After Action Report

A Rockefeller Foundation Bellagio Center Convening

April 10-14, 2017 | Bellagio, Italy

on Transformational Innovations to Extend the Shelf Life of Perishable Crops and Reduce Post-harvest Loss

Global Knowledge Initiative

Acknowledgements

The following staff of the Global Knowledge Initiative (GKI) supported the design and delivery of the Bellagio Convening on Transformational Innovations to Extend the Shelf Life of Perishable Crops and Reduce Post-harvest Loss, inclusive of this After Action Report: Sara Farley (Chief Operating Officer), Renee Vuillame (Program Officer), Amanda Rose (Senior Program Officer), Jill Carter (Program Officer), Chase Keenan (Junior Program Officer), and Ritse Erumi (Doctoral Fellow).

GKI would like to extend a special thanks to The Rockefeller Foundation for their support throughout the Transformational Innovation Scan, and for hosting the convening at such a unique and superlative venue. In particular GKI would like to acknowledge Amira Bliss, Betty Kibaara, Elena Matsui, Olivia Karanja, Kagqwira Koome, and Rafael Flor. Their guidance, insight, and support at every stage leading up to, during, and following the convening has proved invaluable.

GKI would also like to express gratitude to everyone who contributed to the outcomes that were reached, including Nadia Gilardoni, Conference Coordinator of The Rockefeller Foundation Bellagio Center. The convening would not have been possible without the behind-the-scenes efforts of her and her team.

Finally, GKI would like to thank all of those who gave so generously of their time, passion, and reservoirs of knowledge to participate in this convening. None of this would have been possible without their willingness to engage so meaningfully in the quest for transformational innovations to extend the shelf life of perishable crops.

Our hope is that this event will live on as it feeds into a greater body of work to support the transformation of the agricultural sector as it pertains to extensions in shelf life, reductions in postharvest loss, improved livelihoods for smallholder farmers, and ultimately increased food security around the globe.

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Introduction

Background and key insights from the Bellagio Convening

Background

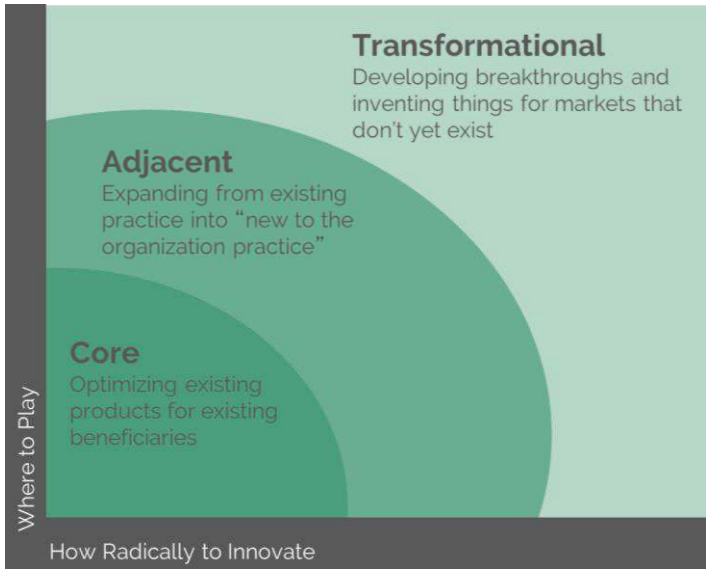
On April 10-14 2017, twenty-one thought-leaders met—many for the first time—at The Rockefeller Foundation Bellagio Center on the shores of Lake Como in Bellagio, Italy. They came from all corners of the globe—Africa, Asia, Europe, and North America—to examine a challenge meaningful to each and essential to The Rockefeller Foundation's YieldWise initiative, a $130m initiative to reduce post-harvest food loss (PHL) by 50% in representative value chains by 2030. The challenge? *How to extend the shelf life of perishable crops to reduce PHL in low-resource contexts*.

Suspecting that this particular challenge demanded innovative solutions, The Rockefeller Foundation brought in its Innovation Partner for YieldWise, the Global Knowledge Initiative (GKI). GKI builds purpose-driven networks to deliver innovative solutions to pressing global challenges and, as the Innovation Partner, works to boost the degree to which innovation is used to improve the efficiency, effectiveness, and, ultimately, the impact of YieldWise**.** GKI accepted the invitation and launched a global scan for transformational innovative solutions with the potential to dramatically extend the shelf life of perishable crops and reduce PHL by 2030. The Bellagio Center Convening in April 2017 served as one input into this larger, ongoing Transformational Innovation Scan.

The Convening goal was to explore shelf life innovations for the next 10 – 15 years and set a "call to action" to rally key stakeholders toward a shared vision for transformational innovation. *This goal was achieved.* For three days, participants shared diverse perspectives; thoughtfully examined prevailing opinions; envisioned a world of possibilities; and, ultimately, collaboratively constructed pathways of innovations with the potential to extend the shelf life of perishable crops, reduce post-harvest loss, and achieve The Rockefeller Foundation's goals of nutritional security, sustainable ecosystems, and secure rural livelihoods.

In the following pages, we report on the proceedings of the Bellagio Convening, culminating in an overview of the innovations generated by participants. These Innovations Pathways, when taken together, form a portfolio of core, adjacent, and transformational innovations that beckon for support and investment from now to 2030 and beyond. With a motto of "innovation for the next 100 years", The Rockefeller Foundation, with support from GKI, is primed to lead this call to action.

Transformational Innovation



Participant Expectations

- Strategize ways to reduce post-harvest loss (PHL) by identifying gaps, building prototypes, finding applications of existing innovations to new contexts, and strengthening business models
- Learn about PHL, particularly the policy and technology needs presented in developing countries
- Learn about the cold chain, including its cost, implementation factors, and demand in developing country contexts
- Generate ideas for affecting real change for SHFs
- Learn about and appreciate the scale of change that The Rockefeller Foundation can achieve with its $130 million investment in PHL reduction through YieldWise

Key Insights

The following key insights emerged from the Bellagio Convening, evidence of which lives throughout this After Action Report:

Innovations aimed at reduced post-harvest loss and shelf life extension are concentrated in eight key categories: (1) transport and logistics (including full integration and cold chain), (2) finance, (3) business models, (4) biological solutions, (5) data creation and access, (6) renewable energy, (7) new partnerships, and (8) behavior change and incentives. **However, innovations in these eight categories must combine technology innovations with process, service, organizational, policy, and business model innovations** to address the multiple **systemic challenges** leading to PHL in low-resource contexts. Innovations can only achieve the bold ambitions envisaged by participants if entire systems change to enable: (1) *full, open, and accessible data* to enable integrated value chains; (2) *improvements in renewable energy* to drive down technology costs and the environmental footprint of agriculture systems; (3) *reimagined business models* to shift incentives and power to the actors in control of PHL reduction and deserving of its benefits; and (4) *continued prioritization of basic R&D* on those innovations that we can only hint at today, but may be transformational in 10 or 50 years; (5) *increased access to finance* for farmers and nascent companies alike; and (6) an appreciation for *the changing profile of the small-holder farmer*, who, in 20 years, may be better educated, closer to urban areas, and aspire to different lifestyles than they do today.

However, innovations that radically extend shelf life do so much more: combined, they allow us to reimagine agricultural systems. Whether one considers modifications to transport and supply systems to expedite the connection between producer and consumer, or hyper-local solutions that enable consumers to rely on locally-produced foods, the innovations considered at Bellagio are bold. Together, they paint a picture of transformed markets, overhauled infrastructure, and a changed labor force. **In fact, some innovations are so catalytic of positive change that they feature in multiple Innovation Pathways aimed at achieving multiple distinct futures.** These include: (1) innovations that build an integrated, end-to-end cold chain; (2) innovations that transition cold chain and other supply chain capital assets from an ownership model to a service model; (3) innovations that capture—continuously and in real-time—production data, which can be used to increase transparency and improve capital influx at multiple points in the value chain; and (4) innovations that incentivize donors, governments, and the private sector to financially support and catalyze PHL reduction. These innovations may offer a strong foundation upon which to base investment choices.

Finally, challenges may need to be reframed to resonate more with decision-makers, particularly governments, investors, and the private sector. For example, PHL may be construed as more critical if it can be rebranded as an environmental challenge, as the resource waste resulting from harvested food that is not consumed contributes substantially to carbon dioxide emissions. Additional research, particularly to build data-based indicators, would be required to effectively reframe the PHL or shelf life challenge.

The Shelf Life Challenge

The current state of the challenge and the case for needed transformation

The First Horizon

The Bellagio convening began by inviting participants to explore the "First Horizon." This is the initial step in envisioning the range of potential futures that may manifest, and the innovation pathways for achieving them. Only once the state of a challenge is clarified can the possibilities for transformation emerge.

At the Bellagio convening, the First Horizon on the **Shelf Life Challenge** was evoked through a combination of activities. First, presenters representing three countries—Kenya, Nigeria, and India—spoke to post-harvest challenges in a single country context. While they were presenting, participants took notes using GKI's active-listening tool called Known, Unknowns, and Assumptions (KUA). They posted these notes around the room using sticky notes, which were reflected back to them during a gallery walk. Following, participants described the state of the challenge through a synthesis of the information they had just learned and their own experience working on these issues.

The shelf life challenge they described is a pervasive problem affecting hundreds of millions of people. One in which innovations aimed at addressing it are scattered and disconnected, and many potential solutions get lost in the pilot phase. The challenge is exacerbated by poor infrastructure and a lack of market transparency. Further, poor data on specific markets segments and supply chains makes the ROI of potential investments difficult to project. This, combined with the accrual of benefits by actors at the end of the supply chain, disincentivizes investments in innovative solutions.

Kenya

In Kenya the shelf life challenge is defined by economic constraints. On a macro-scale, the lack of investment in road and energy infrastructure means that many farmers do not have access to adequate transport options or electricity for cold storage. On a micro-scale, farmers are constrained by the high cost of packaging materials and cold storage facilities. When combined with the lack of commitment to farmer empowerment on the part of both large-buyers and the government, the result is a widespread lack of capacity for implementing solutions that could extend the shelf life of perishable crops.

Nigeria

In Nigeria the shelf life challenge stems from technological gaps. A lack of on-farm infrastructure for shading, cooling, and storage means the shelf life clock of a given fruit or vegetable begins ticking immediately. Poor quality crates lead to rough handling and damaged fruit, which has food safety implications. Farmers have difficulty investing in better quality crates and on-farm infrastructure due to a lack of financial products tailored to their needs. Meanwhile, government policies and data constraints make it unattractive for third party logistics companies to invest in logistics or transport services that could help fill these gaps.

India

In India the shelf life challenge is related to information asymmetries. This applies to both the skills and knowledge needed to improve handling practices, as well as a lack of information on markets, which leads to seasonal gluts. Innovation is primarily on products, which are not necessarily affordable or accessible, rather than processes that could provide more direct benefits to farmers. Farmers are more empowered than in other countries thanks to a robust network of Famer Producer Organizations (FPOs). However, they still face challenges in realizing the benefits of investments and innovations in adjacent areas.

Possible Futures

Exploring the possibilities of four ideal futures for a world with reduced post-harvest loss

The Third Horizon

Before participants could develop innovative solutions to the challenges uncovered in the First Horizon, they first envisioned ideal futures. Dubbed the "Third Horizon" in the Futures Foresight tool that the GKI team used, the distant future participants explored took many forms. However, each of the many futures participants considered revealed a system in which the challenge of extending the shelf life of perishable crops is addressed and post-harvest loss is significantly reduced. Throughout this section of the convening, the GKI team encouraged participants to think of many possible visions of what the future could look like, using prompt questions such as:

- If all shelf life challenges were resolved, what future could you imagine?
- What values, ideals, and aspirations do you hold for the future of global agriculture and post-harvest loss reduction?
- Related to the shelf life challenge what does the ideal future look like for smallholder farmers? For agro-industrial companies? For consumers?

David Smith, the Chief Executive Officer of Global Futures and Foresight, presented on the power of Futures Foresight to stimulate out-of-the-box thinking. In his presentation, David highlighted some of the key "mega trends" futurologists observe, from sky-rocketing demand for food to expanding human life expectancies, and possible visions for what the future of innovation may look like, including the rise of artificial intelligence and the growing importance of FinTech companies. These thought-provoking insights inspired our group to dream big about the possible futures for shelf-life extension and post-harvest loss reduction.

"We find it hard to image a future that isn't a version of today."
- David Smith

Four Distinct Futures

GKI consolidated the visions of the future elicited in the Third Horizon exercise to reveal four ideal futures: (1) Farming as a Lifestyle Choice; (2) Public Sector-Led Sustainable Food Systems, (3) The High-Tech Farmer of the Future; and (4) Hyper-Local Agricultural Innovation and Decision-Making. Throughout the second day of the convening, participants worked in four small groups to explore each of these futures, identifying key features, components, and risks. After presenting these futures to the other participants, the groups refined their ideal futures. The four final futures for the extension of shelf life of perishable crops and significantly reducing post-harvest loss that emerged are:

1) Farming as a Lifestyle
2) Multi-Stakeholder-Led Sustainable Food Systems
3) Sustainable Food Systems through Advanced Farming
4) Market Incentives to Reduce Post-harvest Loss

Future 1: Farming as a Lifestyle

Imagine a future in which, throughout the world and across demographics, farming has become an attractive and respected career. Farmers become community leaders, drivers of innovation, and forces for safer and more dynamic rural areas. Furthermore, farmers now have full access to the financing, resources, and the knowledge necessary to earn a living wage, and are resilient in the face of global changes.

Key Components

- Greater connectivity, visibility between consumers and farmers
- Higher quality education and data enable farmers to more successfully receive credit and funding
- Marketing and brand management increase the value of crops and farmer returns
- Widely used virtual market platform improves sales, distribution, and information transparency

Considerations & Concerns

- For this future to be achieved, first farmers need time and money. Time for training, that in turn generates more time. Time for produce to reach markets in better conditions. Money from improved marketing and brand management. Money from banks in the form of loans.
- Can strong branding be effective in a low-resource context?
- Can a complex, organized physical and virtual infrastructure be achieved in a low-resource context?
- Will consumers buy into this future, even if they bear the burden of the cost in the form of more expensive produce?

Future 2: Multi-Stakeholder-Led Sustainable Food Systems

Imagine a future in which government, the private sector, and civil society serve as co-leads in championing the goals of nutrition, environmental sustainability, and human rights in the food system. Strong government policies provide farmers with the resources and knowledge necessary to sustainably produce quality food, while private sector companies leverage their knowledge and financial resources, as well as strong labor and environmental policies, to support resiliency and food security.

Key Components

- Government and philanthropic financial support are able to de-risk private sector investments
- Public-private partnerships train local aggregators and merchants in marketing skills and enable knowledge-sharing between big and small companies
- Government, NGOs, and companies co-create business models for smallholder farmers (e.g., innovation incubators)
- Uber aggregation model serves as logistics and e-trading platform that collects data for investors

Considerations & Concerns

- How can governments encourage private sector investors who are concerned about risk because they see no ROI?
- Beyond banks, who provides the financing? Can the private sector (e.g., telecom companies) be incentivized to step in?
- How can public and private efforts be consolidated with a clear understanding of data ownership and management responsibility?
- What infrastructure and incentives are needed to ensure that improvements will be accessible to all smallholder farmers?

Future 3: Sustainable Food Systems through Advanced Farming

Imagine a future in which smallholder farming is now a profession in which accessible and affordable breakthrough technologies are able to predict, control for, and prevent loss on the farm and throughout the value chain. With cold chain no longer needed, private sector investment leads the way in extending shelf-life through innovations in breeding, genetic engineering, and yet-to-emerge solutions. As production efficiency is maximized and supplemented through lab-based solutions, land can be restored or repurposed for more sustainable uses.

Key Components

- Incentives and other behavior change techniques encourage farmers to adopt new, advanced technologies
- Advanced-tech innovations are enabled through an integrated model aimed at energy, finance, data, and science & breeding
- Tech platforms encourage new service models in farming, eventually being widely used for sales, distribution, and training
- Drones and satellite imagery allow for data collection and monitoring throughout the value chain

Considerations & Concerns

- Technology is constantly evolving. How do we empower smallholder farmers to adopt newer and newer technologies?
- To align the incentives to value loss-free food, consumer demand must drive change. How do we incentivize processors, exporters, and consumers to reject the status quo?
- When philanthropic and government funding abates, technology adoption usually stagnates. How do we secure funding for high-tech innovations in the long run?

Future 4: Market Incentives to Reduce Post-harvest Loss

Imagine a future in which incentives are aligned along the entire value chain and, as a result, all actors are working toward the same goal: to provide high-quality produce from a loss-free supply chain. Consumers drives this change through new values and preferences, which are ultimately transformed as a result of value chain transparency, access to data, and improved options for processing and sales. As a result, production becomes a more stable and predictable, minimizing resource use, creating circular value chains, and reducing PHL.

Key Components

- Farmers are entrepreneurs, with communities as shareholders
- The localized supply chain increases flexibility for energy use, and renewable energy powers pre-processing, transport, storage, and processing
- "Loss-free" certification increases consumer demand and aligns incentives along the value chain
- Because they are invested in their local farm, consumers value food, especially "loss-free" food, to a new degree
- Big data is used to match buyers and sellers

Considerations & Concerns

- Consumers receive better quality, more nutritious food, but they ultimately may bear the cost of customized, segmented markets
- With thousands of local contexts in which this system operates, data systems must be end-to-end and interoperable
- Processors and exporters traditionally reject produce on the basis of quality; incentivizing change could be challenging.
- Certification may not be the optimal way for consumers to signal demand for loss-free produce. It also creates new intermediaries and the benefits of a certification may not trickle down to farmers.

Innovation Pathways

The journey from the present to the ideal future made possible through transformational innovation

Innovation Pathways

Innovation Pathways offer a powerful way to connect the present to our ideal future through innovation. Building an Innovation Pathway is about transitioning systems—the products, processes, organizations and markets around us—to an improved state in which a challenge is addressed.

Having formed four "Future Teams," participants began the task of building out the Second Horizon, or the pathway of current and emerging innovations that transitions our world from the current state (First Horizon) to the ideal future (Third Horizon). To create these pathways, participants considered four questions that get at the heart of the Second Horizon:

- What aspects of the ideal future are occurring now?
- What innovations existing today are helping advance these aspects?
- What emerging or future innovations have the potential to disrupt the status quo?
- What else could we start today to deliver desired change in the future?

By answering these questions, participants generated innovations with applications for the farm, transportation, storage, infrastructure, policy, financing, education, and more. These innovations spanned all five innovation types—product, process, market, organizational, and service—and included existing, emerging, and wholly new ideas. However, in developing these innovations, participants uncovered a reoccurring challenge: **pushing out the time horizon**. Participants could imagine innovations for the near future, but were challenged to reach beyond the 5-10 year innovation frontier. Through GKI's General Purpose Innovation (GPI) activity, described on the next page, participants were encouraged to push their ideas past the near term. The GPI activity also brought to light another key insight: new innovations are not the *only* answer. If instead we scale existing models in new contexts, can we achieve broader impact in less time?

With a long list of potential innovations, GKI invited participants to consider a number of criteria by which to judge their innovations. Speaker Seth Silverman provided participants with insight into the investor perspective on innovation, while Nithya Ramanathan from NextLeaf Analytics highlighted examples of innovations driving change in the health sector. With these presentations as inspiration, Futures Teams each developed 4-10 innovations that, when combined, had the most potential to usher in their ideal future.

Having refined clear Innovation Pathways that work in concert to achieve the desired futures, one question still remained: **what will be the impact?** Participants evaluated the impact of their Innovation Pathways on 4 metrics: shelf-life extension, loss reduction, income, and energy use. The result: bold, yet actionable, Innovation Pathways.

Innovations that Shape Our Possible Future

To build out the Second Horizon, participants generated dozens of existing and nascent innovations aimed at extending shelf life and reducing PHL. Bridging the gap between the present and 2030 requires bold and even "crazy" methods. Participants used General Purpose Innovation (GPI) Cards to generate such creative ideas and push out the innovation frontier. By matching GPIs with unique innovations from their innovation pathways, participants identified new applications of innovations on pertinent challenges. Participants refined their innovation pathways using pre-selected criteria, or "filters."

From one participant: "GPIs are an out-of-the-box, creative tool that unlocked us from the constraints of methodical and analytic thinking."

Future 1

Farming as a Lifestyle Choice

Considerations

Improving information flow across the supply chain requires (1) effort to ensure that the necessary resources are accurately organized and accessible on- and offline, and (2) buy-in from regulatory, research, and funding actors.

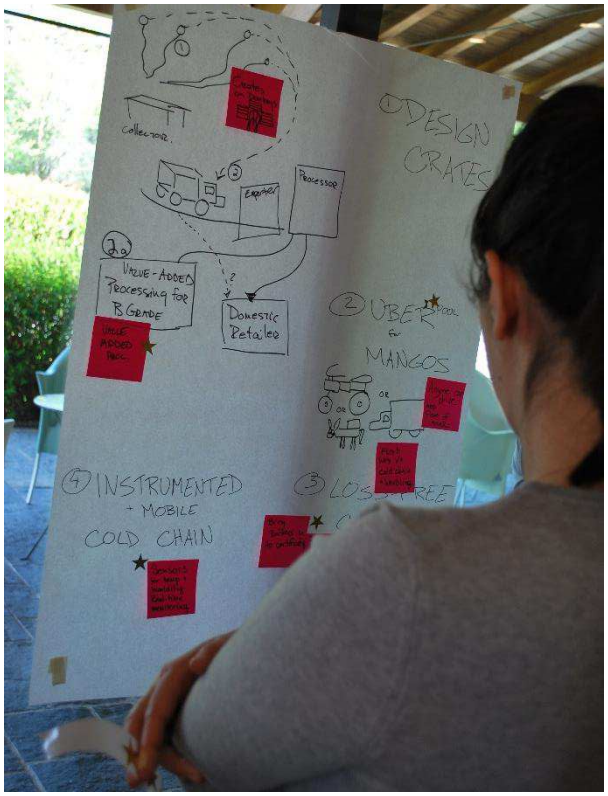
Improved on-farm packaging and coating requires essential R&D and presupposes that farmers are willing to use and consumers are willing to pay for safer, high-tech packaging and coating solutions.

Key Innovations

The transformation to farming as a lifestyle choice would connect four innovations:

1. **Supercooling coating (SCC)** would be a made from waste-byproduct and cool produce when applied, slowing maturation. SCC could be applied to packaging and shipping surfaces. Today, silk keeps produce fresh without refrigeration.
2. **Integrated cold chain as a service**, rather than a fixed asset. Farmers in rural areas could rent or lease mobile cold units. In the future, a renewable energy-powered distribution network might use airspace not land.
3. **Virtual marketplace for produce aggregation** would directly connects farmers to customers. Aggregating crops gives farmers collective bargaining power. A virtual marketplace creates brand recognition for consumers, improving value for farmers.
4. **Biophysical farm data to assess creditworthiness** would be generated by satellite, sensor, and imaging technologies, creating a rich data repository accessible to financers and loan-providers, de-risking investment in/for farmers.

Future 2



Multi-Stakeholder-Led Sustainable Food Systems

Considerations

Sectoral cooperation is possible only if risks are appropriately distributed and incentives are aligned, particularly for massive, cross-sectoral initiatives such as an Uber aggregation e-platform and blockchain data warehouse. Even with aligned actors and incentives, it may be difficult to ensure that smallholder farmers have equitable access to information, innovations, and their benefits. Thus, raising awareness, capacity building, finance, and data transparency are fundamental to the success of this Innovation Pathway.

Key Innovations

The transformation to a multi-stakeholder-led sustainable food system would connect the following six innovations:

1. **Mobile pre-cooler** to reduce field heat**.** The coolers would be rented from a service provider. A good model could be derived from the flower export market in Kenya.
2. **Uber aggregation e-platform** would combine transport, distribution, marketplace, & inventory management systems on one mobile platform, radically enhancing first-mile logistics, even for small- and medium-sized farms in rural areas.
3. **Mobile-based cold storage as a service** funded and managed by telecom companies with the capital and market penetration to reach many farmers.
4. **Blockchain** global open data warehouse for all value chains. The data would be irrefutable, traceable, transparent, and accessible to anyone.
5. **Marketing capacity building** for aggregators and exporters using a PPP model.
6. **Private sector innovation & incubation hub** for small companies to receive financial and technical support from larger companies interested in partnering.

Future 3

Sustainable Food Systems through Advanced Farming

Considerations

Innovations in data, energy, finance, and science & breeding are integral to this Pathway's theory of change—to ensure that advanced technologies service SHFs and don't displace jobs. **Data** innovations require interoperability and have privacy/security concerns. The storage capacity and price point of renewable **energy** needs to improve. Donor fatigue is a risk when seeking **financing** from governments and donors Finally, **science & breeding** advances take time and need to be promoted through outreach and capacity building.

Key Innovations

The Pathway of transformation to sustainable food systems through advanced farming would connect the following six innovations:

1. **Harvest and loss predictive modeling** would improve transparency and decision-making**.** Satellites and drones will survey farms to quantify acreage, monitor crop development, and assess disease potential.
2. **Intelligent sensors** would harness the Internet of Things (IOT) to track key indicators—temperature, weight, emissions, decay—from farm to market.
3. **Mobile energy carts with thermal coolers** would be provided as a service through a network of all-terrain vehicles used for transporting and storing perishable crops.
4. **Capacity building rooted in behavioral economics** would help farmers adopt and use new on-farm innovations.
5. **Farming as a service** would allow farmers to respond directly to the needs of buyers, who would gain visibility into farms through tech-enabled monitoring.
6. **First loss fund** would catalyze innovation deployment, backed by big donors.

Future 4

Market Incentives to Reduce Post-harvest Loss

Considerations

To align incentives along the entire value chain, consumers must ultimately drive demand for reduced PHL, and producers must be confident that their crops won't be wasted by upstream actors, such as exporters who care most about quality. Market-led change creates winners and losers, particularly middlemen who lengthen the chain from farm to market and can engage in cartel-like behavior. Certification can be an effective, transparent motivator, but it requires regulation and demand from end users.

Key Innovations

The Pathway of transformation to reduced PHL through market incentives would connect the following five innovations:

1. **Redesigned crates** would fit on the back of donkeys and motorcycles, improving farmers' access to aggregation points.
2. **Near-farm processing for B-grade produce** would find a use for mature and poor-quality produce that would otherwise be lost.
3. **Uber Pool-like transport** for crops would offer a virtual platform for farmers to directly connect to transporters-cum-aggregators, who is anyone with a vehicle!
4. **Instrumented mobile cold chain** would rely on sensors, real-time monitoring, and transparent relationships to create an end-to-end connection.
5. **Loss-free certification** to differentiate value chain actors who prioritize loss reduction. To motivate change upstream, large processors and exports would rate farms, which would be translated to consumers through labeling. Banks could also use the certification when assessing farmers' creditworthiness.

Investable Innovations

Poised to move the needle on not only shelf life extension but agricultural development more broadly, the following innovations elicited validation through an investment exercise conducted by participants. Each vested with $5 million [fictional] dollars, participants placed bets on those innovations that they deemed most promising. And the winners were….

$12.5m	**Uber e-aggregation platform**	Future 2 & 4
$10.5m	**Integrated cold chain as a service**	Future 1 , 2, & 4
$10m	**Super cooling coating (SCC)**	Future 1
$8m	**Harvest and loss predictive modeling**	Future 3
$8m	**Loss-free certification**	Future 4
$6.5m	**First loss fund**	Future 3
$6m	**Virtual marketplace for produce aggregation**	Future 1
$5m	**Capacity building rooted in behavioral economics**	Future 3
$5m	**Mobile energy carts with thermal coolers**	Future 3
$4.5m	**Intelligent sensors**	Future 3
$4m	**Marketing capacity building**	Future 2
$3.5m	**Farming as a service**	Future 3
$3m	**Private sector innovation & incubation hub**	Future 2
$3m	**Mobile pre-cooler**	Future 2
$3m	**Near-farm processing for B-grade produce**	Future 4
$1m	**Biophysical farm data to assess creditworthiness**	Future 1.
$1m	**Blockchain**	Future 2

Total invested in top innovations to extend shelf life and reduce post-harvest loss:

$94.5m

Other innovation ideas were proposed outside of the Innovation Pathways and voting, and included:

- Solar drying and dehydration
- Solar-heated water-based cooling system
- Research on bacteria, microbiology, and the soil microbiome
- Adaption of advanced containers for low-income contexts
- Clearing house for pre-commercial technologies
- Adaption of veterinary extension model for agriculture
- Early warning system for crop disease
- Advanced battery technology
- Cold fusion
- Bio-based and compostable plastics for packaging

Measuring Impact

As the convening came to a close, participants were asked to articulate the Innovation Ambition agenda for their Innovation Pathways. In doing so they used a set of metrics to declare the degree of aspiration for their pathway. With at least four metrics and multiple innovations for each pathway, this proved to be one of the most difficult feats of the convening.

Discussions arose in the room around insufficient data, the lack of consensus around measurement, and the preponderance of assumptions that would have to be relied upon to assign values to specific indicators.

One of the key takeaways was that, with the reliance of many pathways on cold chain, there is a need to balance economic, environmental, health, and social indicators.

Another key takeaway was that, when examined in the context of actual impact, many innovations might not deliver the expected results. Or perhaps they could, but only if complementary activities are implemented. One example that stood out was the need to develop markets to absorb the increased volume of produce.

Overall, it is clear that there is room for more research related to PHL. The connection between PHL and SHF incomes, cold chain and ROI, cold chain and environmental impacts, PHL and nutrition, and the differences across value chains, are just some questions that arose during the activity.

Metric #1: Shelf Life

Extended shelf life, measured in days. An upper bound of ambition was set at 730 days, or 2 years.

- Future Team 1 projected a 2.5-3.5 day shelf life extension for bananas if temperatures could be reduced to 20 or 15 degrees Celsius by a proposed innovation, the **super cooling coating**. An **Integrated cold chain as a service** would further extend shelf life by 2 months.
- Future Team 2 estimated that that shelf life of mangoes in Kenya could be increased from 11 days currently to 15 days with **mobile pre-coolers.**
- Future Team 3's tech innovations (**crop modeling, intelligent sensors,** and **mobile energy carts**) could extend shelf life by about 15 days altogether.
- Future Team 4 estimated that, if the shelf life of a mango were 15 days, then an **instrumented, mobile cold chain** would double shelf life to 30 days.

Metric #2: Post-harvest Loss Reduction

Reduction in postharvest loss, measured in metric tons (MT) per annum. With an estimated 1.3 billion MT of PHL each year, and the YieldWise target of 50% reduction in representative value chains, an upper bound of ambition was set at 650 MT .

- Future Team 1 projected a savings of 13.5-14.5 million MT of bananas (based on 150M MT produced) associated with the **super cooling coating**. An **Integrated cold chain as a service** would further reduce loss by 25m MT.
- Future Team 2 concluded that a 12% increase in shelf life of mangoes from the **mobile pre-coolers c**ould reduce PHL by 40%, or 1m MT, in Kenya.
- Futures Team 3 predicted that **crop modeling** and **intelligent sensors** could reduce PHL by 50%; **mobile energy carts** and **farming as a service** would further reduce PHL by an additional 25%.
- Future Team 4 estimated that PHL for mangoes could be reduced by 70-90% in Haiti—from 4.8 MT to 1.4 MT—through their Innovation Pathway.

Metric #3: Income

Income reduction for smallholder farmers (SHFs). Studies estimate that SHFs experience a 15% reduction in income as a result of PHL. An upper bound of ambition envisioned SHFs experiencing a 0% reduction in incomes as PHL is reduced.

- Future Team 1 projected that the **super cooling coating** could lead to an 8.5-10% reduction in income. An **Integrated cold chain as a service** would virtually eliminate any income loss associated with PHL.
- Future Team 2 had a long discussion, but concluded that there isn't enough empirical evidence on the beneficiaries and cost-bearers in PHL reduction efforts.
- Futures Team 3 predicted that **mobile energy carts** could reduce income loss to about 7%; **crop modeling** and **intelligent sensors** could reduce income loss another 5%, to 2% total.
- Future Team 4 hypothesized that farmer income would not change because gains would go to collectors, processors, exporters, and other upstream actors.

Metric #4: Energy Use

Energy use, measured in kilograms of Oil Equivalent (kgoe) per capita per annum. 1kgoe is roughly the amount needed to power a refrigerator for 1 day. In this context an upper bound of innovation ambition was set for 6,915 kgoe per capita per annum.

- Future Team 1 attributed zero energy use to the **super cooling coating**, except perhaps for production. An **integrated cold chain as a service** would, eventually, use only renewable energy.
- Future Team 2 projected that the **mobile pre-cooler** could use 499 kgoe in Kenya to power the small compressor on the unit.
- Futures Team 3 realized that their innovations could increase energy use, reinforcing the need for the full integration of renewable energy into agriculture.
- Future Team 4 predicted that energy use could increase, largely due to the spread of cold chain services. The team suggested that other important environmental indicators would be carbon dioxide and methane emissions.

Conclusion

Continuing to scan the horizon for transformational innovations

Conclusion and Next Steps

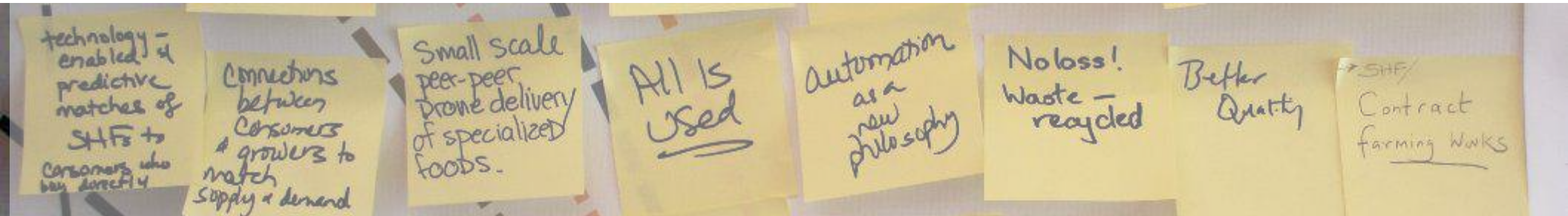
The title of this Bellagio convening was "Transformational Innovations to Extend the Shelf Life of Perishable Crops and Reduce Post-harvest Loss." At every step in the process outlined in the preceding pages, participants pushed the bounds of this title until what resulted became *so much more*.

First, participants fond that it wasn't enough for innovations to singularly address shelf life; they needed to be directed at broader goals—post-harvest loss reduction, environmental sustainability, food and nutrition security, improved livelihoods—to truly have *transformational* potential. However, future shelf life innovations will likely not attain equivalent impact on each of these broader goals. As we project further into the future, our ability to precisely describe the relationship and trade-offs between economic, environmental, and health impacts and those innovations we advocate pursuing becomes increasingly vague. Thus, we must declare which metric we want to impact most, and therefore which should guide the pursuit and support of innovation in the future.

Second, it wasn't enough for ideal futures to be focused, some would argue myopically, on how benefits would accrue to smallholder farmers; smallholder farmers are integrated in a complex, dynamic system. If we permit ourselves to imagine *all of the ways* in which shelf life can be extended and PHL reduced, smallholder farmers may bear the cost burden in some situations even as they elicit outsized benefits in others. We should not constrain ourselves to artificially rosy futures, else we censor options and risk overstating benefits. We must also pair our transformational innovations with clearer strategies for measuring the outcome of deployment so that we can more reliably state the costs and benefits accrued and how they impact different stakeholders.

Finally, it wasn't enough for the ideal futures to be taken at face value; participants realized that Innovation Pathways *point somewhere*. Participants regularly examined the characteristics of their future, appraising its value and questioning the ability of their Innovation Pathway to achieve it. Ambiguity about the future is dangerous; the deliberate choice of a future is something that each innovation we support orients us toward.

Based on the rich fodder that emerged from the this Bellagio Convening, the GKI team will be working closely with The Rockefeller Foundation to examine the innovations generated during the Convening and explore further applications in YieldWise and the agriculture sector more broadly. We hope to remain engaged with participants during this next phase, but are exceptionally grateful for the insight each contributed to date in this Transformational Innovation Scan.



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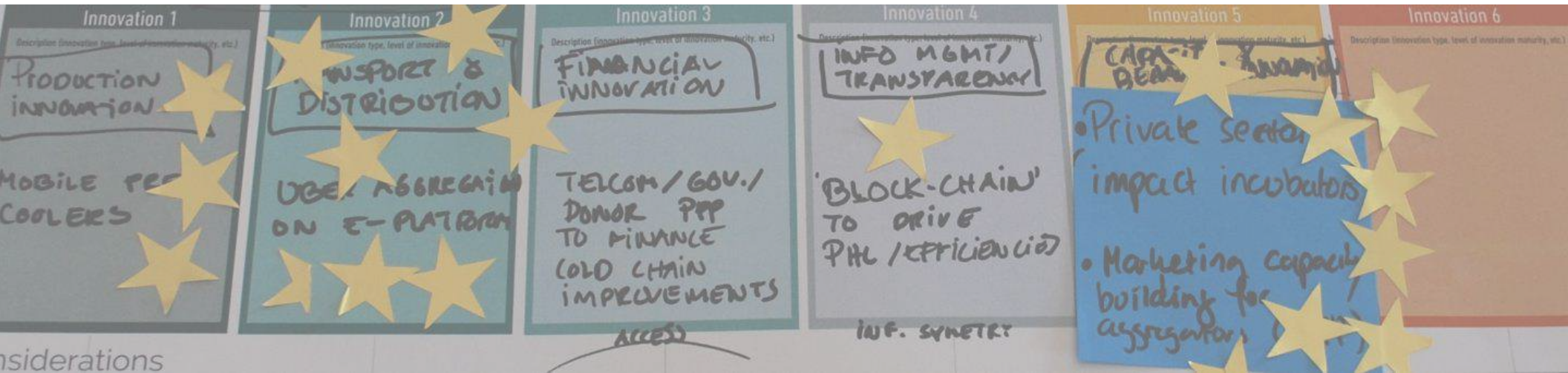

Agenda

LEARN
Day 1

Goal: To learn about the key challenges and innovation drivers in extending shelf life to reduce post-harvest loss (PHL).

Approach: Hear participant perspectives; Explore the challenge from stakeholder and sectoral lenses; Evaluate the current state of affairs and innovation landscape.

INSPIRE
Day 1

Goal: To inspire a future vision in which the challenge of extending the shelf life of perishable crops isaddressed and PHL is significantly reduced.

Approach: Delve into futures foresight via expert provocation; Envision multiple "ideal futures" in which the shelf life challenge is addressed.

EXPLORE
Day 2

Goal: To explore cutting-edge innovations and trends poised to push boundaries and seed ideal future scenarios of the next 10-15 years.

Approach: Probe into new applications for existing innovations and create wholly new ideas for tackling the shelf life challenge; Imagine how existing and yet-to-come innovations might be combined to achieve transformative impact.

REFINE
Day 2

Goal: To create and refine "innovation pathways" that bring together multiple, diverse innovations poised to achieve our ideal futures.

Approach: Integrate high-potential innovation ideas into pathways; Apply various filters to test for systems fit; Adapt singular innovation ideas and integrated pathways to address possible contextual issues.

ADVISE
Day 3

Goal: To advise on an innovation agenda, or "call to action", around which to rally global stakeholders.

Approach: Synthesize top ideas generated from previous discussions; Set aspirational targets for investment in and support for shelf life innovations over the next 10-15 years; Identify critical "first steps" to spur global action on the shelf life challenge.

About the Global Knowledge Initiative

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

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