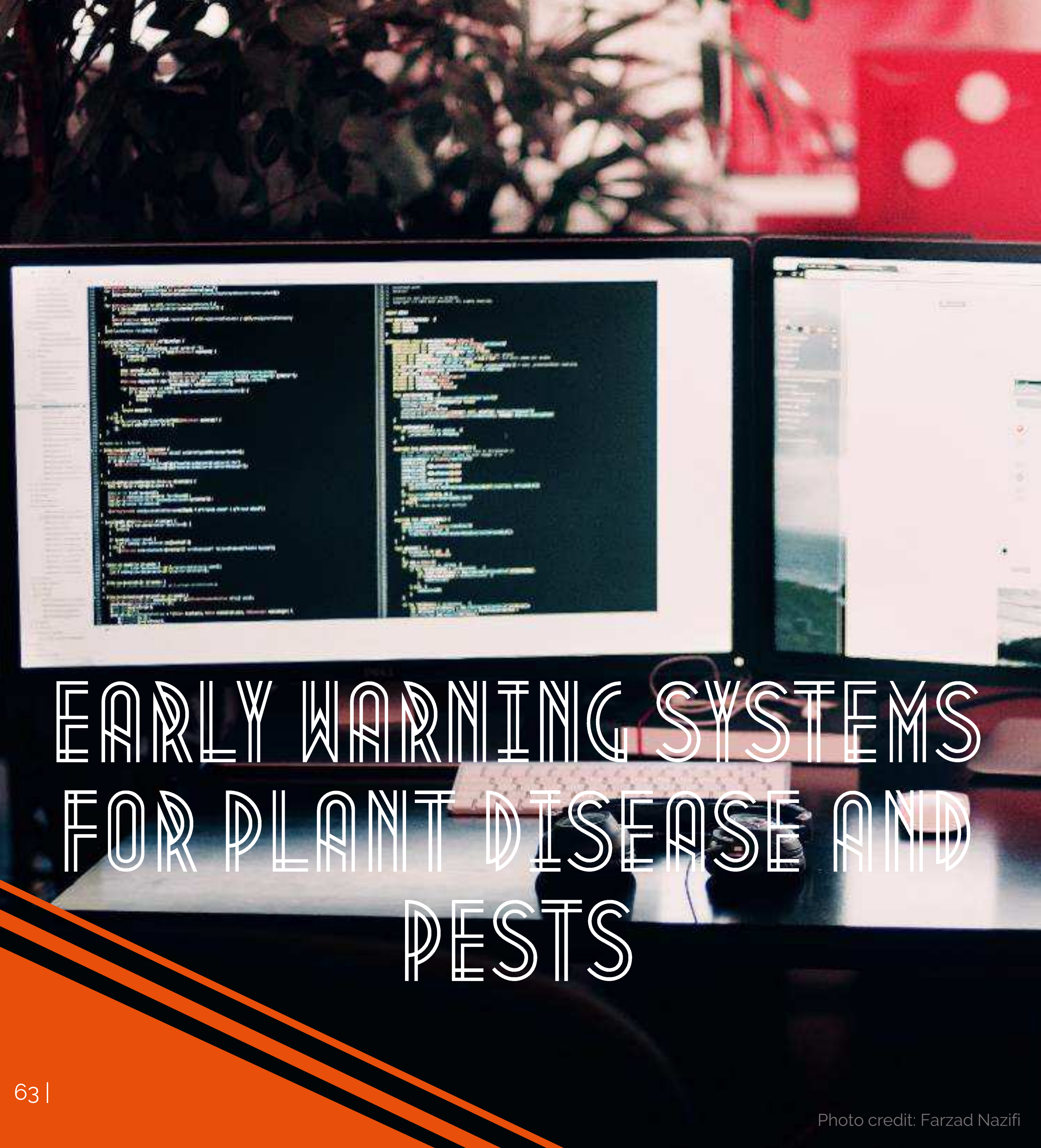


Photo credit: Farzad Nazifi

OVERVIEW

The threat of plant disease and pests does not end once a crop is harvested—they can cause loss up until the point of sale. Early Warning Systems, or EWS, have been used for decades to detect and sound a preventative alarm against potential and emerging threats, such as plant disease, pests, drought, and other climate shocks. To do so, EWS aggregate and analyze data from a wide range of sources, such as producer reports, sensor data, and satellite imagery. EWS have not been applied to post-harvest supply chains, which currently rely primarily on in-person data collection and reporting. By employing better data collection and analysis innovations throughout the supply chain, EWS could be used to the sound the alarm on PHL at any stage.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Grains
- Roots & Tubers

WHAT: A collaborative effort to utilize advancements in data collection and analysis to identify and communicate real-time information on plant disease and pest outbreaks that might affect post-harvest supply chains in emerging markets. EWS could be championed by governments, academic or research institutions, or through a public-private-partnership model in conjunction with industry.

EXAMPLES: The Food and Agricultural Organization of the United Nations (FAO) created the Global Information and Early Warning System on Food and Agriculture (GIEWS) in the early 1970s to monitor overall food security in every country. Next generation EWS could employ satellites, hyperspectral imaging, sensors, cloud computing, and other digital innovations to provide real-time data on post-harvest plant disease and pest outbreaks. Hyperspectral imaging, for example, has been used to detect diseased animal proteins in livestock feeds as a way of reducing mad-cow disease. Alternatively, sensor technology is being used in the US and Canada to detect airborne fungal and bacterial spores coming all the way from Europe.

OTHER CONSIDERATIONS: Successful applications of this innovation could utilize mobile phone technology to gather and transmit data. Information should be shared in a way that emphasizes ease of use and enables actionable responses by farmers. Focusing on a few specific crops rather than trying to collect information on a wide range would likely lead to better results in the near-term.

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non-experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 73 | 100%

PHL Reduction Potential

0 | 48 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

No energy is needed for this innovation.

Environmental Impacts

This innovation would help to reduce all relevant environmental impacts.

SYSTEM ENABLERS & BARRIERS

ICT
ICT is needed to collect, share, analyze, and communicate data

ENERGY
Energy is needed to power the devices required for EWS

PRIVATE SECTOR
Must have a strong commitment from government or industry to sustain

COLLABORATION
Success requires close coordination between actors to share data and information

R&D
This innovation relies on the ability to collect and analyze data

TRANSPORTATION
Transport infrastructure would support the deployment of technologies

GOVERNANCE
Must have a strong commitment from government or industry to sustain

HUMAN RESOURCES
Requires specialists to collect and analyze data, and communicate to farmers

SOCIOCULTURAL
Without the trust of farmers they may be reluctant to work with EWS service providers

IMPROVED TRACEABILITY TECHNOLOGIES

Photo credit: Atlas of the Future

OVERVIEW

Demand for the traceability of agricultural products has risen in recent years. Increased consumer awareness in high-income countries, along with the spread of foodborne pathogens, have helped to drive demand up. But smallholder supply chains often lack transparency in sourcing. As a crop moves through the supply chain it becomes more and more difficult to trace it backward. Another unintended consequence of this is the removal of accountability from the system, which contributes to PHL. Introducing improved traceability technologies would help supply chain actors keep each other accountable by being able to pinpoint where losses are occurring. This can also incentivize actors to reduce inefficiencies in their operations.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Grains
- Roots & Tubers
- Animal Proteins

WHAT: A combination of tracking technologies and an easy-to-use online or mobile interface that can be used to trace product movement across the supply chain.

EXAMPLES: Virtual City is a Kenyan company with operations throughout East Africa. Their traceability software enables real-time tracking and monitoring at various stages of agricultural supply chains. This also includes the value-addition of various actors, so that users can see the benefits of working with their business partners.

A more traditional shipping and tracking company, FedEx, has designed Senseaware, which is an Internet of Things (IoT) traceability platform. It uses sensor technology to feed into an online platform, which can be used as a smartphone app. With this technology users can track the status of their shipments in real time.

OTHER CONSIDERATIONS: A variety of technologies are available to support this innovation, including various sensors, QR Codes, mobile technologies, and more. When designing solutions in this area, careful consideration should be given to the local context in which it will be applied, including the current tracking practices.

SYSTEM ENABLERS & BARRIERS

ICT
Access to ICT is essential for users to be able to track their goods

ENERGY
Would be needed to charge requisite technologies like phones or computers

PRIVATE SECTOR
Strong business environment could support adoption via end-of-chain demand

COLLABORATION
This innovation is predicated on end-to-end coordination

R&D
Current technology exists but needs to be scaled to smallholder food systems

TRANSPORTATION
Would highlight current transport related challenges

GOVERNANCE
Requires an effective regulatory regime, including standards, agencies, and enforcement

HUMAN RESOURCES
Skilled data analysts would be needed

SOCIOCULTURAL
Important that this should not be a high-income imposition on a low-income context

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 51 | 100%

PHL Reduction Potential

0 | 33 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

Requires grid access to charge a mobile device or computer.

Environmental Impacts

This innovation has no clear positive or negative environmental impacts.

SPECIALTY MARKETING FOR PHL-PRONE CROPS

Photo credit: Ulleo via Pixabay

OVERVIEW

Reducing PHL is not a panacea for helping smallholders improve their livelihoods. In fact, a significant reduction in PHL could result in supply-side surges that reduce the price farmers receive for their products. So, if PHL is going to be reduced and simultaneously help smallholders improve their economic outlook, it follows that this should be supported by developing new markets able to absorb the increased volume of goods. One option for doing so is to play up a region's agricultural conditions and the qualities this imparts on a crop. As incomes continue to rise across most of the world, demand for specialty goods will likely rise with it. Producers in these emerging economies are primed to take advantage of this shift.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Roots & Tubers
- Animal Proteins

ENABLING INNOVATIONS

WHAT: A campaign to increase global demand for a product grown in a specific country or region. A successful specialty marketing campaign could lead to increased international demand as well as shaping the spending habits of burgeoning regional economies with increasing disposable income.

EXAMPLE: Ancient grains are experiencing a renaissance in the global supply chain, thanks to specialty marketing campaigns in North America and Europe for quinoa from Peru. Today, other grains like Teff from Ethiopia and Amaranth from across sub-Saharan Africa are following suit. A similar trajectory occurred for the South American acai berry and is occurring for products from the moringa oleifera tree, native to Africa and South Asia. While these products weren't promoted to specifically reduce PHL, their successful specialty marketing campaigns could offer lessons—both positive and negative—for actors seeking to increase international demand (or even national) for regional products with high levels of PHL in their supply chains.

OTHER CONSIDERATIONS: A strong marketing campaign may also introduce the added benefit of encouraging younger generations to consider careers in farming and agriculture as opposed to traveling to urban areas in search for work.

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non-experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 80 | 100%

PHL Reduction Potential

0 | 69 | 100%

Sustainability

This innovation requires **1 – 5 years** external support to sustain impact over the long-term.

Energy

No energy is needed for this innovation.

Environmental Impacts

This innovation could help increase the market for more diverse production, supporting better land management and increasing biodiversity.

SYSTEM ENABLERS & BARRIERS

ICT
ICT would be useful to coordinate between implicated actors

ENERGY
Energy infrastructure is not needed for this innovation

PRIVATE SECTOR
A strong private sector environment is needed to market and ship specialty goods overseas

COLLABORATION
Success requires concerted efforts of private sector, government, and farmers

R&D
Market research would improve the effectiveness of a marketing initiative

TRANSPORTATION
This innovation requires port and/or roads infrastructure to ship goods overseas

GOVERNANCE
Governments would be key partners in a successful version of this innovation

HUMAN RESOURCES
Skilled marketers are needed to promote specialty crops

SOCIOCULTURAL
Local culture must be amenable to the crop being prioritized

Photo credit: Neil Palmer via Creative Commons

FARM-TO-FORK VIRTUAL MARKETPLACE

OVERVIEW

Smallholders often lose out in the convoluted supply chains of modern food systems and end up receiving only a small portion of the final price paid for their produce. However, using recent advancements in mobile technology, producers and purchasers can connect directly. This model is already helping farmers in high-income countries increase their profits, as consumer preferences have shifted in favor of locally-sourced foods. There also exists a massive opportunity to bring these sorts of models to emerging markets, where populations are burgeoning and incomes are rising. But rather than the "eat local" movement, the driving force is the fragmented, inefficient nature of supply chains, which suffer from the unnecessary number of players involved.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Grains
- Roots & Tubers
- Animal Proteins

ENABLING INNOVATIONS

WHAT: An online- or mobile phone-based platform that connects farmers to food purchasers, including end-consumers but also restaurants and hotels. With roughly 65% of the world able to access mobile phones and a continued increase in smartphone usage, the potential for farmer-to-market connection allows for more efficient and timely supply chains.

EXAMPLES: M-Farm, a Kenyan company started to help farmers get their produce to market for a fair price, is being used to connect buyers and sellers of produce through an online platform. When a farmer's produce is ready, producers can upload their product to M-Farm's online marketplace, along with a brief description or a picture. Buyers can then use the marketplace to filter through different products to find what they need. In addition to these services, M-Farm provides information on past price trends to help farmers get a fair price at the best time to sell.

The India-based company Truce offers an app that connects farmers, aggregators, wholesalers, and processors interested in stable business and reliable business partners. Farmers and aggregators can use the app to offer deals on their produce; wholesalers and processors can use it to search for suppliers, and both can benefit from the logistical support Truce provides to ensure orders are delivered.

OTHER CONSIDERATIONS: Aggregation can help increase supply chain efficiencies and farmer profits. Though dubbed farm-to-fork, this innovation does not necessarily have to go all the way to fork, but instead to a retail point.

SYSTEM ENABLERS & BARRIERS

ENERGY
Energy is needed to charge a mobile device or computer

ICT
This innovation requires internet connectivity

COLLABORATION
It is necessary to align a number of partners such as farmers, aggregators, and consumers

PRIVATE SECTOR
A strong business environment is a prerequisite for this innovation to be in demand

R&D
Platform development is a critical first step

TRANSPORTATION
Transport infrastructure is needed to deliver goods

GOVERNANCE
A supporting regulatory environment for businesses is needed

HUMAN RESOURCES
Entrepreneurs and skilled workers are needed to facilitate connections

SOCIOCULTURAL
Farmers must be willing to engage directly with local or international consumers

CRITERIA

Affordability
<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.
Individuals | Institutions

Usability
No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability
No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits
0 | 38 | 100%

PHL Reduction Potential
0 | 29 | 100%

Sustainability
This innovation requires **5 or more YEARS** external support to sustain impact over the long-term.

Energy
Requires electricity to charge mobile phones and/or computers, but this could come from renewable sources.

Environmental Impacts
This innovation could help reduce GHG emissions by supporting more efficient transport routes.

FIRST-LOSS CAPITAL GUARANTEE FOR PHL

Photo credit: AMISOM Public Information

OVERVIEW

Adopting any new innovation into business operations is an inherently risky endeavor. This is even more the case for smallholder farmers who, by definition, have limited resources. If smallholders invest in a new technology or process that does not result in improved economic returns and pay itself off, that can have significant implications on their lives and livelihoods. With risk aversion comes the propensity to trust only those innovations with tangible benefits one can see. This is a challenge with farmer-oriented PHL solutions, the benefits of which might not show themselves until a crop is at the market. A first loss guarantee takes aim at this very problem.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Grains
- Roots & Tubers
- Animal Proteins

ENABLING INNOVATIONS

WHAT: A financial mechanism used to catalyze investment in pursuit of social and environmental goals. Guarantees are made by a “Provider” who agrees to bear an agreed-upon amount of financial loss, should it occur. In doing so, the Provider de-risks the “Recipient”, thus improving their risk-return profile and ability to invest their own resources, or pursue additional finance from more risk-averse investors.

EXAMPLES/OTHER CONSIDERATION: The Global Impact Investment Network, GIIN, identifies two purposes for catalytic first loss capital—market development, and leverage-for-impact. The latter could look similar to a crop insurance safety-net provided by a philanthropic organization. For example, if a farmer tests a new technology, such as a cold storage solution, and power is lost for a week due to inclement weather, the guarantee would cover the lost returns on the crops that spoiled. Leverage-for-impact is most applicable in scenarios where the social and/or environmental goals are not close to being realized at the same time as commercial viability.

By contrast, market development is when seasoned investors who believe some aspect of an emerging or frontier market, one with tangible social or environmental benefits, is on the brink of becoming commercially viable. In these instances their guarantee is used to draw other investors in so they can see first-hand the viability of the market in question. Once they experience a return on their investment, it follows that they will be inclined to adjust their risk-return profiles for the market in question and re-invest.

SYSTEM ENABLERS & BARRIERS

ICT
ICT infrastructure is not needed

ENERGY
It is not clear what connection to energy infrastructure would be needed

PRIVATE SECTOR
A strong financial sector is needed for first loss guarantee to catalyze further investment

COLLABORATION
Essential to coordinate with farmers and finance to identify best solution

R&D
No R&D is needed for this solution

TRANSPORTATION
No transport infrastructure needed beyond what is in place

GOVERNANCE
Theoretically governments could be a provider of guarantees

HUMAN RESOURCES
Does not necessarily require local specialists but it would be beneficial

SOCIOCULTURAL
Programs designed for farmers may be viewed with a measure of skepticism

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ — Individuals
Sm. | Md. | Lg. — Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 — 72 — 100%

PHL Reduction Potential

0 — 23 — 100%

Sustainability

This innovation requires **5 or more years** external support to sustain impact over the long-term.

Energy

No energy is needed for this innovation.

Environmental Impacts

This innovation has no clear positive or negative environmental impacts.

Photo credit: Agriculture for Impact

MOBILE EDUCATION CENTERS

OVERVIEW

Agricultural Extension is a staple of functioning food systems. Even in high-income countries, farmers benefit from educational services that help them keep up-to-date on trends and best practices emerging from the research community. One of the challenges bringing extension services to smallholders in low-income regions of the world is infrastructure: rough terrain, inclement weather, and limited internet access prevent widespread knowledge dissemination. Mobile healthcare is seen as instrumental for advancing access to healthcare in rural areas globally. Initial investments in mobile agricultural centers could reduce costs, enhance and foster new partnerships, and improve agricultural practices for millions of smallholder farmers.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Grains
- Roots & Tubers
- Animal Proteins

WHAT: An education center that can be moved, assembled, and disassembled so that it can travel and bring extension services to farmers in disparate areas.

EXAMPLES: Mashambas is an idea for an East African movable education center providing agricultural extension and training, as well as cheap fertilizers and new technologies to rural smallholder farmers. The center is designed to be made from simple modular units making it easy to construct, deconstruct, and transport the various components. If employed by government or private extension workers, modular education centers could serve as a semi-permanent community resource, but with the possibility to serve a new community in time.

The Alliance for a Green Revolution in Africa (AGRA) has a goal to train 100,000 Tanzanian farmers in post-harvest management techniques for 2017. In order to reach regions of the country where farmers lack the capacity to travel to major cities for support, AGRA has rolled out a regional training program that brings new techniques and products to the farmer through its staff and implementing partners. These mobile units work to harmonize farmer education and pre-emptively address new challenges while venturing to even the most rural areas.

OTHER CONSIDERATIONS: This innovation could be brought directly to farmers, but fees would need to match the market value and demonstrated benefits. Another option would be to sell the units to governments who then provide extension services.

SYSTEM ENABLERS & BARRIERS

ENERGY
Rural fueling stations would be needed to move the education centers

ICT
ICT could be used to pair this with virtual education

PRIVATE SECTOR
This innovation could be provided by governments or as an alternative

COLLABORATION
The success of this innovation is dependent on stakeholder collaboration

R&D
The education centers would distill R&D for the benefit of farmers

TRANSPORTATION
Transport infrastructure is needed to move the centers

GOVERNANCE
This innovation could be provided by governments or as an alternative

HUMAN RESOURCES
Extension services would need to be provided by skilled trainers

SOCIOCULTURAL
Service providers would need to build trust with the farmers they work with

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ (Individuals)
Sm. | Md. | Lg. (Institutions)

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 — 79 — 100%

PHL Reduction Potential

0 — 31 — 100%

Sustainability

This innovation requires **5 or more years** external support to sustain impact over the long-term.

Energy

Requires energy from non-renewable sources to move to different locations.

Environmental Impacts

This innovation would increase greenhouse gas emissions due to the need to transport the centers.

Photo credit: Flickr

BEHAVIORAL ECONOMICS FOR AGRICULTURE

OVERVIEW

Traditional economics stems from one simple premise — that humans are rational beings trying to maximize their utility. However, psychological, sociological, and anthropological evidence suggests that this is actually not the case. By contrast, behavioral economics starts from the premise that there are bounds to the rational capacity of any given agent. In other words we, as humans, are a complex stew of thoughts, emotions, habits, biases, and assumptions that shape our behavior. From this starting point, the field of behavioral economics endeavors to understand the context in which economic agents act, and it thus becomes possible to incentivize beneficial behaviors that could lead to the reduction of PHL.

Likely Crop Applications in Emerging Markets

- Fresh Fruits & Vegetables
- Grains
- Roots & Tubers
- Animal Proteins

WHAT: The application of behavioral economics (BE) principles, tools, and approaches to incentivize actors in smallholder value chains to engage in practices that ultimately reduce PHL. BE principles explain how people make choices, view risks and rewards, react to changing conditions, form habits, plan for the future, interact with others, and even remember things that happened in the past – all of which can be applied to incentivize PHL reduction.

EXAMPLES: Today, BE tools are widely applied across sectors. For example, Uber uses goal-oriented text messages to motivate its drivers to continue working. France introduced an opt-out organ donation policy to increase organ donations. And the Grameen Foundation uses personalized commitments to increase saving in low-income countries.

In the food and agriculture sector, the Busara Center in East Africa uses BE interventions to increase uptake of technologies and inputs. For example, they saw a 70% increase in fertilizer uptake through home-delivery instead of traditional outside-purchasing. Similarly, the Agricultural Technology Adoption Initiative (ATAI) is testing whether extension services aimed at agro-dealers are more effective in encouraging adoption of a flood-tolerant rice variety in India compared to extension services targeted toward farmers.

OTHER CONSIDERATIONS: BE tools should not be used to change cultural values, but instead to help those who want to implement improvements in their lives and business operations. Practitioners should also be cognizant of the balance between studying the effectiveness of and implementing BE approaches more widely.

SYSTEM ENABLERS & BARRIERS

ENERGY
There is no clear connection to energy infrastructure for this innovation

COLLABORATION
A PPP approach would be a beneficial model for impactful change

GOVERNANCE
Likely to be driven by a strong political or commercial interest

ICT
ICT could be one method of communicating with farmers in a BE intervention

PRIVATE SECTOR
BE interventions are likely to be driven by a strong political or commercial interest

TRANSPORTATION
Would be needed for interventions that span a large geography

SOCIOCULTURAL
Needs to be designed with farmers in mind or risk being perceived as manipulative

R&D
Research is needed to better understand BE models for engaging smallholders

HUMAN RESOURCES
Requires trained practitioners to design and deliver programs

CRITERIA

Affordability

<$1.90 | $1.90—$10 | $10+ | Sm. | Md. | Lg.

Individuals | Institutions

Usability

No training required | Simple explanation | Short training | Prolonged training | Not usable by non experts

Scalability

No Adoption | Early Adopters | Early Majority | Late Majority | Laggards

Smallholder Benefits

0 | 67 | 100%

PHL Reduction Potential

0 | 55 | 100%

Sustainability

This innovation require **5 or more years** external support to sustain impact over the long-term.

Energy

No energy is needed for this innovation.

Environmental Impacts

This innovation has no clear environmental benefits or impacts.

PART 3

EMERGING INNOVATIONS

...INTO THE FUTURE

While the previous 22 innovations offer an exciting picture of how we might improve global food systems and reduce rates of post-harvest loss (PHL) in the short-term, the systems barriers and enablers to innovation are presumed to be fixed in their present state. But the future isn't fixed and systems change in profound ways. From climate change and shifting consumer preferences to globalization and the changing winds of trade relations, macro and micro trends are shaping and reshaping the systems around us. With each passing moment we find ourselves in a different world.

In their report *Shaping the Future of Global Food Systems: A Scenarios Analysis,* the World Economic Forum (WEF) offers four scenarios for how global agricultural systems could look in 2030, based on signals of change that we can identify today. These scenarios of the future are provocative. But they don't shine a light on the shifts occurring in emerging markets—locations with large agricultural histories and untapped potential, and where new markets may open the door to new partnerships. Nor do they unpack the powerful role that innovation can play to shape food systems for the better. This is where our endeavor began.

Looking across the WEF scenarios, we asked:

- **How would these scenarios affect food systems in emerging markets in particular? What are the global forces that exert the most influence on emerging market food systems?**
- **What mounting global forces most urgently demand transformational innovation?**
- **What emerging innovations are best poised to meaningfully contribute to the realization of a future that we desire?**

THE 4 WEF SCENARIOS OFFERED A STARTING POINT FOR THE EXPLORATION OF THOSE EMERGING INNOVATIONS MOST LIKELY TO IMPROVE FOOD SYSTEMS IN EMERGING MARKETS.

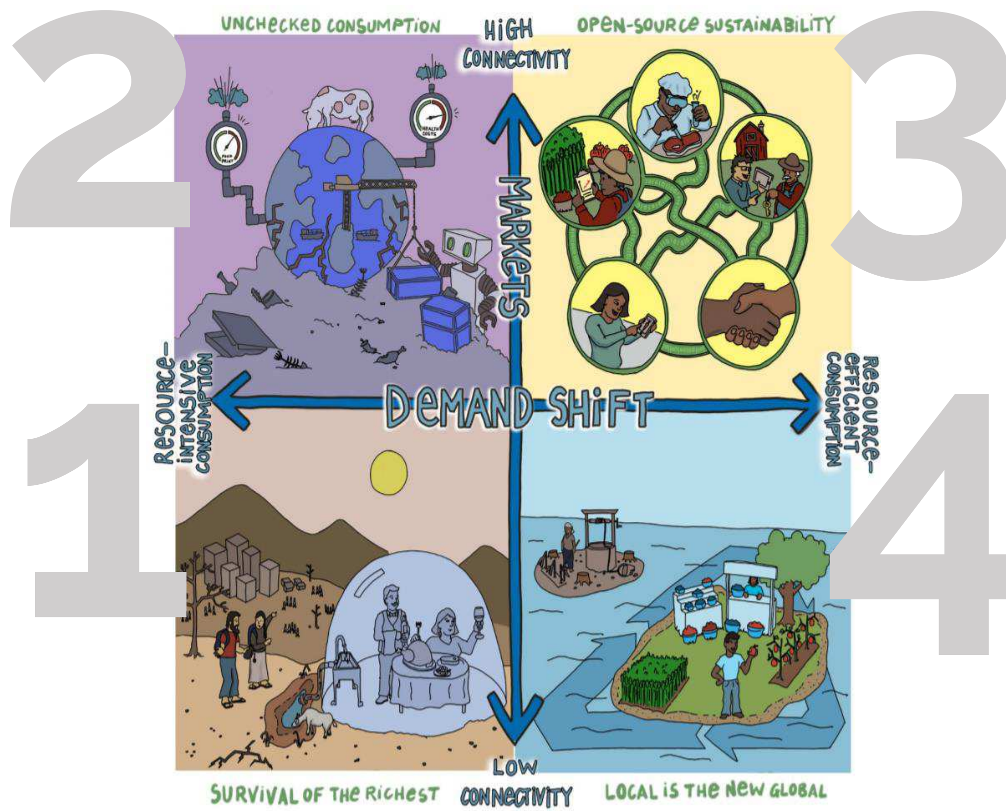
To answer these questions, we enlisted the help of a panel of global experts through the Delphi process outlined on pg. 17-19. We catapulted our experts to 2030-2035 to identify the harbingers of change for food systems in emerging markets. As a starting point for this thought experiment, we asked them to offer their interpretations of the WEF scenarios through this lens. WEF's four scenarios are summarized below.

Scenario 1: Survival of the Richest

This is a world in which governments have turned inward, closing their nations off to the rest of the world. Simultaneously, consumption and production patterns have prioritized short-term profits over longer-term concerns, like climate change and resource degradation. The result is a toxic mix where the rich get richer and the poor are left on their own.

Scenario 2: Unchecked Consumption

This future scenario, judged by our experts to be the most likely of all four, is best characterized by intensified global trade and economic growth at any cost. While the reduction of trade barriers means lower prices for consumers, it also masks the true costs of our food, in terms of the environmental price tag for its production, and makes it more difficult for small- and medium-sized businesses to compete against an agro-industry with significantly lower operating costs. The combined effects of lower prices for businesses and consumers alike inhibits action on complex multi-stakeholder challenges like the Sustainable Development Goals.



Source: "Shaping the Future of Global Food Systems: A Scenarios Analysis", World Economic Forum, 2017.

WHAT ARE THE DRIVING FORCES THAT WOULD RENDER POSSIBLE ANY ONE OF THE FOUR WEF SCENARIOS?

Scenario 3: Open-Source Sustainability

In this scenario, open data has increased connectivity and helped to usher in an era of innovation in the service of improved resource efficiency. The private sector, recognizing the challenges posed by global environmental change, have prioritized sustainability and resilience, diversifying their production sources. However, rural livelihoods have been compromised by the rapidity of change, and aging farmers struggle to keep pace.

Scenario 4: Local is the New Global

This future, deemed least likely by our panel, represents a scenario in which nations and regions have been disconnected from the global marketplace and instead rely on self-sufficient food systems. For countries rich in natural capital, this means an abundant supply of locally grown, seasonal crop varieties, albeit at a higher cost to consumers. For those countries lacking in arable land or sufficient water, their populations face increased malnutrition and societal unrest, In short, inequality has grown between countries and within them.

Armed with these portrayals, our expert panel set out to unearth the driving forces that would usher in such futures, looking in particular to unearth those forces that would render such changes to food systems in emerging markets. The most prominent forces identified are listed below.

FORCES

Scenario 2: Unchecked Consumption

1. Changing dietary preferences impact nutrition & health
2. Supply chains become more efficient
3. Environmental costs and resource degradation escalate
4. Continued globalization reduces smallholder competitiveness
5. Inequality exacerbates
6. Yields increase through technology
7. Lax regulation results in market-driven food system
8. Climate-related shocks disrupt food systems

Scenario 3: Open-Source Sustainability

1. Improved data increases transparency
2. Food systems attract innovation
3. Agriculture benefits accrue from improved resource efficiency
4. Rapid change compromises rural livelihoods
5. The public & private sector prioritize sustainability & resilience
6. Production sources diversify for crops and geographies
7. Farmers gain greater access to capital

Scenario 1: Survival of the Richest

1. Agriculture continues to degrade the environment
2. Isolationism become a force for good
3. Regional trade increases
4. Innovation is championed and privatized
5. Consumption becomes unsustainable
6. Continued inaction on climate change
7. Low-nutrition consumption proliferates
8. Mounting crises overcome apathy and inaction

Scenario 4: Local is the New Global

1. Local economies enable shorter supply chains
2. Inequality grows between countries and within them
3. Food choices reflect full costs (environmental, etc.)
4. Government policies support the triple bottom line
5. Localized systems increase resource efficiency
6. Resource disparities lead to food scarcity
7. Food systems reduce environmental footprint
8. Reduced collaboration inhibits innovation and its diffusion
9. Agriculture shifts to urban production systems

THE FUTURE OF FOOD SYSTEMS IN 2035 WILL NOT BE ONE OF THE 4 SCENARIOS OFFERED BY WEF — IT WILL BE A FIFTH, ONE THAT WE BUILD TOGETHER.

The list of global forces on the previous page portend significant trends that are shaping our world, and will shape food systems in emerging markets over the next twenty years. While the way in which these forces manifest are specific to the scenario within which they exist, it is the confluence of these forces that can point us toward areas ripe for research, policy-making, investment, private sector action, and improved decision making by consumers. These are the areas that beckon for transformational innovation to alter the future of food systems.

With these forces in hand, we tasked our panel of experts to imagine how innovation could alter the course of the future offered in the four WEF scenarios. In some instances, the panel described specific applications for emerging innovations that could fundamentally rewrite the way our food systems work. Quantum computing, blockchain, Internet for All, and synthetic biology are but a few of the innovations they indicated as promising in the pursuit of such transformation. Still, given the arduous nature of this thought experiment, at times our panel found it difficult to speak to exactly which innovation might shape the future and how. Instead they offered ideas about the opportunities that exist for transformational innovation to reshape food systems altogether.

What you will find on the following pages is a synthesis of what was elicited through three rounds of engagement with our experts. At the end of those rounds we found ourselves at the intersection of the trends that are shaping our world, the emerging innovations that can rewrite the future of food systems, and a white space for new ideas. We view this intersection as an *Invitation for Transformational Innovation*. In this section we issue 10 such invitations, each of which offers a mid-level abstraction meant to capture the imagination of investors, policymakers, innovators, researchers, and *you* to inspire bold efforts to reshape our food systems. Because the future is not fixed and the future of food systems in 2035 will not be one of the four scenarios offered by WEF—it will be a fifth, one that we build together.

Photo credit:Chinh le Duc

10 INVITATIONS FOR INNOVATION

1. How might we engineer production systems impervious to crop failure and spoilage?

2. How might we reimagine the relationship between consumers and producers?

3. How might we create closed-loop agricultural systems?

4. How might we assure that all food everywhere is priced to account for its true cost?

5. How might we create farm-free foods?

6. How might we open, share, and use data across the supply chain to eliminate information asymmetries?

7. How might we transform conventional agriculture into regenerative agriculture?

8. How might we scale hyper-adaptive, localized polyculture?

9. How might we build and scale a model of self-sufficient city-based agriculture?

10. How might we reposition rural areas as places of opportunity?

1

THE CASE FOR TRANSFORMATIONAL INNOVATION

Imagine a future in which every seed planted and every harvested fruit, grain, root, or tuber is edible no matter what happens to it on the way from field to fork. What would this mean for a farmer, who has to make decisions about how to utilize limited resources; or a mother, who has to make decisions about what to feed her children?

This would be a future food system absent many existing tradeoffs. The aforementioned farmer would not have to worry whether her harvested maize would be ravaged by pests in storage. The aforementioned mother would not have to worry about whether the tomatoes and potatoes she purchased to make stew for her family would stay fresh long enough to provide her kids with the nutrition they need to be healthy. This is a vision for a future that calls for transformational innovation.

INVITATION TO INNOVATE:

HOW MIGHT WE ENGINEER PRODUCTION SYSTEMS IMPERVIOUS TO CROP FAILURE AND SPOILAGE?

TODAY VERSUS 2035

Every year massive amounts of crops are destroyed by hazards like drought, floods, and pests; go to waste when consumers let them spoil; or are lost in the long journey from farm to market. Climate change will exacerbate these and other trends. The declining reliability of fresh water resources, more extreme heat waves, and longer, more intense droughts will make it more difficult to grow food, leading to greater volumes of failure. Hotter mean temperatures will increase the geographic footprint of many pests that can damage crops both on field and in storage. For places lacking proper storage facilities this could mean an increase to the proportion of crops lost post-harvest. What would this mean for a world that needs to feed 8.5 billion people by 2030?

RELEVANT WEF SCENARIOS 1, 2 3, 4

If we go back to that future we imagined and think about the innovations that could help us achieve it, we have to start with information and analysis. Quantum computing could help us design away some of the traditional challenges that agriculture production faces by helping us model natural processes, which could be used to pinpoint the exact areas where intervention is needed to prevent crop failure or spoilage. Information from sensors and other data gathering technologies could feed accurate data into the quantum models, but knowledge is only so powerful on its own. Other technologies are needed to act upon this information. Nanobots, for instance, could be used to guard crops from pests, acting as a swarm of sentries ready to counterstrike against enemies like crop diseases and pests, and relying on smart sensors to provide the signal to act. Meanwhile synthetic biology and genetic engineering could be used to build resistance to pests, heat, drought, or flooding directly into the genetic makeup of entirely new crop varieties.

EMERGING INNOVATIONS

QUANTUM COMPUTING

Description

Conventional computers do one thing at a time, using many steps to solve a problem. Quantum computers, rather, would store and process lots of information simultaneously, using the principles of quantum mechanics. This would make problem-solving millions of times faster than today's computers. Researchers believe that quantum computers will have the ability to read encrypted messages, search huge amounts of data, and even model nature and natural processes.

NANOBOTS

Description

Nanobots are microscopic robots that function through a combination of machine learning and swarm behavior. This enables the nanobots to work as a collective mass in which the whole is greater than the sum of individuals. Because of the scale at which nanobots operate, they could have a broad range of applications, such as reconnaissance, molecular level engineering, artificial antibodies that swim through your bloodstream, and smart clothing that adapts to changing circumstances.

NEXT GEN. SENSORS

Description

Truly intelligent sensors do more than monitor environments and provide data—they are capable of analyzing that data and making decisions. This could be as simple as sending a signal to a microwave to keep it from overheating a meal, or as complex as redirecting a fraction of power from an artificial organ to a pacemaker, keeping a medical patient alive.

SYNTHETIC BIOLOGY

Description

Genetic engineering focuses on the cutting and editing of naturally occurring DNA sequences. Instead of a cut-and-paste methodology, synthetic biology incorporates the design and assembly of new biological entities or the redesign of existing biological systems. These new sequences can then be produced by machines at incredibly low cost using basic inputs, such as sugar. Theoretically it could allow scientists to integrate the DNA of multiple species to create entirely new hybrids

2

THE CASE FOR TRANSFORMATIONAL INNOVATION

In a world of increasing technological advancement and declining human-to-human connections, what would it mean for people to reconnect with their food and those who produce it? What would it mean for you, when you purchase your favorite fruit or vegetable, to know exactly where it came from and who your purchase supported? What would it mean for a farmer to know that her hard work helped nourish a family of four 1,000 miles away? This would be a food system that represents empathy and accountability; a food system where actions matter, not just for individuals, but for dozens of people suddenly more closely connected. If this is a world we want to create, transformational innovation is needed.

INVITATION TO INNOVATE:

HOW MIGHT WE REIMAGINE THE RELATIONSHIP OF CONSUMERS AND PRODUCERS?

TODAY VERSUS 2035

The food system of today is characterized by global supply chains, opaque transactions, and hidden costs for people and the environment. As the producers, procurers, movers, and sellers of food, large agro-industry players are steadily accumulating more wealth and power. How they choose to utilize this power is important for anyone who grows or eats food—that is, all of us. At the same time, consumer interest in understanding the origin, production methods, and environmental footprint of their food is on the rise. This demand is at odds with the increasing scale of industrialized agriculture and the accompanying land acquisitions that support it, which have spiked in the last decade. We may wake up in a future where big industry dictates terms to governments, consumers, and farmers alike.

RELEVANT WEF SCENARIOS

1, 2

In other industries, the sharing economy has enabled a peer-to-peer model that has upended traditional power brokers. Transformational innovation that builds upon the ethos of the sharing economy has the power to disintermediate established food systems actors. Such innovation could redraw the lines between consumers and producers, and bring more transparency and connectivity. Imagine a future where a seamless virtual reality (VR) experience could be used to introduce you to the producer of your food. Don't speak the same language? Advanced translation technologies could help with that. Once you've met a farmer you trust to grow your food, you could personally invest in their farm by purchasing their specific cryptocurrency, to be exchanged for their crops at harvest. Using a sensor-enabled mini hologram, you could watch them grow your produce in real time. And using predictive behavioral modeling to indicate to farmers which product you want to eat before you want it, farmers could load mangoes or apples on a drone and deliver them just as you desire them.

EMERGING INNOVATIONS

PREDICTIVE BEHAVIORAL MODELING

Description

What if you could know what someone was going to do before they did it? Predictive behavioral modeling holds this potential. It combines advances in big data, neuroscience, raw computing power, and analytics to predict the most likely behavior based on prior actions. Predictive behavioral monitoring could hold important implications for resource distribution, public safety, and even the concept of free will.

ADVANCED TRANSLATION TECHNOLOGIES

Description

Advanced translation technologies, such as DARPA's Broad Operational Language Translation (BOLT), could be used to translate other languages in real time, potentially directly into your ear. If these were to become commercially available, they would have implications for any multi-lingual industry such as agriculture, tourism, diplomacy, and shipping.

CRYPTO-CURRENCY

Description

Cryptocurrency is no longer a new concept, but the surface is still being scratched in terms of possible applications. These online currencies represent a decentralized system of value creation and transfer, meaning they are not tied to a centralized institution. Theoretically, this means that they represent a truer depiction of supply and demand. If cryptocurrencies proliferate, it could upend the current transaction systems of dollars and yuan by one that is explicitly tied to goods, a hi-tech equivalent of bartering.

VIRTUAL REALITY

Description

A seamless VR experience has long been the fantasy of gamers, but recently its potential applications have been reimagined. Among many other things, developers are interested in multi-person VR and how VR can be used to experience life in another person's world. While there are certainly concerns that VR could further facilitate societal detachment, it also has the potential to educate and develop connections between previously disparate populations, including agricultural value chain actors.

3

THE CASE FOR TRANSFORMATIONAL INNOVATION

There are signals today that point to humanity embracing its communal nature to such a degree that everything—all decisions, all flows of goods and people, and all norms and values—becomes global. But there are equally strong signals driving us toward an insular, isolationist state of the world. Our food systems need to be prepared for both realities, as the scale could tip in either's favor. The option that offers the most resilience is to entirely close the loop of our food production and consumption systems; to ensure that all necessary energy, fertilizer, and water can be generated on a single farm or in a single community; to ensure that all animal and water waste, banana peels and chicken bones, discarded packaging and uneaten foods are converted into useful secondary products. To see seas of treasure in a pile of trash will require nothing short of bold, transformational innovation.

INVITATION TO INNOVATE:

HOW MIGHT WE CREATE CLOSED LOOP AGRICULTURAL SYSTEMS?

TODAY VERSUS 2035

We often hear tales of the large number of "food miles" a food item travels from producer to consumer. Even in remote locations, globalization provides many consumers with year-round access to off-season or imported products. But we rarely hear about the grand-scale exchange of agricultural inputs, waste, and byproducts that result every day behind the scenes. A maize farmer in Tanzania may use fertilizer produced by a potash company in Canada and feed her cows with grain grown in India. The waste from her farm may leach into the soil and ground water locally only to then travel hundreds of miles to a distant estuary, or be transported 100 km away to a waste-processing plant. To save our dwindling natural resources and create resilient local agricultural systems, we must create closed loop systems that recycle all agricultural and consumer waste.

RELEVANT WEF SCENARIOS 1, 2 3, 4

Imagine a local cluster of farms able to exclusively support each other's production. The local dairy farmer could use bacterial slurries to turn cow dung into a safe, nutrient-rich fertilizer for the local maize farmer; and use microbes to convert methane from the cow's belching to electricity that feeds into the local microgrid. Husks and stalks left in the field after the maize harvest could be picked up by young entrepreneurs who process these byproducts into home storage items and furniture for local sale. And when a months-long drought threatens to destroy the local fruit producer's entire harvest, water could be summoned from the air, soil, and other vegetation through advanced water harvesting technologies that eliminate the need for groundwater or reservoir connections.

EMERGING INNOVATIONS

MICROBES

Description

Fungi, bacteria, and viruses are often only thought of as pests in the agricultural system. But these micro-organisms, all known as microbes, can be harnessed, or domesticated, to provide services that they perform naturally: decomposing organic matter, sanitizing and disinfecting diseased tissue, and converting one compound, such as CO_2, into another, such as electricity.

BIO-WASTE CONSUMER GOODS

Description

Already rotten, wasted, and inedible portions of food can be turned into new products, such as bricks, shoes, packaging materials, and animal feed. Researchers in Italy developed a can lining from tomato peels that is a safe alternative to Bishpenol A (BPA); Studio Gionata Gatto in the Netherlands is making biodegradable lamps from fruit and vegetable waste. These companies are two of many working to find profitable secondary markets for wasted food and food byproducts.

WATER HARVESTING

Description

Water harvesting, or collecting water at one time to be used for a different purpose later, isn't new. Rainwater has been harvested for irrigation purposes for centuries. In recent years, gray water from bathrooms, kitchens, and washing machines has been harvested, treated, and reused. New technologies are making it possible to now harvest fresh water from fog, dry air, and even dryland vegetation.

NEXT GEN. BIOFUELS

Descriptio

First-generation biofuels, such as ethanol, were created by fermenting sugar, starch, or vegetable oil, which threatens the food supply, biodiversity, and natural resource sustainability. Enter second-generation biofuels, which can be made from non-edible biomass such as leaves, stems, and husks, as well as processed waste products, such as fruit skins and pulp. BioUrja in India, for example, designed a small-scale anaerobic digestion system that allows farmers to convert bio-waste to biogas.

4

THE CASE FOR TRANSFORMATIONAL INNOVATION

A chocolate bar from the super market costs $1-2 just about everywhere in the world. This may seem like a reasonable price given its ubiquity, but what if it isn't? What if we could accurately price the deforestation, in terms of biodiversity loss and carbon release, from palm oil production—which is but one ingredient in a chocolate bar? Could we say for certain what another ingredient, cocoa, costs in lost educational attainment and exposure to environmental hazards for the 1.8 million children working on cocoa farms in the Ivory Coast and Ghana alone? And what if we could estimate the cost to public health via the chocolate bar-enabled diet-related diseases, like diabetes, that will manifest some time in the future? If we could value these externalities, and more, would we still think that a chocolate bar should cost only $1-2? But monetizing these environmental, societal, and health externalities, and integrating them into the price of goods, is a challenge requiring nothing short of transformational innovation.

INVITATION TO INNOVATE:

HOW MIGHT WE ASSURE THAT ALL FOOD EVERYWHERE IS PRICED TO ACCOUNT FOR ITS TRUE COST?

TODAY VERSUS 2035

True cost accounting is an evolving method for assessing the costs and benefits of food systems. It takes into account the miles food travels, man-hours spent cultivating crops, adjustments for imbalanced taxes and subsidies, natural resource use, soil and air pollution, diet-related health costs, and more. There are early signs that true cost accounting is gaining steam. In the last year, the Natural Capital Protocol and Social Capital Protocol have emerged to build methods for estimating environmental and social impacts. For instance, obesity-related healthcare costs the world $2 trillion each year, almost 3% of global GDP, and nitrogen fertilizer is three times cheaper to purchase than to clean an equivalent level of nitrogen pollution out of the soil and waterways. But, even if we discover how to account for all agricultural externalities, what would we do with the information? How might we ensure that it will be transmitted universally to enable better decision-making by and for all?

RELEVANT WEF SCENARIOS

2, 3

If true cost accounting protocols are supported from today on, and all agricultural externalities are calculated, our challenge in the future might be one of information sharing. A consumer in 2035 could begin his shopping experience outside a local market, arming himself with a personalized nutrition guide from his doctor. With this, he will be confident that every item he purchases aligns with his genetic makeup, helping to prevent chronic illnesses later in life. Inside the market, "Internet for All" combined with wearable technologies could enable a seamless VR experience with the True Cost Accounting Protocol, where an artificial intelligence (AI) advocate would accompany him through his shopping experience. The AI could explain why some chocolate bars are $2 while others are now $25, and how these costs have been tracked from source to market using blockchain-enabled transparency protocols, ultimately giving him confidence that his money has been well spent.

EMERGING INNOVATIONS

PERSONALIZED NUTRITION

Description

Nutrigenomics and nutrigenetics are two areas of research at the interface of the food and human genome, and together constitute the concept of personalized nutrition. Nutrigenomics looks at the effect that food has on the expression of genes. For instance, if a certain disease runs in a family, eating certain foods can make it more or less likely that said gene will express itself in an individual. Nutrigenetics, on the other hand, endeavors to understand how genetic variation responds to nutrients in specific foods.

VIRTUAL REALITY

Description

A seamless VR experience has long been the fantasy of gamers, but recently its potential applications have been reimagined. Among many other things, developers are interested in multi-person VR and how VR can be used to experience life in another person's world. While there are certainly concerns that VR could further facilitate societal detachment, it also has the potential to educate and develop connections between previously disparate populations, including agricultural value chain actors.

BLOCKCHAIN

Description

Blockchain is a distributed, secure, transparent, and autonomous means of record generation and storage. Records (called blocks) are generated in real-time through transactions. Each record is given a timestamp, which cannot be altered. Blockchain originated in the financial sector, but is finding commercial applications in healthcare and trade and logistics, where it coordinates supply chain interactions to reduce fraud, errors, waste, and time products spend in transit.

ACCOUNTING PROTOCOLS

Description

Often, innovations and programs are designed to only perform well on the indicators they're being measured against. This presents a challenge in accounting for foods' full cost because there isn't a standard measurement. While it's often difficult to reconcile the difference between quantitative and qualitative costs, creating a standard accounting protocol would help build consensus and stimulate reform across agricultural supply chains.

5

THE CASE FOR TRANSFORMATIONAL INNOVATION

Today, 11% of the world's land is used for crop production. An additional 26% is used for livestock production. Together, that's over 45 *billion* hectares. How different would the world be if *zero* hectares were used for agriculture? Could some of that land be transitioned back to natural areas, where carbon emissions can be captured and biodiversity can thrive? Could some be used to house our expanding population in safe locations near to economic opportunities? We could imagine many ways to partition 45 billion acres of land to build a more sustainable, resilient world. In all likelihood, we would still dedicate many of those acres to food production. The logistical costs and risk of economic and social destabilization may be too great to bear a zero-farming future. But, if we only have 60 years of farming left if current rates of soil degradation continue, according to a senior official at the United Nations, then we owe it to future generations to explore this very idea.

INVITATION TO INNOVATE:

HOW MIGHT WE CREATE FARM-FREE FOODS?

TODAY VERSUS 2035

Since the Green Revolution, agricultural yield improvements have partially offset the continued expansion of land dedicated to food production. But improved seeds and farming practices cannot hope to totally offset land conversion rates. This is especially so given that animal products dominate agricultural land use, accounting for 65 percent of the world's agricultural land. Larger changes are needed, particularly if we are to meet the ever-increasing demand for meat protein in emerging markets. In a grim future of impending natural resource depletion through food production, offsetting traditional agriculture with farm-free foods is a must. But there's hope: if 66% of the population resides in urban centers by 2050, and if advances in biology, data science, and engineering are geared toward food production, we can innovate our way out of this predicament.

RELEVANT WEF SCENARIOS

1, 4

How exactly could the next generation sustain itself on farm-free food? With synthetic biology, we could engineer seeds capable of growing in any condition. One could "plant" a seed in concrete, off the side of a building, or on the roof of a car—a whole new meaning to vertical farming. Local printshops could be reimagined as well. Instead of printing documents and signs with ink, printshops could use DNA sequences as a print medium to create on-demand proteins. Using a next-gen air filter, beneficial bacteria could be harvested from the air around us; the printshop owner could then add a solution of microbial compounds to the bacteria. With time, a patch of genetic material would grow, ripe for printing. Using a 4D printer, the genetic material could transform into a meat alternative over the course of hours. This local printshop could be just one cell in an organism of local businesses working together to create a farm-free ecosystem.

EMERGING INNOVATIONS

LAB-BASED PROTEIN

Description

A movement of scientists is aiming to synthesize animal protein in labs by synthesizing the DNA of cow's milk or chicken eggs, and culturing it using yeast. Their goal is an end product indistinguishable from the real thing. While the science behind the world's first test-tube hamburger cost over USD 300k, as the price comes down these lab-based proteins could become cheaper and more efficient (and perhaps safer) than traditional animal proteins.

SYNTHETIC BIOLOGY

Description

Genetic engineering focuses on the cutting and editing of naturally occurring DNA sequences. Instead of a cut-and-paste methodology, synthetic biology incorporates the design and assembly of new biological entities or the redesign of existing biological systems. These new sequences can then be produced by machines at incredibly low cost using basic inputs, such as sugar. Theoretically it could allow scientists to integrate the DNA of multiple species to create entirely new hybrids

VERTICAL FARMING

Description

Vertical farming is the practice of growing food using a vertical structure, such as multiple soil beds stacked upon one another. Vertical farming encompasses various technologies, such as hydroponics, aquaponics, and pink farming. State-of-the-art vertical farms utilize controlled environments to optimize growing conditions. Currently, the most economically viable crops for vertical farming are leafy greens. For the practice to proliferate models that produce profits as well as variety will be needed.

4D PRINTING

Description

While 3D printing can be used to make static objects, 4D printing infuses the dimension of time. A printed object is capable of transforming itself over minutes, hours, or days. Depending on the object's programming, this could be in response to certain stimuli or simply chronology. Applications could include buildings that assemble themselves, infrastructure that changes according to ambient conditions, or food that "grows" on its own.

6

THE CASE FOR TRANSFORMATIONAL INNOVATION

Data has emerged over the past two decades as one of the single most important commodities of the 21st Century. More data was created in the past two years than in the entire history of the human race. We also search for data at a staggering rate of 40,000 search queries per second, on Google alone. And we are on the precipice of an even more unprecedented deluge. The falling cost and size of computing processors will lead to true ubiquity. With this, data will be generated from seemingly impossible places—the wing of a bee, the root nodule of a pea plant, the inside of your digestive tract. All of this will be data that can be collected, mined, and analyzed. But to the benefit of whom? Can the rising tide lift all boats (or tractors) and help all food system actors compete in new and exciting ways? For the data revolution to be truly transformational it will need to help producers access new markets, bring more choices and lower prices to consumers, and help remedy a range of economic and environmental inefficiencies. The result would be a food system that rewards quality of product, and quality of process over access to private data caches.

INVITATION TO INNOVATE:

HOW MIGHT WE OPEN, SHARE, AND USE DATA ACROSS THE SUPPLY CHAIN TO ELIMINATE INFORMATION ASYMMETRIES?

TODAY VERSUS 2035

Big data is part of the zeitgeist of the 21st Century. Yet it is largely under the purview of a few well-connected, well-funded private actors—and is used to their benefit, though certainly not exclusively. This trend, however, is creating massive information asymmetries. While economic principles aver that information asymmetries are a desirable outcome of a market economy, this traditionally applies to specialization within a field. For instance, a farmer with information asymmetries in her favor can grow better quality crops than her competitors. It is fair, though, to ask whether this still applies in the context of data collection and analysis on a global scale. When agro-industry uses information asymmetries in its favor, it becomes less about reliability and validity, and more about finding ways to drive costs down and price out competitors.

RELEVANT WEF SCENARIOS 1, 2, 3

We live in an era where a straight line can be drawn between information and economic opportunity. To promote the interests of actors up and down the supply chain there is a need for open, shared, and usable data. First, this requires access. Internet for All would transform the internet from a commodity to a right. How useful this is for a farmer in Burkina Faso, a processor in Bolivia, or a transporter in Bhutan will depend on what is communicated. Blockchain offers the possibility of transparent, autonomous data sharing. If integrated with sensor technology it could create a stream of data and analytics throughout the supply chain. Personal satellites could be used by small- and medium-sized enterprises to pinpoint new market opportunities from space, such as farms from which to source lower-cost produce that would otherwise be gobbled up by multinationals. Once food is in the supply chain, intelligent packaging could be used to create transparency about how a product was produced, stored, and transported, thus ensuring that prices truly account for quality.

EMERGING INNOVATIONS

BLOCKCHAIN

Description

Blockchain is a distributed, secure, transparent, and autonomous means of record generation and storage. Records (called blocks) are generated in real-time through transactions. Each record is given a timestamp, which cannot be altered. Blockchain originated in the financial sector, but is finding commercial applications in healthcare and trade and logistics, where it coordinates supply chain interactions to reduce fraud, errors, waste, and time products spend in transit.

INTERNET FOR ALL

Description

The Internet is currently treated as a commodity to be bought and sold. But in the current era of information, connectivity and innovation, the Internet has become a fundamental part of daily life and is inextricably tied to upward economic mobility. An "Internet for All" reality would require political will to regulate internet service providers and fund full-coverage connectivity throughout the world.

PERSONAL SATELLITES

Description

Satellites used to be exclusively owned by global superpowers. That time is no more. Researchers and hobbyists are already able to put small-scale personal satellites in low earth orbit. As the price falls for different sensing, scanning, and imaging technologies, tapping into an information stream from space will become more accessible. While this could promote nefarious uses, like espionage, personal satellites could be beneficial, promoting the use and analysis of previously inaccessible data.

INTELLIGENT PACKAGING

Description

Intelligent packaging senses or measures the packaged environment to provide information on changes to the product within. In the agricultural sector, intelligent packaging can be equipped with temperature indicators, shock and vibration detectors, and radio-frequency identification (RFID) tracking labels to alert supply chain actors to product damage, decay, or pest and disease presence. Today, large companies like Apple and Dow are creating intelligent packaging for their high-margin products, like computers and chemicals.

7

THE CASE FOR TRANSFORMATIONAL INNOVATION

Regenerative agriculture presents a fundamental shift from the way things are currently done. Instead of chopping down forests to graze animals and plant row crops; instead of letting topsoil erode and carbon escape with every till of the plow; and instead of chemicals and soil running off into local waterways, restorative agriculture seeks to replace conventional agricultural practices with those that encourage ecological stewardship. Already, restorative agricultural practices are gaining traction. No-till farming, for example, has seen a renaissance in commercial agriculture in recent years. By simply skipping the step of turning over the soil before planting, no-till methods can prevent soil erosion, replace soil nutrients with organic humus, and sequester carbon emissions. If we used this simple regenerative technique on all cultivated land, it's estimated that nearly 40% of all global carbon emissions could be offset. Imagine what further benefits could be achieved with ubiquitous transformation to regenerative agriculture.

INVITATION TO INNOVATE:

HOW MIGHT WE TRANSFORM CONVENTIONAL AGRICULTURE INTO REGENERATIVE AGRICULTURE?

TODAY VERSUS 2035

Despite progress in no-till farming, early signals point to a global agricultural system unresponsive to the gravity of resource depletion. Agriculture is still the single greatest driver of deforestation, accounting for 80% in tropical and subtropical countries over the last decade. Further, agriculture remains the single largest user of freshwater resources, consuming an estimated 70% of global supplies. At the same time, agriculture drives the use of chemical pesticides, which has increased by 25 times in the last 50 years. And, the final nail in the coffin: a senior official at the United Nations believes that we only have 60 years left of farming [as we know it] if current rates of soil degradation continue. If we are to flip the script on this regrettable narrative in less than 20 years time, regenerative agriculture offers a host of options.

RELEVANT WEF SCENARIOS

2, 3

The regenerative farm of the future could mimic nature with the help of man. Complex polyculture fields could be calibrated with autonomous sensors responsive to every plant's optimal nutrients and water levels, root depth, and sun exposure. If one falls out of balance, sensors could trigger tiny robots to bore into the soil to aerate the plant's roots or release pheromones to attract a surge of pollinators. As a result, chemical application could be fine-tuned and reduced to a fraction of today's usage. Water resources, on the other hand, could be dramatically offset through an endless cycle of use and reuse, made possible through industrial-scale biomimetic water filters, which could use both organic and synthetic materials to replicate a cell's highly-selective and efficient transport of water molecules. Finally, farmers could be incentivized to continue protecting his or her soil, and sequestering carbon in its depths, by selling carbon credits on the global soil carbon market.

EMERGING INNOVATIONS

NEXT GEN. SENSORS

Description

Truly intelligent sensors do more than monitor environments and provide data—they are capable of analyzing that data and making decisions. This could be as simple as sending a signal to a microwave to keep it from overheating a meal, or as complex as redirecting a fraction of power from an artificial organ to a pacemaker, keeping a medical patient alive.

BIOMIMETIC WATER FILTERS

Description

Biomimetic water filters could use both organic and synthetic materials to replicate a cell's highly-selective and efficient transport of water molecules across its membrane. Researchers are currently studying how aquaporin molecules, a naturally-existing protein that regulates osmosis, can be harnessed to restrict the passage of contaminants such as bacteria, viruses, minerals, proteins, DNA, dissolved gases, salts, and detergents without restricting the passage of water.

SOIL CARBON MARKETS

Description

A soil carbon marketplace would allow farmers who practice regenerative methods to sell carbon credits to polluters for the carbon emissions they sequester in their soil. By setting industry limits for carbon emissions, those farmers able to store carbon could earn money by doing so, provided that a price can be assigned to the amount and benefits of soil carbon sequestration.

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THE CASE FOR TRANSFORMATIONAL INNOVATION

Imagine if every time you went to the market you saw a diverse selection of foods—exotic fruits, seasonal vegetables, noble and ancient grains—each of which you *knew* was grown nearby. Not because a label says so, but because locally produced foods always outperform and outprice imported foods. Now imagine 11 months from now, your region is hit by a storm that brings catastrophic flooding. When the water recedes, you return to that same market and the same selection of foods is available. Diversity, reliability, access, sustainability, and resilience. This is the opportunity that hyper-adaptive, localized polyculture offers. If scaled, it could bring these benefits to every corner of the planet—from New York City, USA to Ulaanbaatar, Mongolia.

INVITATION TO INNOVATE:

HOW MIGHT WE SCALE HYPER-ADAPTIVE, LOCALIZED POLYCULTURE?

TODAY VERSUS 2035

Two of the dominant trends agriculture has experienced over the past 50 years—the shifts toward monoculture cropping and global supply chains—leave food systems vulnerable to climate change in important ways. First, monoculture is the agricultural equivalent of putting all eggs in one basket. With climate change it is only a matter of time before something happens to the basket. Further, the cultivation practices that allow for the large scale production of commodity crops degrade the environment, particularly in the form of soil erosion, which further increases the vulnerability of agricultural ecosystems. The second shift toward interconnected supply chains and markets that move food all over the world all but guarantees that a shock to a commodity crop in one area of the world will be felt throughout the system.

RELEVANT WEF SCENARIOS

1, 2

4

Our current reality is distinctly different from the scenario of hyper-adaptive, localized polyculture, which entails the cultivation of diverse crops, including traditional and exotic varieties, adapted to local conditions for sale to local consumers. But what innovations hold the potential to make this concept a reality? Synthetic biology could be used to create new species of crop varieties capable of growing in climates that previously would have been inhospitable. Combining this with the modeling abilities of quantum computing enables prediction of the likelihood of various climate and environmental risks to design crops to withstand them. Further, quantum computing could be used to ascertain the optimal composition of a polyculture agro-ecosystem, including ratios of crop varieties, other flora, insects, and soil microbes. Identifying and cultivating the optimal microbial species would support overall ecosystem resilience, helping agriculture adapt to the changing climate.

EMERGING INNOVATIONS

SYNTHETIC BIOLOGY

Description

Genetic engineering focuses on the cutting and editing of naturally occurring DNA sequences. Instead of a cut-and-paste methodology, synthetic biology incorporates the design and assembly of new biological entities or the redesign of existing biological systems. These new sequences can then be produced by machines at incredibly low cost using basic inputs, such as sugar. Theoretically it could allow scientists to integrate the DNA of multiple species to create entirely new hybrids

MICROBES

Description

Fungi, bacteria, and viruses are often only thought of as pests in the agricultural system. But these micro-organisms, all known as microbes, can be harnessed, or domesticated, to provide services that they perform naturally: decomposing organic matter, sanitizing and disinfecting diseased tissue, and converting one compound, such as CO2, into another, such as electricity.

QUANTUM COMPUTING

Description

Conventional computers do one thing at a time, using many steps to solve a problem. Quantum computers, rather, would store and process lots of information simultaneously, using the principles of quantum mechanics. This would make problem-solving millions of times faster than today's computers. Researchers believe that quantum computers will have the ability to read encrypted messages, search huge amounts of data, and even model nature and natural processes.

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THE CASE FOR TRANSFORMATIONAL INNOVATION

Since the beginning of human civilization, farming has primarily taken place in rural fields. Recently, urban agriculture has sprouted in cities all over the world. For now, urban agriculture is a niche movement, predominantly composed of small-scale community growers and, more recently, indoor farmers seeking increased efficiencies and year-round growing seasons. But rooftop farms and urban gardens will not feed megacities. What kind of transformation would be required for cities to produce all the food needed to feed their residents? For a world to emerge in which cities serve as the primary location for food production, and the longest distance a mango ever travels is a few stories down to the market on the ground floor, dramatic and transformational innovation would be required.

INVITATION TO INNOVATE:

HOW MIGHT WE BUILD AND SCALE A MODEL OF SELF-SUFFICIENT CITY-BASED AGRICULTURE?

TODAY VERSUS 2035

The world is becoming more urban. In 1950, 30% of the world's population lived in cities. Today, that number is over 50%, and it is estimated that 66% of global inhabits will call a city home by 2050. Yet cities produce almost no food. This presents quite a conundrum—people must eat, but live in a place with no agriculture. Thus, food is brought in from the countryside via road and rail, and from other countries via ships and ports. The price of transporting food around the globe cannot be calculated in dollars alone, it must also be calculated in the resources used to ship, store, and cool food along the way. Further, when disruptions occur at any point along the complex supply chains that link distant city-based markets to their far-flung sources, food imports stall, prices rise, and, in worst case scenarios, food shortages trigger public unrest.

RELEVANT WEF SCENARIOS

1, 3

4

To create a world absent these problems it will take transformational innovation to build and scale a model of self-sufficient city-based agriculture. While we see early signals in the form of rooftop farms and zoning policies for urban agriculture, a truly self-sufficient model would require urban policymakers to develop a strong legal framework to guide the proliferation of vertical farms. Such policies could be built into requirements for property developers, nudging them to design new residential and commercial developments capable of growing enough food to sustain the people who live and work there. Other innovations that could enable this transformation include water harvesting systems that are integrated into buildings to direct water to indoor farms. Beyond plant-based foods, animal-based proteins will also need to be produced in new, city-friendly ways. Scientists capable of developing lab-based proteins could satisfy city inhabitants' meat-tooth with proteins grown in labs.

EMERGING INNOVATIONS

VERTICAL FARMING

Description

Vertical farming is the practice of growing food using a vertical structure, such as multiple soil beds stacked upon one another. Vertical farming encompasses various technologies, such as hydroponics, aquaponics, and pink farming. State-of-the-art vertical farms utilize controlled environments to optimize growing conditions. Currently, the most economically viable crops for vertical farming are leafy greens. For the practice to proliferate models that produce profits as well as variety will be needed.

LAB-BASED PROTEINS

Description

A movement of scientists is aiming to synthesize animal protein in labs by synthesizing the DNA of cow's milk or chicken eggs, and culturing it using yeast. Their goal is an end product indistinguishable from the real thing. While the science behind the world's first test-tube hamburger cost over USD 300k, as the price comes down these lab-based proteins could become cheaper and more efficient (and perhaps safer) than traditional animal proteins.

WATER HARVESTING

Description

Water harvesting, or collecting water at one time to be used for a different purpose later, isn't new. Rainwater has been harvested for irrigation purposes for centuries. In recent years, gray water from bathrooms, kitchens, and washing machines has been harvested, treated, and reused. New technologies are making it possible to now harvest fresh water from fog, dry air, and even dryland vegetation.

URBAN AG. ZONING

Description

Zoning policies are a staple of city planning, as they designate the potential uses for land. For cities to become truly self-sufficient, a legal framework for urban agriculture land use will be needed. Options could include a specific zone for urban agriculture, tax breaks or subsidies, or a mixed-use approach that requires new development to produce a certain amount of nutrients per resident.

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THE CASE FOR TRANSFORMATIONAL INNOVATION

Envision a world in which everyone has the opportunity to sustain themselves and their families, find ways to pursue their passions, and participate in the global marketplace, no matter what region they inhabit. This would be a world of incredible possibilities, especially for those living in neglected rural areas. What benefits can be realized if mothers and fathers no longer had to worry whether their harvest will support their children until the next season? Those children would be able to experience the beauty of nature alongside the benefits of education. And when they grow up they would be able to contribute to their communities and humanity as a whole, helping to unlock the human potential of others. The benefits of such a future extend far beyond economics. Now, juxtapose this picture with one characterized by the continued accumulation of wealth at the top, and deprivation by those living at the bottom of the economic pyramid, often in rural contexts. This is an imperative to innovate.

INVITATION TO INNOVATE:

HOW MIGHT WE REPOSITION RURAL AREAS AS PLACES OF OPPORTUNITY?

TODAY VERSUS 2035

The current trend of globalization has generated enormous wealth, lifted hundreds of millions of people out of poverty, and ushered in an era of unprecedented global cooperation, but it has also left many behind. This is evident between nations, but also within them, where the magnetism of cities has drawn struggling farmers in from the countryside in search of a better life. Additionally, the paucity of opportunity within large portions of the rural context in low-income countries has been compounded by urban migration. There is a lack of incentive to invest in rural areas where public goods like education and infrastructure must serve a distributed population. In the face of global environmental change, and as trends like automation lower operating costs and eliminate jobs, traditional livelihoods like farming and fishing become more difficult to sustain.

RELEVANT WEF SCENARIOS 1, 2

If we are to achieve a future in which everyone has the opportunity to feed themselves and their families, find ways to pursue their passions, and participate in the global marketplace, it will take bold, transformational innovation. Universal Basic Income, or UBI, would provide a living wage to every citizen irrespective of employment. Such a policy would decouple survival from labor, opening up tremendous resources in the form of human capital. Non-monetized food, which would treat food as a right, could have similar effects. A two-tiered food system would classify food staples as a right, but assign a price to other foods, like chocolate and soda. Another promising innovation is remuneration for data. As data increasingly becomes the fuel that powers economies, it follows that those generating data, like farmers with sensors in their tractors, should be paid for their contribution.

EMERGING INNOVATIONS

UNIVERSAL BASIC INCOME

Description

UBI is experiencing a surge in popularity. While the many critics of UBI point to the way it divorces income from labor, the reality is that the changing economic landscape of the 21st century begs the question of what will happen to the labor economy. Efficiency gains from automation and robotics, combined with the burgeoning population, may reduce the need for labor and the availability of jobs. UBI is one approach to supporting people who will be hit hardest during this transition.

NON-MONETIZED FOOD

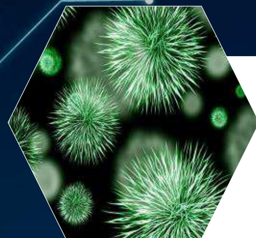
Description

A non-monetized food system is founded on the idea that, in a world already capable of producing enough food for 10 billion people, everyone should be able to eat. We could, therefore, reposition food and its production not as a commodity to be bought and sold, but as a common good and right.

REMUNERATION FOR DATA

Description

Companies, particularly in the tech industry, currently treat data as their property. Data is collected by providing services on personal devices. Remuneration for data would treat data as the property of the individual or organization creating it. For companies to use that data, they would need to remunerate the creator accordingly. This would empower people all over the world to make choices about whether and how their data is used, and what they receive in return for it.



PART 4

CONCLUSION

WHAT HAVE WE LEARNED ABOUT TRANSFORMATIONAL INNOVATION FOR FOOD SYSTEMS?

Photo credit: Paul Garic

When we began this Innovation Scan in April 2017, we hoped to uncover overlooked gaps in food systems in emerging markets. It's within such gaps that we suspected to find the root causes of inefficiency, information asymmetry, and lost opportunity. By orienting our efforts toward innovation, we wanted to activate a global response to innovate within those spaces, creating reverberating impacts across supply chains and reducing post-harvest loss (PHL). Beckoning for transformational innovation was, and is, our charge.

Through this process of discovery we learned a lot about what's needed now, in the next 5 years, and by 2035 for food systems in emerging markets to become more environmentally, economically, and socially sustainable. We've argued within this report that transformational innovation is a must if we're to outpace the global forces bearing on the planet that threaten to render global food systems more inequitable, less integrated, and less vulnerable to change. Indeed, transformational innovation is uniquely fit for the task in scenarios in which both the nature of the problem and the pathway to a solution are somewhat unclear. We identified several such thorny problems ripe for transformational innovation through our Innovation Scan. We spoke to these challenges, and their resultant "Invitations for Innovation", in Section 3: Emerging Innovations on pg. 77-102.

Closer to the present, core innovation (the current, standard area of innovation for a company) and adjacent innovation (that area of innovation just beyond current practice that entails serving existing customers and markets with a new product, process, or organization) offer just as much promise as transformational innovation in addressing a host of agricultural challenges. Our Innovation Scan also surfaced core and adjacent innovations that could be supported today to dramatically reduce PHL in emerging markets in 5 years. We described these "Investible Innovations" in Section 2 on pg. 20-76.

In Section 2, we shared profiles for 22 innovations that we believe offer the most promise to have a positive impact on smallholder supply chains in emerging markets in the next 5 years. From this list, we can point to clusters of innovation that would allow us to confront pressing challenges from different entry points, including:

INNOVATION QUICK WINS

1. Evaporative cooling systems (pg. 57)
2. Cooperative packaging solutions (pg. 33)
3. Crates adapted to smallholder supply chains (pg. 47)
4. Biodegradable coatings (pg. 59)
5. First-loss capital guarantee for PHL (pg. 71)

PHL REDUCTION POTENTIAL

1. Modular factories (pg. 35)
2. Near-farm mobile processing (pg. 37)
3. Dehydration (pg. 41)
4. Micro-warehousing & shipping (pg. 55)
5. Specialty marketing for PHL-prone crops (pg. 67)

INNOVATIONS WITH THE LOWEST BARRIERS

Some innovations, such as evaporative cooling systems and cooperative packaging solutions, offer **quick wins**. These low-hanging fruit are solutions positioned for value chain actors to adopt them quickly with minimal training and low up-front costs. While farmers would be able to see the effects of these near-farm innovations, it's likely that their benefits—improvements in quality and shelf-life—won't be realized until the crop moves further along the value chain. The challenge, therefore, is ensuring that farmers share in the financial benefits. Additionally, these quick-win innovations provide opportunities for local entrepreneurs to adapt, manufacture, and distribute these innovations in accordance with their local context. To encourage strong local entrepreneurship, governments investors or institutions could create first-loss capital guarantees to help de-risk investments for farmers who wish to invest in new innovations to reduce PHL.

INNOVATIONS WITH THE MOST PHL IMPACT

Other innovations, such as modular factories and near-farm mobile processing, were identified as having the most **potential to reduce PHL**. These innovations may not be quick-win solutions because they involve processing, which is labor- and energy-intensive, or logistics, which requires effective flows of knowledge and goods. If these considerations can be addressed, however, these innovations could offer the greatest opportunity to reduce PHL over the next 5 years.

INNOVATIONS WITH THE GREATEST SMALLHOLDER BENEFITS

We can also point to those innovations that offer **benefits** most **likely to accrue to smallholders**. In general, these innovations do this in one of two ways. First, they provide a value-added service that will enhance the quality of a product. Mobile pre-cooling & packhouses, for instance, offer near-farm cooling and storage that can significantly extend shelf life of a crop while preserving its nutritional quality. The second way the benefits of these innovations accrue to farmers is by helping farmers reach new markets, such as through specialty marketing and adaptable reefer containers.

ENVIRONMENTALLY SUSTAINABLE INNOVATIONS

There is also a cohort of innovations that offer the most benefits for **environmental sustainability**. Technologies like batteries and on-farm solar preservation offer the ability to bring clean energy to rural areas and bypass the negative consequences of conventional energy infrastructure. One innovation, microbes for PHL reduction, might offer positive effects for the environment in the form of improved soil fertility. Other environmentally sustainable innovations, such as evaporative cooling, offer substitutes to existing practices that pose negative externalities for the environment.

SMALLHOLDER BENEFITS

1. Adaptable reefer containers (pg. 51)
2. Behavioral economics for agriculture (pg. 75)
3. Mobile pre-cooling & packhouses (pg. 39)
4. Specialty marketing (pg. 67)
5. Mobile education centers (pg. 73)

ENVIRONMENTAL SUSTAINABILITY

1. Battery technologies (pg. 43)
2. On-farm solar preservation (pg. 45)
3. Evaporative cooling (pg. 57)
4. Early warning systems for plant disease and pests (pg. 63)
5. Microbes for agriculture (pg. 61)

INNOVATIONS WITH THE GREATEST BARRIERS

Another way to draw conclusions from the insights offered in the 22 Investible Innovations in Section 2 is to ask "which systems enablers and barriers, such as infrastructure and sociocultural considerations, are most influential in accelerating (or inhibiting) an innovation's potential?" By scoring each innovation on the 9 Systems Enablers and Barriers (transportation infrastructure, energy infrastructure, ICT infrastructure, human resources, R&D, governance, private sector landscape, collaboration, and sociocultural considerations), we identified the relative degree of influence that these systems factors have across innovations. From this synthetic perspective, we observed which innovations are most vulnerable to specific systems factors. Our research shows that five innovations appear likely to face the most significant **systems barriers** (see chart at right).

INNOVATIONS FACING SUBSTANTIAL SYSTEMS BARRIERS

1. Cold chain as a service (pg. 53)
2. Early warning systems for plant disease and pests (pg. 63)
3. Improved traceability technologies (pg. 65)
4. Farm-to-fork virtual marketplace (pg. 69)
5. Mobile education centers (pg. 73)

READY FOR THE DATA REVOLUTION?

While it wasn't our explicit pursuit in conducting this Innovation Scan, one conclusion we drew is that, absent substantial prioritization of systems improvements, many potential innovations will not deliver. Case in point: we introduced 15 data innovations to our expert panel at the beginning of the Delphi process (see pg. 22). Of those, only two—early warning systems for plant disease and pests and Improved traceability technologies—were prioritized by our expert panel. The resounding message we received is that, absent concerted efforts to improve transport and data infrastructure, smallholder value chains are not ready for the "data revolution". But many of these innovations *will* be needed over the long-term, and thus many found their way into the longer term pictures of future innovation presented in Section 3: Emerging Innovations (pg. 77).

CHANGE ON THE HORIZON

When we shifted our scanning mechanism from the foreseeable near-term state of food systems in emerging markets to the more distant possible horizons of 2035, we picked up different innovation prospects. The 22 Investible Innovations, like evaporative cooling and cooperative packaging, are not among the list of emerging innovations that could shepherd food systems in emerging markets through the obstacle course of global trends presented in the WEF scenarios. What does this mean for the way we approach today's problems versus those of tomorrow?

A pessimistic view might surmise that present bias prevents us from prioritizing solutions for complex global challenges for which the stakes of inaction today are greater in the years ahead, like climate change and urban migration. After all, can we expect a smallholder farmer to prioritize environmental sustainability, the top cross-cutting global force identified in this scan, if it doesn't directly impact his or her ability to feed his or her family? But another interpretation might suggest that, if we want to address the large-scale global challenges on the horizon, we must work with actors in emerging markets food systems to ensure that they have the resources needed to maximize the existing potential of today's food system. Innovation is one of the ways we can do this. Near-term innovations are needed to overcome those existing challenges related to immediate concerns, while emerging innovations like quantum computing and blockchain need to be supported today so that we may push the forces shaping the world in more desirable directions, and, in doing so, shape the future of food systems unfolding tomorrow.

CROSS-CUTTING GLOBAL FORCES

1. Environmental degradation
2. Climate change impacts
3. Vast urban opportunities in the face of rural decline
4. Hidden costs in global supply chains
5. Private sector influence

TOP EMERGING INNOVATIONS

1. Quantum computing
2. Synthetic biology
3. Blockchain
4. Next generation sensor technology
5. Microbes

Photo credit: Alice Young

In conclusion, the global forces that are driving us toward a future different from our world today, and the ten vignettes we created around them in Section 3 of this report, are not fixed destinations awaiting our arrival in 2035. Furthermore, these stories that illustrate how these forces might be met with emerging innovations are not exclusive. They may be combined in powerful ways, depending upon which forces come to ultimately exert the most significant effects on food systems in emerging markets. The future that we, and the community that contributed to this report, aspire to—of a sustainable, healthy, inclusive food system—is much bigger than four scenarios or ten Invitations for Innovation. And it will require all of us to take action. By engaging with this report and grappling with these challenges we are working toward that future together.

The GKI team would love to hear your reactions, questions, and ideas for engagement.
Please contact us: Renee Vuillaume at renee@gkinitiative.org

Global Knowledge Initiative

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