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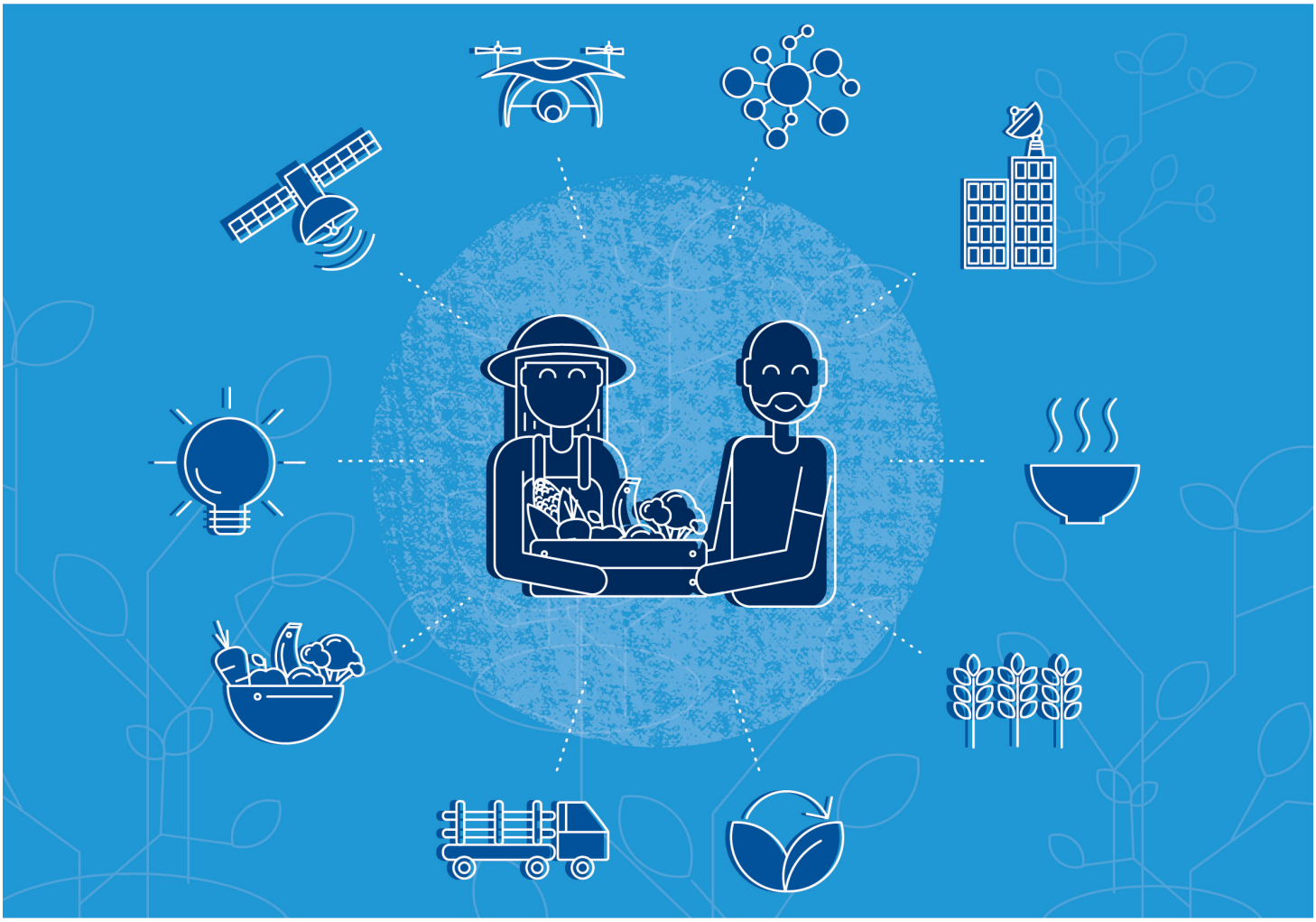
System Initiative on Shaping the Future of Food

Innovation with a Purpose: Improving Traceability in Food Value Chains through Technology Innovations

In collaboration with McKinsey & Company

January 2019



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Quotes

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The NGO community is mobilizing to give companies and governments the information they need to implement sustainability commitments. Technology is unlocking new opportunities to help fulfil these commitments by improving traceability in supply chains – and demonstrating the value of doing so.

Mark R. Tercek
Chief Executive Officer, The Nature Conservancy and author of *Nature's Fortune: How Business and Society Thrive by Investing in Nature*

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The Fourth Industrial Revolution is transforming food systems under our eyes. But we cannot take its benefits for granted, especially in developing countries where the value chain is dominated by smallholder farmers and small and medium food enterprises. Now is the time to look at emerging technologies and ask ourselves what we can do, on the policy and advocacy side, to make sure they are moving the world in the direction of inclusive and sustainable development.

Juergen Voegele
Senior Director, Food and Agriculture Global Practice, The World Bank

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Food systems begin with crop planting. Traceability technologies are essential for small holder farmers in developing countries, where it will help deliver the missing personalized farm advisory services based on farm input purchase and use. Tracing farm inputs from the factory floor to the farm will help reduce the chemical footprint in food production and antibiotic use in livestock. It will be a win-win for farmers, food companies and consumers.

Ajay Vir Jakhar
Chairman, Bharat Krishak Samaj (Farmers' Forum India)

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Ensuring traceability is vital to providing transparency and building consumer trust in the content, quality and sustainability of the end-to-end food supply chain. New technologies, such as blockchain and satellite imaging, can strengthen traceability programmes and lead to better transparency and value across the supply chain.

Paul Bulcke
Chairman of the Board, Nestlé, Switzerland

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Disruptive technologies like digital agriculture can accelerate implementation and adoption of solutions across the global food chain and allow mitigation of critical food safety concerns.

Keerti Melkote
President, Intelligent Edge, and SVP/ GM and a founder of Aruba Networks (business unit of HPE)

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Preface

Dominic Waughray
Head of Centre for Global Public Goods, World Economic Forum

Sean de Cleene
Head of Future of Food, World Economic Forum

This report supports the Innovation with a Purpose Platform, which is curated by the World Economic Forum's System Initiative on Shaping the Future of Food.

Innovation with a Purpose was initiated in 2017. The platform's goal is to help public and private stakeholders in the global food system harness the transformative power of the Fourth Industrial Revolution to better address food-system challenges.

This report focuses on traceability.

Many stakeholders engaged in the development of the Innovation with a Purpose Platform have noted how the food traceability agenda – a vital driver of food systems improvement – can be transformed through the application of Fourth Industrial Revolution technologies.

Traceability offers a powerful opportunity to improve information about the provenance, safety, efficiency and sustainability of food and food supplies, as well as much else besides. However, the application of such technologies also comes with risks if common protocols and policies are not put in place. For example, small-scale producers may potentially be excluded from more commercial value chains, where traceability technology is being applied, if those small-scale producers do not receive help to engage with such new technologies.

This risk illustrates the fact that simply applying new technologies for traceability within food systems will not necessarily provide the desired outcome. In this case, there will be a need to establish new pathways that enable small-scale producers, among others, to use disruptive technologies that underpin traceability in a way that ensures market access for all.

It is these sorts of complexities – inherent within the food system – that the report highlights. While traceability technologies have the potential to transform many current practices for the better, the report underscores the fact that these benefits will not occur automatically. Platforms to enable enhanced collaboration between diverse stakeholders throughout the food system, ranging from technology industries to smallholder farmer associations and governments, will be critical if truly distributed solutions encouraging traceability are to flourish. This will require new forms of multi-actor collaboration and co-designed policy interventions within the food system, especially in developing and emerging economies.

The Innovation with a Purpose Platform and the Future of Food System Initiative form part of the World Economic Forum's Centre for Global Public Goods. Drawing on the Forum's unique capability to help the international community make full use of public-private cooperation, the Fourth Industrial Revolution and systems thinking, the Centre for Global Public Goods is responsible for all of the Forum's multistakeholder collaborations related to shaping the international agenda for improved management of the global commons and building sustainable markets for the 2030 development goals.

It is our hope that the following report will stimulate stakeholders to engage both in this agenda in taking it to scale and the wider Innovation with a Purpose Platform at the World Economic Forum.

Executive Summary

Food plays a central role in human societies and is essential to the well-being of people and the planet. But a fundamental transformation is needed to meet the aspirations of an inclusive, efficient, sustainable, nutritious and healthy food system. The food and agriculture sector is the single largest employer in the world, despite a majority of its workers living in poverty. Nearly one-third of global food production is wasted, yet up to 800 million people are chronically undernourished.[1] In addition, food systems are responsible for 25% of global greenhouse-gas emissions,[2] while climate change in turn threatens up to 25% of crop yields.[3] And a rising global population, expected to reach almost 10 billion by 2050, exacerbates our already strained food systems.[4]

Addressing food-system challenges requires a transformative approach rooted in technological investments, partnerships and incentives. The food and agriculture sector, however, lags far behind other sectors in its investment in and adoption of technology, despite the necessity of agricultural technology to meet food-system needs. This need is particularly pronounced in developing countries, as more than 75% of agriculture and food-technology investments occur in developed countries, highlighting unequal access to new solutions.[5]

In 2017, the World Economic Forum launched the Innovation with a Purpose Initiative to support the sector's investment in technology solutions to meet these systemic challenges. The following year the Forum published a report on this topic, *Innovation with a Purpose: The role of technology innovation in accelerating food systems transformation,* which identified the 'Transformative Twelve': 12 technologies with the potential to enhance food systems.

Traceability, which builds on several of these transformative technologies, provides a foundation to address many of today's food-systems issues in addition to contributing to the advancement of the Sustainable Development Goals (see Figure 1) – and has potential throughout developed and developing markets. Many of these technologies are already beginning to disrupt food systems and drive new business models. However, such a transformation of global food systems presents risks, such as the potential exclusion of small-scale producers. Therefore, multistakeholder collaborations focused on inclusivity and innovation will be vital to optimizing the potential benefits of traceability.

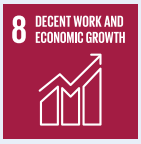
Figure 1: Supply chain improvements, like traceability, contribute to the advancement of the Sustainable Development Goals (SDGs).

The United Nations Global Compact defines "supply chain sustainability" as the "management of environmental, social and economic impacts, and the encouragement of good governance practices throughout the lifecycles of goods and services".[6] Supply chain policies and programmes, like traceability, offer key opportunities for companies to scale up their sustainability practices, thus contributing to the advancement of SDGs such as these:

End hunger, achieve food security and improved nutrition and promote sustainable agriculture – Traceability can help improve productivity to support small-scale producer livelihoods and more efficiently deliver food across the globe.

Build resilient infrastructure, promote sustainable industrialization and foster innovation – Traceability could enable improved visibility of loss points and inefficiencies in the supply chain to support sustainability goals.

Strengthen the means of implementation and revitalize the global partnership for sustainable development – Traceability can improve data collection efforts to complement statistical building in developing countries.



Promote inclusive and sustainable economic growth, employment and decent work for all – Opportunity to create new value for producers through better market transparency and access to new financial resources.

Ensure sustainable consumption and production patterns – Traceability could make it possible to measure and track the environmental, economic, health and social externalities to promote more responsible consumption and production.

The potential benefits of traceability

Traceability helps make much of what is currently "invisible" within our food systems "visible". It could potentially facilitate comprehensive tracking of the environmental, economic, health and social consequences of different agricultural production processes, even making it possible to calculate the "true cost of food", which will help meet consumer demand for transparency. In addition, producers, including small-scale producers, look to harness potential efficiencies brought about through traceability-enabled transparency, such as associated cost savings and new value sources. Traceability could improve producer revenue, market access and opportunities for affordable access to capital.

In particular, four primary areas of emerging traceability technologies can affect today's food system. These technologies can:

Meet consumer demand for food production transparency. Consumers are calling for greater food-system transparency to inform their purchase decisions and reduce the risk of buying illegal, unethical or counterfeit products. Traceability can meet this demand through in-depth tracking of supply-chain data.

Further enhance the ability to identify, respond to and even prevent food safety issues. Traceability can help food companies and governments more efficiently identify, isolate and address the source of a food safety issue. The potential outcomes could be better inspection processes to reduce prevalence of food safety issues and minimized cost of product recalls.

Support supply-chain optimization and reduce food loss. Traceability enables more effective identification of vulnerabilities in the supply chain (by, for example, determining and measuring food loss occurring at inspections or in transit), which will make food value chains more efficient and better equipped to meet growing demand. In addition, the underlying technology for traceability can garner additional efficiencies, such as accelerating product processing and reducing spoilage costs.

Validate and verify sourcing claims to support sustainability goals. Better traceability could make it easier to validate sustainability claims, hold companies and governments accountable to their commitments and more accurately measure the social and environmental footprint of production, in real time and at lower cost.

An agenda for action – with a focus on inclusivity and transformation

Traceability is not a silver-bullet solution, but it holds distinct promise in helping drive food-systems transformation. It has the potential to strengthen inclusivity and empower small-scale producers with improved market visibility and access to new services and resources. However, to ensure that its potential impact is maximized, the traceability agenda must focus on ways to introduce inclusive scaling, particularly in relation to underserved communities.

There are four priority areas for establishing inclusive pathways to scale.

An economic model to support the financing of capital expenditures and ongoing operational costs. Multistakeholder collaborations focused on scaling commercially viable solutions – combined with catalytic financing and policy incentives – can support small-scale producers. This enables them to adopt emerging technologies that would otherwise necessitate high capital investments and operational costs.

Investment to overcome infrastructure gaps and develop more robust technology and lower-cost solutions. Ongoing technological development to drive down costs and support the efficient adoption of traceability solutions will require close collaboration between providers, users, government and civil society to advance as quickly as possible.

Development of clear, consistent and globally harmonized standards for data collection, governance, ownership and sharing. Without alignment, traceability could inhibit scaling by imposing inconsistent standards and requirements that prove burdensome, particularly for small-scale producers. Neutral third-party organizations will play an important role in bringing stakeholders together to align on clear, consistent and harmonized standards.

Training on traceability requirements and access to advisory services. Helping small-scale producers make the appropriate changes to comply with traceability requirements will entail effective communication of aligned standards. This will need to be paired with training and advisory services on how to comply with these standards.

These priorities will also benefit other valuable stakeholders, like small-scale food processors or distributors, who may face similar risks.

Accelerating positive food systems impact

Creating a transformation agenda that accelerates progress towards achieving a healthy, nutritious, sustainable, efficient and inclusive food system will require unprecedented collaboration within and between organizations, initiatives and actors. Depending on a stakeholder's role in the value chain, the specific traceability challenges and opportunities it encounters will differ. Mutual understanding of these opportunities, challenges and enabling priorities will underpin effective collaboration (Figure 2). **Governments** can incentivize traceability and support adoption. **Technology companies** have the potential to further develop the transformative traceability technologies needed to reduce costs, improve delivery and maximize efficacy. **Retailers** can take the lead when convening with other stakeholders to build the right multistakeholder collaborations to bring about transparency. **Agribusiness companies** can support the application of traceability for food value chains by coming to the table with an open mind, considering new business opportunities and pushing forward on existing commitments. **Food producers**, especially small-scale producers, are at risk of being left behind; they should identify clearly what they need to ensure traceability will help their operations. **Civil society and system leaders** can play the role of convener to ensure all stakeholders have a chance for input when creating standards and requirements.

Traceability offers one example of how the 'Transformative Twelve' can be applied to address food-system challenges and bring significant positive impacts, to both more mature and emerging markets. As it develops, traceability will enable broader opportunities, though this collaboration should be built on a shared vision and executed with a recognition of the mutual benefits of partnership. To achieve traceability's full potential, stakeholders will need to come together to enable emerging technologies to go to scale inclusively and to install a broad ecosystem agenda supported by appropriate standards.

Figure 2: Every stakeholder has a collective role in supporting an inclusive model of traceability.

Section 1

Introduction

The case for food systems transformation

Global food systems are ripe for transformation. Food systems are responsible for 25% of global greenhouse-gas emissions,[7] 70% of freshwater withdrawals,[8] and 60%–70% of biodiversity loss.[9] Climate change in turn threatens up to 25% of crop yields.[10] In addition, the food and agriculture sector is the single largest employer in the world, despite a majority of its workers living in poverty. There is more food available today than ever before, yet up to 800 million people are chronically undernourished, and more than 4 billion people are either micronutrient-deficient or overweight.[11] Exacerbating the strain on food systems is a rising global population, which is expected to reach nearly 10 billion by 2050, an increase of more than 30% from today.[12]

For these reasons, a transformative approach rooted in technology and "innovation ecosystems" – enabling environments consisting of business models, investments, policy frameworks, governance models and capacity building – is required to address today's food-system challenges. Fourth Industrial Revolution technologies, such as the internet of things (IoT), artificial intelligence, precision agriculture and advanced robotics, can disrupt food systems and help shape their transformation. These technologies are developing quickly and changing the systems of production, management and governance across industries and geographies.[13]

Although Fourth Industrial Revolution technologies have the potential to positively transform food systems, investment in agricultural technology lags far behind other sectors' technological investments and is disproportionately concentrated in certain markets. For example, cumulative start-up investments since 2010 are more than ten times greater for healthcare than food systems.[14] Further, only 25% of investments in technology for agriculture and food technology are dedicated to developing countries, despite the fact that developing countries are the source of nearly 75% of agricultural value added.[15]

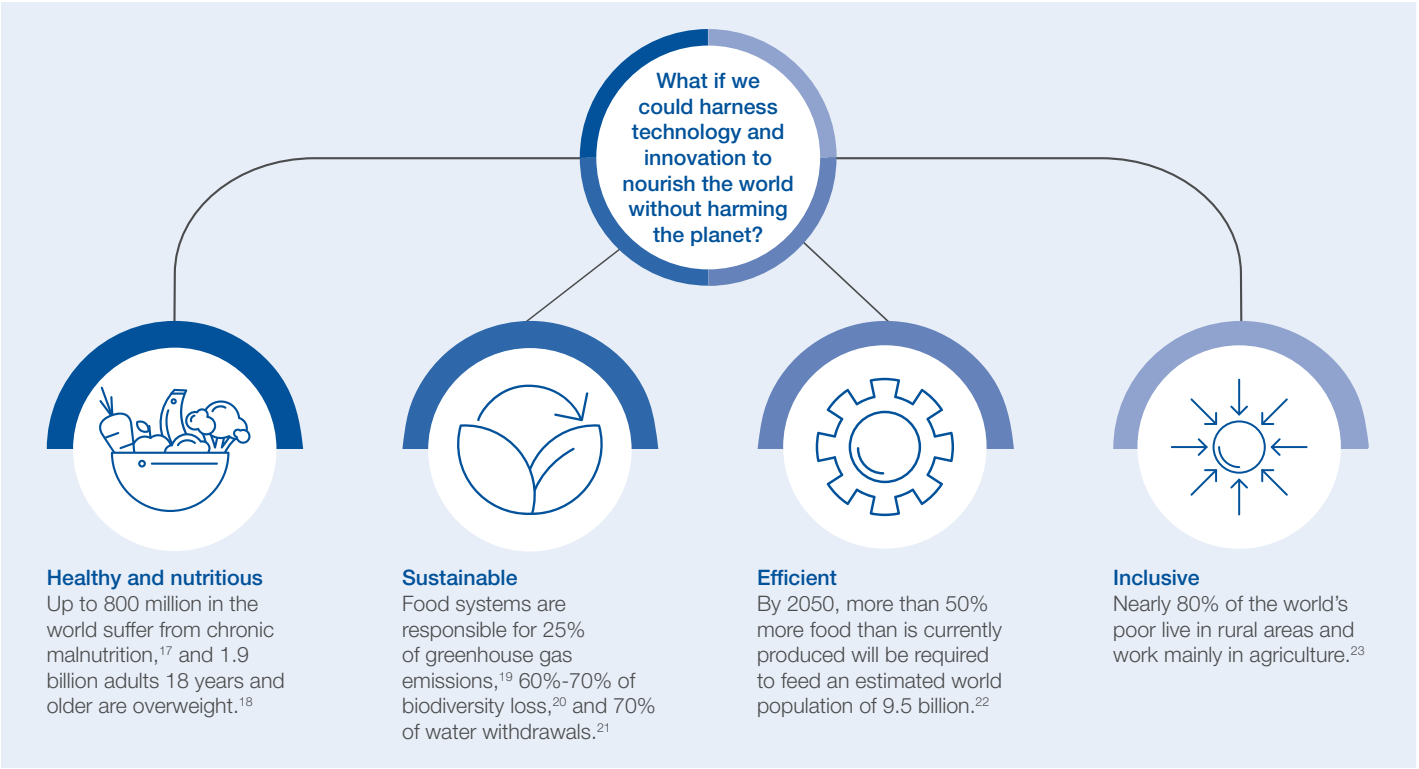
The World Economic Forum's Innovation with a Purpose

In 2017, the World Economic Forum's Food System Initiative launched Innovation with a Purpose to harness the transformative power of the Fourth Industrial Revolution to better address food-system challenges (for additional details, see Annex). The initiative launched a flagship report in January 2018 entitled *Innovation with a Purpose: The role of technology innovation in accelerating food systems transformation* that identified the "Transformative Twelve" – 12 technologies with the potential to positively affect food systems. The report states that if these technologies could scale, they could reduce the environmental footprint of agriculture, support small-scale producers (e.g. the report found that scaling mobile service delivery by 2030 could increase farmers' income by 3%–6% and reduce food loss by 2%–5%) and support healthier and more nutritious food systems (see Figure 4 for an overview).[16]

Building on this initial work, the Forum will launch Innovation with a Purpose as a platform for multistakeholder collaboration that develops and scales technology solutions for food-systems transformation. Operating as a large-scale partnership aggregator and project accelerator, the platform model will leverage a distributed set of actors for four main avenues of action: 1) to develop leadership alignment, agenda-setting and commitment to action; 2) to facilitate an ecosystem approach by promoting innovations in investments, financing and policies; 3) to catalyse, support and advance new initiatives to scale technological innovations; and 4) to develop new insights, build capacity and measure impact (for more information on Innovation with a Purpose, please see Annex).

Following the launch of the 2018 insights report, Innovation with a Purpose has aimed to actively support the scaling of emerging technologies to address food-system challenges. Three of the 'Transformative Twelve' are: blockchain-enabled traceability; using the IoT for real-time supply-chain transparency and traceability; and food-sensing technologies for food safety, quality and traceability. These, together with their underlying digital and analytics systems, are directly linked to full end-to-end technology-enabled traceability. As such, traceability is an important application of the "Transformative Twelve" to improve food systems – and is the focus of this report.

Figure 3: Aspirational vision for the global food system: Four pillars of directing the power of technology and innovation towards transforming food systems.



Improving traceability in food value chains

Traceability builds on many transformative technologies and provides a foundation to address many issues facing today's food systems. Traceability can create improved supply-chain visibility to deliver food production transparency to consumers, reduce fraud, improve food safety, increase supply-chain efficiency and reduce food loss. Further, this visibility could make it possible to capture and calculate externalities of food systems to support sustainability goals and help empower producers by linking them to markets and providing affordable access to capital.

Given the amount of trade flows between developed and developing countries, traceability is a relevant concern for both – but it is particularly relevant for the latter. Much has already been written about traceability in developed countries, and the literature has primarily focused on the role and benefits to these markets. That said, there is also important impact potential for developing countries.

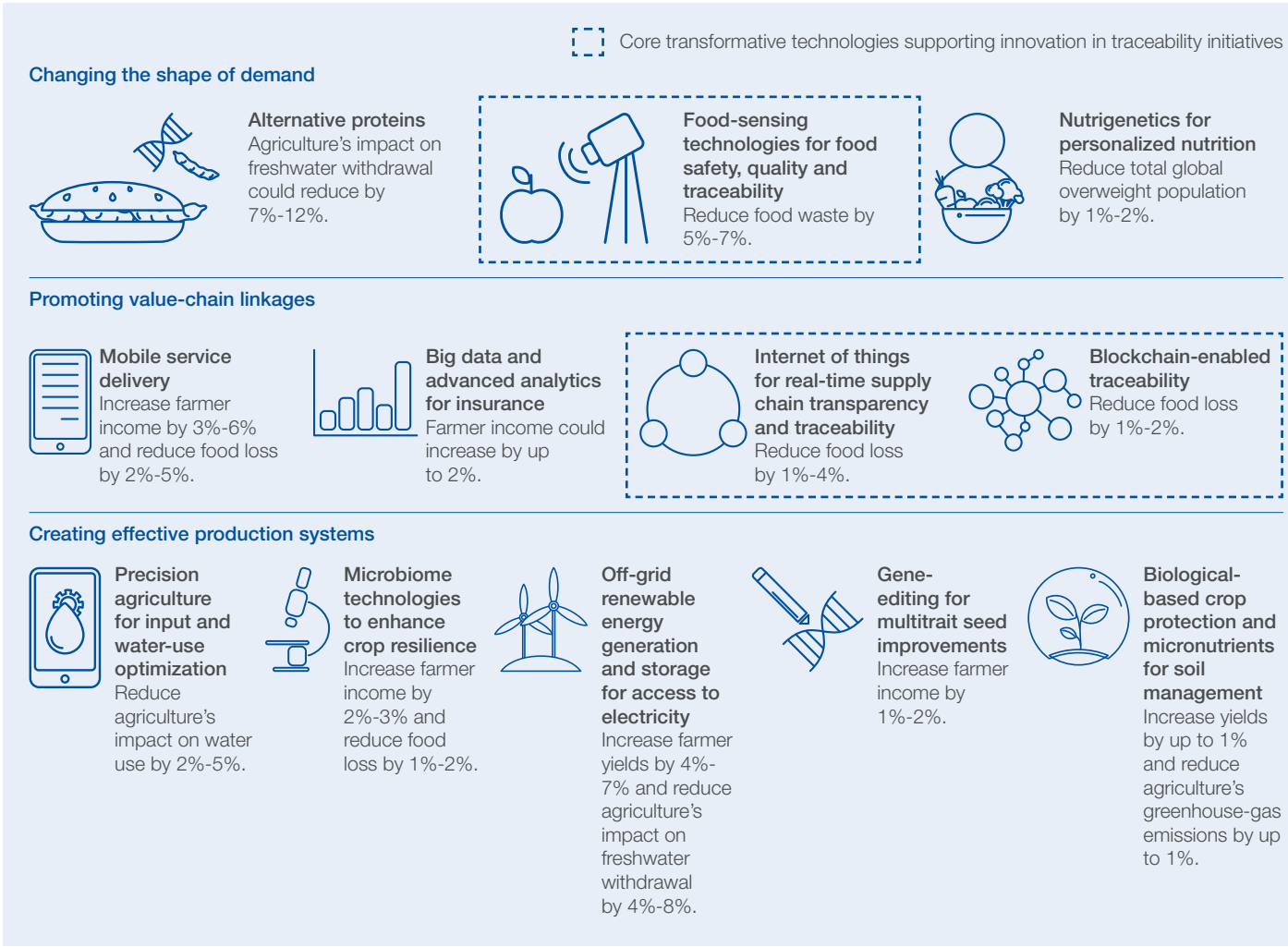
In the case of developing countries, traceability provides a significant opportunity to create value for consumers, producers and supply-chain operators. One key opportunity is the potential to identify and address loss points in the supply chain, which is a particular challenge for developing countries. For example, in developing regions, 14%-21% of production for fruits and vegetables is lost during processing; whereas, the loss rate at this stage is under 2% for developed regions.[24] Considering the increased transparency, accountability and efficiency that technology-enabled traceability can provide, there is the potential to not only reduce food loss and improve supply-chain efficiencies but to ultimately increase revenues for small-scale producers. Food safety is also a big concern in developing markets (approximately one-third of global deaths from food-borne diseases occur in Africa) and traceability can swiftly and more efficiently reduce the risk of food fraud – the misrepresentation or tampering with food or food packaging – and exposure to food outbreak risks. With the development of low-cost technology solutions to enable greater traceability, there is an opportunity for developing countries to capitalize on incremental innovations through the right capabilities and multistakeholder collaborations. These so-called leapfrogging opportunities could also enable ancillary services such as access to financial services and better market information, which are common bottlenecks in developing countries.

At the same time, while traceability has the potential to make a positive impact across markets and value chains, it also poses potential risks. One important risk is its potential to disadvantage small-scale producers, processors, and distributors who have more limited financial capital and operational bandwidth to implement new processes.

A number of traceability pilots have launched in recent years, suggesting that if business continues as usual, traceability will likely emerge in pockets. If this is the case, traceability will not necessarily deliver a broad positive impact. This report aims to assist in the transition from pilots to successfully scaled initiatives by laying the groundwork necessary for the effective and inclusive scaling of emerging traceability technologies for positive food-system impact.[25]

Food-system transformation requires a multipronged approach and, as the 2018 insights report found, effective multistakeholder collaboration is a consistent scaling requirement across the 'Transformative Twelve'. Therefore, while this report is focused on traceability, it also aims to provide framing for multistakeholder collaborations to support the scaling of other emerging technologies to address additional food-system challenges.

Figure 4: The 'Transformative Twelve' technologies affecting food systems, if scaled, could deliver significant impact by 2030.[26]



Section 2

Overview of End-to-End Technology-Enabled Traceability

Technology-enabled end-to-end traceability would represent a significant shift in how supply chains are managed today by:

- Providing comprehensive and consistent data collection along the supply chain
- Adopting new distributed ledger technology that allows for easy sharing, aggregating and analysing of data
- Creating low-cost, commercially viable and comprehensive food-testing and monitoring solutions (see Figure 5).

Figure 5: Traceability system and the role of the 'Transformative Twelve' technologies for traceability.

Components of a traceability system[27]

	Details
Data elements	Specific data captured through the traceability system (e.g. origin, water usage, etc.)
Unique identifiers	An assigned unique identifier to the individual food product for tracking along the supply chain; examples include RFID tag or barcodes
A **Sensor technology**	Real-time tracking of identified data elements through supply chain; enables automated data capture
B **Distributed ledger technology**	Enables easier aggregation, integration, analysis and sharing of data; today, ledgers are often completed using suboptimal paper-based systems but can be significantly improved through technology adoptions

Traceability system

"The totality of data and operations that is capable of maintaining desired information about a product and its components through all or part of its production and utilisation chain."

International Organization of Standardization

Specific 'Transformative Twelve' technologies

	Role	Examples
A **Internet of Things for real-time supply-chain transparency and traceability**	Collect comprehensive and consistent data about food products along the supply chain.	Key technology for traceability includes sensors, which facilitate identification and tracking (e.g. animal GPS tracking), health monitors or condition tracking (e.g. rumen pH, temperature, etc.) Sensors can be paired with other capabilities, including: – Equipment and tools – tracking paired with on-farm automation (e.g. milking) and smart equipment (e.g. smart grain-drying silos, new robots for harvesting, etc.) – Data integration and artificial intelligence – data paired with artificial intelligence for smarter farming (e.g. prescriptive farming, crop-monitoring and fleet management)
Food-sensing technologies for food safety, quality and traceability	Comprehensive testing to ensure food is safe and not subject to fraud.	Non-invasive and non-destructive food-sensing approaches (e.g. hyperspectral imaging, image analysis and spectroscopy) identify information related to the structure of a product (e.g. near-infrared spectrometers use spot measurements to assess specific wavelengths to rapidly analyze moisture, protein and fat content), upload information to the cloud and analyze it through machine learning and imaging-processing algorithms.[28]
B **Blockchain-enabled traceability**	Where transaction data is stored, enabling potentially easy sharing, aggregating and analyzing of data.	Blockchain-enabled technology to potentially more efficiently track, aggregate and share supply-chain data; blockchain is: first, distributed (shared record keeping system that eliminates the need to aggregate or reconcile across several separate ledgers); second, immutable (once information is added, it cannot be deleted); and third, requires a specific "key" to view specific information or add to the ledger. An alternative distributed ledger solution could include a system such as an ERP system with a ledger controlled by a third party with different access rights for different players.[29]

Other technologies (e.g. remote sensing, photo and video monitoring and machine learning) can also be applied to support traceability initiatives

Together, these technologies can provide value for food systems (as detailed in section 3). A number of food-system actors have begun to collaborate, testing the potential of different emerging traceability technologies and forming the necessary environment to enable change. These collaborations incorporate different players in the value chain, lead to a number of new and innovative start-ups and include significant engagement from a number of civil-society organizations (see Figure 6).

There is still work to be done before there is conclusive proof of concept for an operational model in which all of these technologies work together. As such, there are three broad challenges in need of further investigation:

Technology gaps need to be addressed and supply-chain models enabled. Certain products are easier than others to consistently track throughout the supply chain. For example, an identifier can be placed on an apple early on in its supply-chain journey and remain consistent throughout, whereas most meat products change form through their journeys, requiring new labelling of products. This is further complicated by commingling (e.g. a single hamburger patty is not necessarily from a single cow). Short of new and more advanced identifiers, extensive supply-chain changes would likely be necessary to disaggregate products by source or quality. Important hurdles will need to be cleared to facilitate comprehensive end-to-end traceability, including the "material" nature of identifiers and supply-chain operation changes.

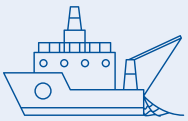
In addition, current technologies can help reduce the input of false or fraudulent information, but relying on them is an imperfect solution. For example, blockchain is very good at validating the "who" but not necessarily the "what", and sensor technology could be susceptible to hacking. Finally, certain sensing technologies will require additional development to be commercially viable across markets.

Alignment on standards and technology infrastructure is needed. Value-chain players will need to align on standards, including on what data needs to be collected, how it must be collected, how it will be governed and how it will be shared. One vital debate remains over whether blockchain or a different distributed ledger solution is better suited for food systems.

Solutions tailored to overcome infrastructure gaps must be found. Globally, there is unequal access to important enabling technologies (e.g. approximately 765 million people in rural communities lack access to electricity[30] and less than 50% of the global population uses the internet).[31] However, simple mobile phones are much more widespread and solutions adapting to this type of technology could be instrumental in overcoming near-term gaps.

Figure 6: Ecosystem engagement throughout the value chain signals promise for emerging traceability technologies.

IBM has developed the "IBM Food Trust", engaging food and agriculture players on its blockchain-based traceability system, including Dole, Driscoll's, Golden State Foods, Kroger, McCormick & Company, McLane Company, Nestlé S.A., Tyson Foods, Unilever N.V. and Walmart.[32]



The World Wide Fund for Nature has collaborated with several organizations on the use of blockchain and other technologies to validate sustainable production practices and ensure the legal and ethical sourcing of seafood.[36]

Private-sector food and agriculture organizations have developed a series of partnerships to perform multistakeholder collaborations

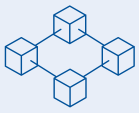
Traceability pilots and initiatives

Civil-society organizations are advancing the transparency/ traceability agenda, with a specific focus on achieving environmental and social sustainability goals

Archer Daniels Midland, Bunge Limited, Cargill and Louis Dreyfus Company issued a joint statement in October 2018 that they are investigating methods to "standardize and digitize global agricultural shipping transactions for the benefit of the entire industry".[33]

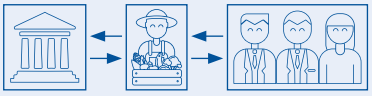
Start-ups focused on traceability solutions have received a wave of funding

FoodLogiQ, a supply-chain software that tracks food safety, raised $19.5 million in a 2018 round with investors such as Tyson Foods, Renewal Funds, Greenhouse Capital Partners and Pontifax AgTech.[34]



Ripe.io, a blockchain-based traceability solution, recently received $2.4 million in financing from investors such as Maersk and Relish Works.[35]

Field to Market, an alliance for sustainable agriculture, fosters collaboration across agribusiness, the public sector, universities and conservation groups to "define, measure and advance the sustainability of food, fiber and fuel production in the United States". The organization aims to unite the agriculture supply chain around a common measurement framework for continuous improvement.[37]



Section 3

Potential Benefits of Traceability on Food Systems

Consumers want more information about where their food comes from, how it was grown and how the food and agriculture sector is ensuring transparency, safety, equity and sustainability. Such a transformation of the food system, however, will require implementing tools such as traceability that can create improved market visibility and understand the environmental, economic, health, and social externalities of agricultural production. Further, producers hope to harness potential efficiencies in the system to realize associated cost savings and new forms of value and market access brought about by the resulting change.

By increasing transparency into food value chains, traceability can affect food systems in the following ways:

1. Meet consumer demand for food production transparency.
2. Further enhance the ability to identify, respond to and even prevent food safety issues.
3. Support supply-chain optimization and reduce food loss.
4. Validate sourcing claims to support sustainability goals.

Different models for implementing traceability can be built to target a specific area of impact. However, these areas are not mutually exclusive, and it is possible to develop traceability models that achieve impact in all of the above dimensions.

There is both demand and impact potential across developed and developing markets, though questions remain regarding the feasibility of implementation and the extent of impact. For example, implementation will pose a greater challenge and operation plans will need to be adjusted for communities with more limited digital and physical infrastructure. In addition, certain stakeholders, like small-scale producers, may be increasingly burdened financially and operationally when implementing traceability requirements. Considerations for inclusive scaling are discussed in section 4.

A. Areas of impact for improving traceability in food value chains

1. Meet consumer demand for food production transparency

Most consumers want access to product data that can help better inform their purchase decisions and provide additional assurance that products purchased were produced legally and therefore not subject to fraud.

Recent research suggests that consumers are increasingly using food production data to inform purchase decisions (e.g. “locally sourced”, “organic” and “antibiotic-free”). Though the specifics may vary by region, demand for transparency is significant – and growing in all major world regions. One 2016 survey found that of the 30,000 participants, an average of 72% of consumers in Asia–Pacific, Europe, Africa, the Middle East, Latin America and North America “want to know everything that is going into [their] food”.[38]

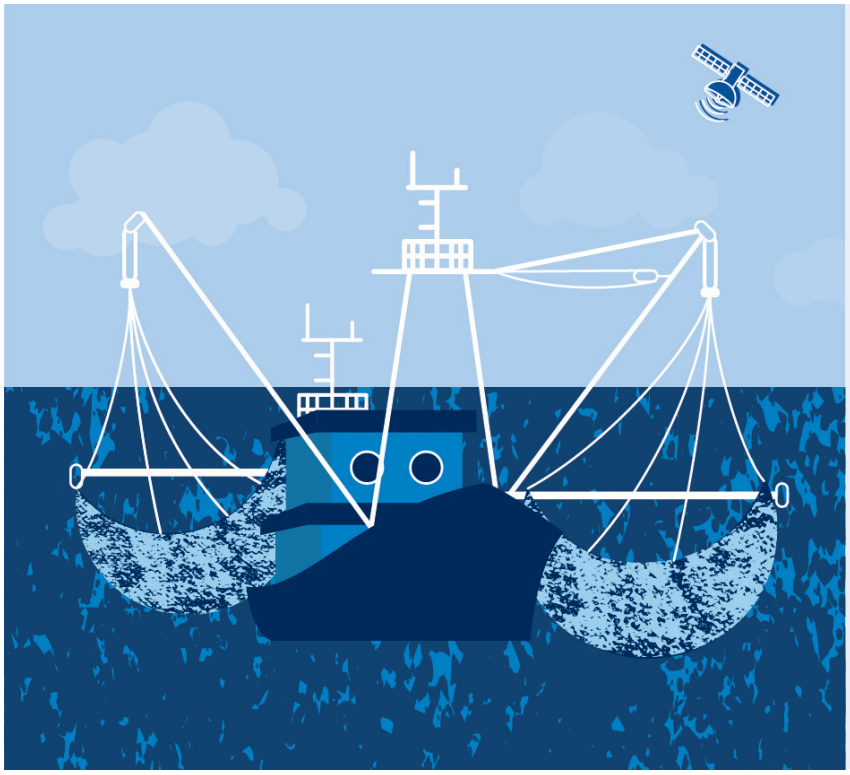
In addition, government regulation has contributed to demand for transparency, and many countries have imposed food import requirements, such as the European Union’s Genetically Modified Organism (GMO) regulation.[39] In certain cases, this type of regulation has the effect of traceability not only being advantageous to meeting consumer demand but also being a requirement to reaching consumers in the first place.

While consumers use labels and certifications to inform their purchase decisions, many believe labels are insufficient to provide the transparency they demand – the information is incomplete, at times confusing or subject to fraud. Of 1,500 US consumers surveyed, 75% do not trust the way brands currently provide product information.[40] This issue is driven in part by a financial incentive to mislabel products to the highest price premium possible with certain labels or certifications,[41] such as “organic” or “Fair Trade Certified”.

Food fraud can be prevalent and far-reaching. According to the Food and Agriculture Organization (FAO), food fraud is defined as the “intentional adulteration of food for financial gain. This can include deliberate substitution, dilution, counterfeiting or misrepresentation of food, ingredients or packaging; or packaging; or even false or misleading statements made about a product”.[42] The annual estimated cost of food fraud is $30 billion to $40 billion.[43] Bad players in the industry can cause public health risks (e.g. melamine-tainted milk or olive oil contaminated with common allergens such as seed oil), loss of consumer confidence and market inefficiencies, where those providing genuine high-quality products lose out to those who only claim to do the same (e.g. approximately 33% of seafood in the US is mislabelled).[44]

In China, for example, several instances of food fraud, such as the 2015 "zombie meat scandal", when authorities seized 100,000 tonnes of expired meat, have caused consumer concern regarding the safety and validity of their food. According to one report, 71% of China's population believes food safety is a very big or moderately big problem,[45] encouraging the government to strengthen its food safety laws and enact tough penalties on violators.[46]

Distributed ledger technology (e.g. blockchain), paired with automated data capture by IoT sensors and robust food-sensing technologies, could help address consumer demand for transparency and support government aims to protect citizens from fraud (see Figure 7). This can be done by validating the source of inputted information and increasing automation to lessen the risk of human error and prevent data from being deleted. These solutions, however, are not foolproof and currently cannot completely safeguard against substitution fraud.



Traceability in Sustainable Ocean Production

In the seafood sector, Illegal, Unregulated, and Unreported (IUU) fishing causes an estimated $23 billion in global economic losses annually.[47] The largest hurdle to combatting IUU fishing historically has been a lack of transparency and traceability in the supply chain.

As the importance of seafood to meet global protein demand becomes increasingly clear, momentum to implement new technological capabilities to combat IUU fishing has developed. The governments of more than 50 countries and the European Union have ratified the United Nations' Port State Measures Agreement (PSMA), imposing new controls on boats landing fish in their harbours. Sixty-six major retailers and processors have signed the Tuna Traceability Declaration, committing to sustainability and, specifically, to full traceability, from boat to plate, by 2020. Innovations in data technology provide the essential foundation for implementation of these commitments. For example, satellites can now be used to track the movements of every large fishing boat on the water, while digital ledgers and other technologies can create immutable records of transactions throughout the supply chain. These capabilities are already creating important change for the seafood industry.

Figure 7: Traceability initiatives can help reduce food fraud.

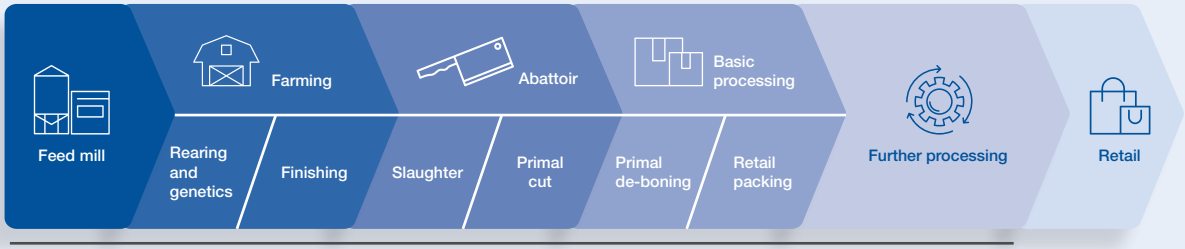
Situation: A Chinese fast food provider aims to safeguard against domestic food fraud.

Context

China has been affected by a number of food fraud scandals in the 21st century (e.g. the 2015 "zombie meat" scandal when authorities seized 100,000 tonnes of expired meat).[48]

71% of the population considers food safety to be a big or very big problem.[49]

Solution overview



Each transaction is input on distributed **ledger technology** (e.g. blockchain) that enables data input to **be tracked back to the source and cannot be changed** (e.g. expiration dates cannot be easily replaced with fake labels in the packaging process).

Tracking of content is facilitated with a unique digital identifier, such as an **RFID tag, and sensors along the supply chain**.[50]

Food-sensing technologies, such as hyperspectral imaging, if advanced and made commercially viable, **could result in comprehensive inspection of nearly 100% of commercially available food**.[51]

Operational consideration:

Meat is difficult to track consistently along the supply chain, because products sourced from different farms often commingle;[52] new supply-chain processes and/ or new types of individual identifiers may be needed to overcome this challenge.[53]

Traceability initiatives could also become a significant differentiator among companies by increasing the amount of information available to consumers. For example, the price paid to the producer and the amount of water used to grow the crop could be made available, and companies could even market and label the products according to verifiable taste and quality. Such guarantees would likely promote increased customer satisfaction and brand loyalty.

2. Further enhance the ability to identify, respond to and even prevent a food safety issue

The World Health Organization estimates that 600 million people – nearly 1 in 10 – fall ill and 420,000 die each year due to contaminated food.[54] Although the prevalence and severity of food safety risks is comparatively higher in developing markets (e.g. approximately one-third of the global deaths from food-borne diseases occur in Africa),[55] the issue remains a concern globally. For example, the USDA finds that the economic burden of major food-borne illnesses in the United States is approximately $15.5 billion.[56] Although this challenge is relatively small in comparison to the overall size of the industry (agriculture, food and related industries contributed $992 billion to US GDP),[57] it still presents a material risk to public health and the economy. For instance, it is estimated that 48 million Americans get sick each year because of food-borne illnesses,[58] and the International Trade Commission found that trade restrictions due to "mad cow disease" cost the US beef industry $1.5 billion to $2.7 billion in annual revenues from 2004 to 2007.[59]

Traceability is not a cure-all to eradicate food-borne illnesses, but it can help food companies and governments more precisely address a food safety issue. It can also result in better inspection processes through new sensing technology, therefore reducing the prevalence of food safety concerns.

Food safety issues that trigger a recall are relatively rare but pose significant financial risks to the food industry. A survey of Grocer Manufacturers Association (GMA) companies found that 81% of respondents evaluated the financial risk from recalls as "significant to catastrophic". Of those surveyed, 58% indicated that they had been "affected by a product recall in the past five years", while 23% of those affected estimated the cost to be more than $30 million, which accounts for both direct recall costs and losses in sales.[60]

Traceability could reduce the exposure to food outbreak risks by making it faster, more efficient and more feasible to identify a source of food contamination precisely, thus containing the impact. Currently, these processes are time-intensive and costly. For example, the 2018 outbreak of *E. coli* infections linked to romaine lettuce from the Yuma growing region took about three months to resolve and resulted in 210 individuals falling ill, 96 hospitalizations and five deaths.[61]

Adoption of IoT and distributed ledger technologies would improve the health of consumers and the bottom line of players throughout the food value chain, ensuring that only the contaminated product is removed from shelves rather than all similar products (see Figure 8).

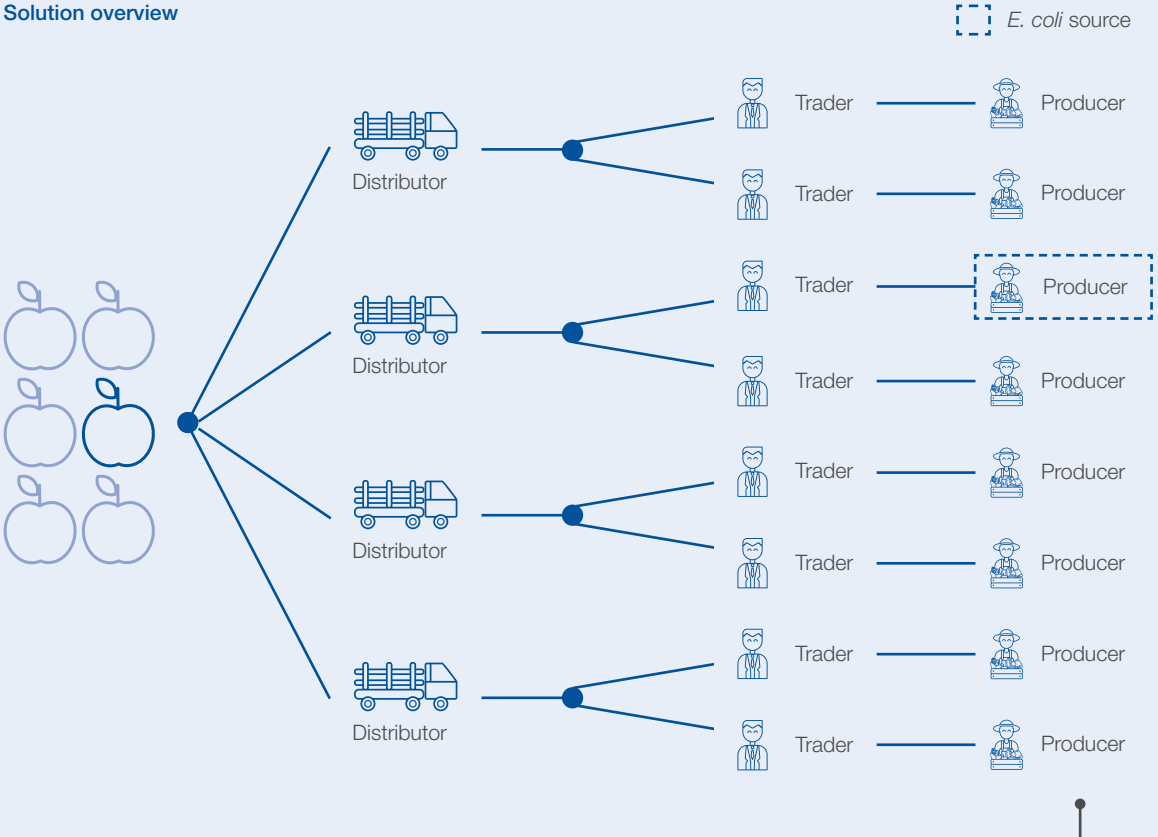
Figure 8: Technologies can work side by side to facilitate more effective identification of contamination sources.

Situation: A grocery company in the European Union imports fresh fruit and vegetables from smallholder farmers in developing countries and wants to develop a traceability system to efficiently identify and address any potential food-safety issues.

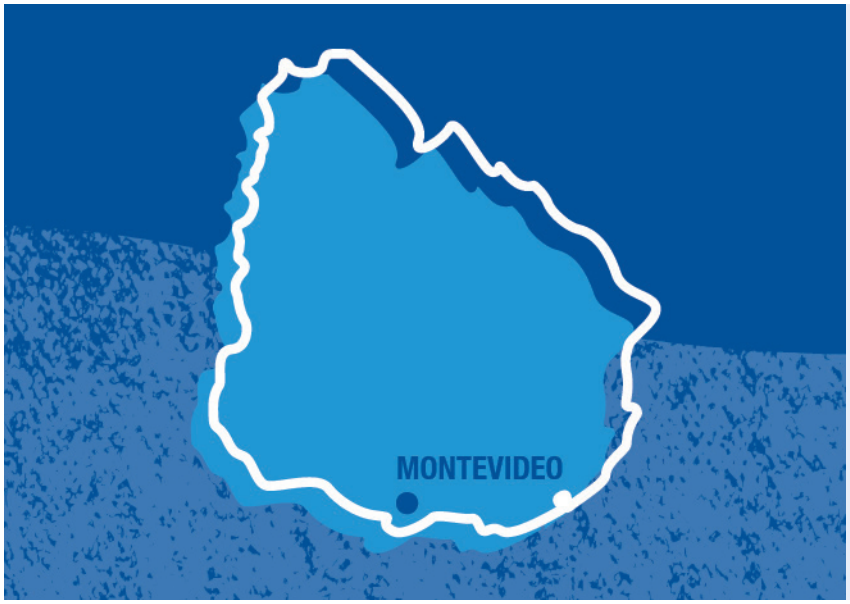
Context

Despite leading the world in food safety regulation, the EU still faces food safety challenges: in 2016, the EU's Rapid Alert System for Food and Feed (RASFF) found more than **700 instances of "alert notifications" that were "serious", in which "food, feed or food contact material presenting a serious risk on the market [is found] and when rapid action is or might be required"**.[62]

Solution overview



In most foodborne illness outbreaks today, all of the producer's products would be recalled or removed from shelves; whereas traceability could make it possible to remove only the contaminated products.[63]



Public sector–driven investment in Uruguay created a technology-based traceability system for cattle and beef

In 2001, a foot-and-mouth disease outbreak severely affected Uruguay, resulting in costs of $243.6 million.[64] With 3.8 cattle per capita, beef is Uruguay's second-largest export product. As a result, disease outbreaks like this pose a significant economic risk to the country.

To reduce risk exposure and promote food safety, Uruguay implemented an individual livestock traceability system, that requires electronic ear tags for all cattle populations.

These devices are considered a "public good". As a result, the government provides and distributes the ear tags at no cost to food producers.[65]

With improved data collection, agronomists and others have also used the data to deliver new targeted advisory services to producers.

To address susceptibility to food outbreak risks, companies in the food and technology space have invested in traceability initiatives. A 2016 pilot involving a partnership between Walmart and IBM serves as one example. Using blockchain, the companies were able to identify the source of a mango in 2.2 seconds compared with nearly seven days using standard processes.[66]

That said, traceability initiatives will need to carefully consider the impact on small-scale producers, ensuring the requirements support inclusive adoption. (This topic will be discussed in depth in section 4.) In addition, governments are increasingly investing in technologies that enable traceability to meet objectives considered a "public good", such as when Uruguay's government implemented a traceability initiative.

Traceability initiatives could also improve product testing and prevent the likelihood of contaminated food entering the market. Food-sensing technologies, such as hyperspectral imaging, are being developed to more efficiently inspect a higher percentage of food. A series of 2016 experiments tested the technology's ability to identify contaminants in red meat. The results were promising: the test achieved up to a 99.67% success rate in identifying contamination, fat or lean pixels.[67] Additional technological development is needed before this technology can achieve widespread commercial viability. Technology entrepreneurs, however, are rising to the challenge and hope to eventually make it possible for consumers to use similar technology on their mobile devices.[68]

The combined implementation of IoT, distributed ledger technology and food-sensing technologies could also lead to significant improvements in food safety for low- and middle-income countries, which tend to have more food safety issues than their developed-market counterparts. Consumers in these countries with the means to do so often purchase imported products they believe are safer rather than purchasing from local markets. Paired with a proper enabling environment (e.g. improved governance and an attractive business case for producers), implementing these technologies could provide the incentive and the means to meet domestic demand for food safety.[69]

3. Support supply-chain optimization and reduce food loss

Approximately 1.3 billion tonnes, or one-third of all food produced, is wasted or is lost in the supply chain. Supply-chain inefficiency is a core contributor to food loss across food systems and is a particularly strong cause of loss in developing countries. For example, in Sub-Saharan Africa, over 35% of fruit and vegetable production is lost or wasted during post-harvest, processing, or distribution; whereas in Europe, less than 15% of production is lost or wasted during these same stages.[70]

In addition to straining food systems, food loss results in unnecessary procurement and distribution costs along the supply chain, which in turn causes businesses and consumers to pay more.[71] Due to a higher degree of perishability, fresh (typically nutritious) foods are most vulnerable to loss, compounding the negative affect on the health of consumers.

Setting up sensors along the supply chain to facilitate automated data capture of food's supply-chain journey would enable better loss identification. Based on the agricultural product, region and specific supply chain, the source of loss can differ. Some common examples of contributors to loss include poor harvesting practices, limited-storage cold chain and processing facilities and unreliable transport networks. Once the primary causes of food loss and waste have been identified, however, the appropriate stakeholder can better address the problem.

Traceability initiatives make it possible to better identify sources of food loss – and the use of the underlying technology could provide several other supply-chain efficiency opportunities, including but not limited to:[72]

- Increased supply-chain automation, saving hours of processing
- Faster real-time information collection, improving a manager's ability to make rapid and informed decisions
- Improved product scanning, resulting in faster ordering

In addition to cost-saving opportunities, these efficiency improvements also make it possible to increase the rate at which food moves through the supply chain, reducing spoilage costs and thereby creating incremental improvements to our supply chain's ability to meet rising future food demand and improve sustainability.

4. Validate sourcing claims to support sustainability goals

The environmental and social impacts of food systems are significant. In fact, food systems are responsible for 25% of global greenhouse-gas emissions, account for 70% of freshwater withdrawals and are the most significant contributor to deforestation.[73] If the status quo is maintained, there will be a 40% gap between global water supply and demand by 2030.[74]

There are many complex factors underlying the effects of food systems on the environment – and a multifaceted approach will be necessary to address any challenges. Indeed, traceability alone is insufficient to address the environmental footprint of food, though it could play an important role in supporting global sustainability goals.

Traceability initiatives involve more comprehensive data collection than is currently available. They could make it possible to calculate multiple metrics related to food production in real time, such as CO_2 per product and the environmental impact of excess water usage. For example, Purdue University, in partnership with Hewlett-Packard Enterprise, have implemented an IoT test-bed infrastructure to measure weather and climate effects and to trace the increased impact of nitrogen emissions on agriculture production and water and air quality. Soil-bound sensors could measure how much water was applied to the crop and link to precision irrigation systems. Such a granular approach would not only help increase water efficiency but could also help identify areas in a value chain with the largest environmental footprint.

Over time, it is possible that these technologies could comprehensively track the environmental, economic, health and social externalities of different agricultural production processes to calculate the "true cost of food", or the value of food after calculating externalities such as carbon emissions. Access to this verified information could help governments incentivize more sustainable and socially responsible production processes, enabling consumers to more confidently make choices based on true cost. Indeed, this effort would help reward food value chain players for engaging in sustainable practices while limiting illegal activities or unethical actors. As has been seen with carbon and water footprints in other industries, applying data to assess the comprehensive impact of different options is an essential step towards effective policy and multistakeholder solutions.

Organizations have already begun to experiment with emerging traceability technologies to support sustainability goals. For example, the World Wide Fund for Nature (WWF) has collaborated with several organizations on the use of blockchain and other technologies to validate sustainable production practices to ensure the legal and ethical sourcing of seafood.[75] This approach has the potential for widespread application to other food commodities.

The ability to calculate the "true cost of food", however, risks negatively affecting small-scale producers depending on their location and practices. The collection of this data and its analysis will be contentious and problematic for some, but could prove foundational to advancing the broader food system – and traceability serves as an enabling tool to support the development of this approach.

Furthermore, it may not always be economically or operationally viable to employ a granular level of product-based end-to-end traceability. Other methods to increase transparency should also be considered, such as solutions that provide visibility to the performance of the supply chain as a whole, rather just one individual unit of product. For example, the Nature Conservancy, WWF, Greenpeace and others have teamed up to establish the Accountability Framework initiative (AFi), to establish "definition, norms and good practices for delivering on companies' ethical supply-chain commitments".

The current preliminary draft of the AFi suggests that Geographic Information Systems, paired with other open-sourced and customizable data (e.g. government trade data), can help monitor how companies comprehensively stack up against their deforestation-free and conversion-free commitments.[76] Likewise, Trase, a partnership between the Stockholm Environment Institute and Global Canopy Programme, used publicly available data to trace the links between consumer countries – by way of trading companies – and the place of production. Trase aims to provide mapping of 70% of total production in major forest risk commodities by 2021.[77] These types of solutions do not enable traceability for a specific unit of product, but they do help increase the visibility and transparency of the supply chain and enable supply-chain players to evaluate their performance against their commitments.

B. Considerations for the business case of traceability

The value of traceability will differ according to the value-chain player and product. As a result, it is dependent on each value-chain player to consider their traceability use-case and conduct their own cost-benefit analysis.

As a starting point, determining cost-saving opportunities will be relatively straightforward. Food recall costs and supply-chain inefficiency costs, though they differ according to the stakeholder, are fairly well defined.[78] These cost-saving opportunities will need to be weighed against the capital expenditures of acquiring technology and operational costs such as new training. A consortium approach, or partnership involving several different companies interested in traceability, can be a way to reduce such costs.

For example, a consortium of the world's largest retailers, in addition to other supply-chain players, could realize economies of scale for traceable products. Such a consortium would be able to spread investment and implementation costs across a greater percentage of sales in addition to sharing costs between supply-chain players. This sort of solution could be particularly compelling in cases where up-front capital is needed to kick-start traceability for producers or other value-chain players that cannot afford the up-front capital costs on their own.

If traceability could not only provide cost-saving opportunities but also be a source of new revenue, the case for traceability would become particularly compelling. A number of studies indicate that consumers are willing to pay more for traceable products; in fact, consumer willingness to pay could even result in topline revenue growth of 0.8%–3.4%,[79] while other figures are as high as 10% on average.[80] However, there is doubt as to whether or not the information provided by consumers in such surveys is truly representative of their willingness to pay. If consumers are indeed willing to pay more for traceable products, then a compelling business case for industry could be made – serving as a strong driver of traceability initiatives. In some cases, determining consumer willingness to pay will require the industry to implement pilots or initiatives, in which case pursuing high-growth-potential opportunities, such as high-distribution perishable products sourced from emerging markets, could prove advantageous.

Section 4

An Agenda for Action – with a Focus on Inclusivity and Transformation

Traceability can provide significant value to food systems. However, to maximize its potential impact, the traceability agenda must focus on pathways for inclusive scaling, particularly in relation to underserved communities.

A. The case for an inclusive model for traceability

The areas of food-system impact created by enhanced traceability – meeting consumer demand for transparency and reduced fraud, improving food safety, optimizing efficiency and supporting sustainability initiatives – are relevant to both developed and developing markets. In addition, because significant amounts of agricultural products are involved in international trade, a traceability initiative implemented in one country will affect other countries that export to that market. Implementation considerations, however, will differ according to the market and must be tailored to the specific context of the country or region.

A focus on "pathways to scale" – policies, standards and economic models – that help support the inclusive scaling of new agricultural technology is critical to support global poverty alleviation goals. Agriculture plays a central role in the lives of many of the world's poor – approximately 2.5 billion people in developing countries make their living from the food and agriculture sector, and about 60% of those individuals live in small-scale producer households.[81] In addition, GDP growth from agriculture is at least twice as effective on average at benefitting the poorest half of a country's population than growth based in other sectors.[82]

1. In the absence of effective pathways to scale, traceability has the potential to disadvantage small-scale producers

Traceability is likely to entail more demanding requirements, including added cost. In the absence of effective supporting models, these requirements risk favouring larger producers or developed-country firms that can more easily absorb the added cost and adjustments. Furthermore, the required up-front capital expenditures (e.g. sensors) pose a particular risk in the near term. In the past, implementation of new standards or regulations has resulted in drops in market participation by small-scale producers. For example, following the compulsory GLOBALG.A.P. certification in Kenya, small-scale producer participation in formal export markets dropped by 60%, as the certification required more financial capital than small-scale producers could afford on their own.[83] Poorly executed traceability standards and requirements could have a similar effect. Establishing pathways that help empower small-scale producers to use these technologies so they can obtain markets is a vital strategy for helping such producers escape from poverty.

In addition, many small-scale producers who source primarily to informal local markets may be largely unaffected by traceability initiatives. It is unlikely that traceability standards will evolve in informal markets, at least in the near future. Therefore, the potential impact of traceability will be most relevant, especially in the near term, to producers who sell their products in export markets as well as domestic formal markets.

USAID's traceability system for fruits and vegetables in Ghana[84]

USAID's Trade and Investment Program for Competitive Export Economy implemented a traceability system for growers of fruit and vegetables in Ghana. Their goal was to increase exports to the EU and increase smallholder participation in these markets. The solution, which ran between 2005 and 2009, took advantage of GIS and barcode applications with GPS research, barcode scanners, a wireless mobile network and networked computers. In one programme evaluation, half of respondents in the mango value chain reported that they had expanded their mango-growing area, which resulted in other livelihood improvements, including an increased ability to educate children and make home improvements.

2. Traceability has the potential to empower small-scale producers with improved market visibility and access to new services and resources

If near-term financing and operational challenges can be overcome, traceability could create new value for producers in developing countries by increasing market transparency between producers and consumers.

For example, traceability could help producers verify that their products meet production standards, helping them gain access to better markets. Producers could also negotiate a higher price for preferential products of better quality. For instance, coffee with a known source can earn a producer as much as two to three times more in revenue compared with coffee from less-known areas.

Increased access to data could give producers insight into consumer preferences, provide feedback on products and enable them to adjust production processes according to performance. For instance, if Farmer A knows that Restaurant Z prefers extra-sweet tomatoes, Farmer A can adjust the production process, knowing they will be compensated for delivering tomatoes with the preferred taste profile.

Market transparency would also increase visibility of the percentage of a product's final price, translated into the value for the producer. This insight could create market pressure for more equitable realization of value throughout the food value chain.

From a funding perspective, traceability could help garner new financing options for small-scale producers, many of whom currently lack consistent and affordable access to credit. Establishing e-commerce platforms that link buyers and sellers is one way to develop credit histories for small-scale producers and entrepreneurs. Furthermore, lenders can better understand potential risk by studying transaction data derived through traceability initiatives.

Pairing data platform initiatives with traceability could also better inform public-sector investment in rural communities and help the private sector tailor their product offerings more effectively. For example, more accurate production-level data could support the development of apps aimed at delivering improved agronomic and market advice to small-scale producers.[85]

Lastly, traceability technologies could have additional benefits for producers, potentially increasing overall productivity and efficiency. For example, average dairy farm productivity in India is low – productivity per animal is less than half of the global average. With IoT technologies, however, employing sensors could help identify sick animals and then help them recover, increasing productivity (see Figure 9).[86]

Figure 9: A traceability initiative could enable small-scale producers to gain better market access.

Situation: An Indian dairy cooperative sourcing dairy from local small-scale producers aims to improve product safety for better market access.

Context

Dairy farming plays an important economic and social role in India: it is a secondary occupation for about 69% of its farming population,[87] and about 27% of agricultural GDP,[88] and about 83% of agricultural landholdings are less than 2 hectares.[89]

While India's dairy farming economy is large, the average productivity is low – productivity per animal is less than 50% of the global average.[90]

In addition to low productivity, smallholders also face poor market access.[91]

Solution overview

A driver of inefficiency and a challenge faced by many cooperatives is identifying the exact sources of inefficiency within a particular supply chain. Without being able to identify the source of loss or inefficiency, it is not possible to address these challenges, which IoT solutions can help to support in the following ways:[92]

Potential "loss point"	How traceability technologies help
Health and tracking of animals	Improve productivity through: 1. Easy identification of sickness for effective and early treatment. 2. Improved accuracy of ovulation to improve rate of insemination.
High wastage due to product safety testing occurring after product has been commingled with other product from several sources	Traceability can reduce loss through enhanced testing – now, disease testing usually takes place only after milk has been mixed from multiple sources.
Time-intensive manual processes	Improve automation for more efficient payment-processing and data collection.

Many producers lack the means to finance the capital expenditures needed to implement emerging traceability technologies; financing options would need to be considered (e.g. micro-consignment model or public-private investment to offset initial investment, etc.)

HARA: Blockchain-based ecosystem in Indonesia

HARA is developing a blockchain-based ecosystem that supports data collection and traceability goals in Indonesia. The HARA ecosystem enables farmers to enter data related to their farming production into their mobile phones. Farmers, as well as others who engage in the data exchange (e.g. cooperatives, NGOs, etc.), receive HARA loyalty points for their contributions. These points can then be redeemed for services and products, including phone credits and discounts on agriculture and education supplies. In addition to data providers, the system also involves data qualifiers who help validate the quality of data in exchange for loyalty points. HARA aims to engage more than 1 million Indonesian farmers on its platform by 2020.

B. Pathways to an inclusive scaling model for traceability

Establishing pathways to scale that empower small-scale producers to use emerging technologies is fundamental for an inclusive and broadly applied model of traceability. Unfortunately, small-scale producers tend to have much less political and economic power than larger players, so a thoughtful approach to bringing small-scale producers to the table is important. Priority areas for an inclusive model will need to be tailored to the specific regional or country context. There are four priority areas for action:

1. An economic model to support financing of capital expenditures and ongoing operational costs

Traceability initiatives will require small-scale producers to adopt new technologies. This will in turn require an up-front capital investment cost. In the long term, the cost of these technologies is expected to decline and the rate of adoption to increase.

In the near term, however, these capital expenditures will likely remain unaffordable for many small-scale producers. Government, civil society, investors or other value-chain players could structure financial support for some of the up-front investment to help jump-start the platform. In many cases, large retailers are likely to act as leaders, pushing forward requirements and supporting the rollout of necessary infrastructure, especially for stakeholders with more limited investment ability. Large buyers could be encouraged to provide financial support for small-scale producers to adopt this technology through a combination of a tailored traceability business case (e.g. consumer demand, reduced risk exposure to recalls and improved efficiency) and shareholder pressure. If these technologies are viewed by investors as quantifiable investments in supporting a business's long-term future and reducing the environmental and social impact of food systems, shareholders may be more supportive of capital expenditures to mitigate the risk. Donors can play an important role in supporting catalytic financing (e.g. blended financing models) to support adoption. Policies should also balance the range of local conditions and the ability for multiple food-system types and locations to interlink as needed. In addition, digital IDs and formal national IDs could be paired, making it possible to "stitch together" sufficient information about each farmer to assess risk and therefore provide more affordable financing.

Market players throughout the supply chain may require incentives to share data. Direct payments in exchange for data can be challenging, especially in the case of delivery to small-scale producers. Therefore, the food industry could consider offering other incentives such as preferential access to credit and other production inputs, as well as access to data or tools that can help inform business decisions, among other things.

Given the diversity of producers – even among small-scale producers – multiple models (e.g. direct payments, input credits or access to services most attractive to producers and feasible to implement) will be necessary and require a long-term view. Such models will likely be aided by the perspective of practitioners with an in-depth understanding of small-scale producers.

2. Investment to overcome infrastructure gaps and develop more robust technology and lower-cost solutions

Emerging traceability technologies work best when paired with a robust underlying technological infrastructure (e.g. comprehensive access to internet and electricity). That said, around 765 million people in rural communities lack access to electricity,[93] and less than 50% of the global population uses the internet today.[94] These infrastructure gaps could pose a challenge for small-scale producers who wish to comply with a traceability initiative. However, mobile technology is widespread and could help bridge the gap. For example, a small-scale producer can input simple product information through SMS text messages rather than technologies that require constant access to data. A vital priority is to develop efficient software solutions that are adapted for users with limited bandwidth, while also providing affordable hardware for use by small-scale, capital-constrained operators. In addition, governments and private companies may view this use-case as an additional benefit of advancing broader infrastructure efforts.

Further technological development is needed to support the efficient adoption of traceability solutions, such as:

- Enhanced digital identifiers – with a specific focus on processed products, eliminating the need to relabel products
- Low-cost, robust food-sensing technologies, such as a mobile delivery model that could easily put power in the hands of both consumers and supply-chain participants
- Low-cost, advanced sensors to efficiently automate information capture or advanced satellite or drone information collection to amass information at scale, with limited work required from the producer
- Technological infrastructure focused on open-source software standards, which can provide a backbone for a range of digital traceability initiatives, as well as better access to electricity, internet and data, cloud-computing networks and communication satellites
- Technology development to ensure minimal use of electricity to limit environmental impact

Global Open Data for Agriculture and Nutrition (GODAN)

Global Open Data for Agriculture and Nutrition (GODAN) is an initiative focused on building support across governments, policy-makers, international organizations and businesses to harness the growing availability of data to solve problems that "benefit farmers and the health of consumers". The initiative aims to make "agricultural and nutritionally relevant data available, accessible and usable for unrestricted use worldwide". In these efforts, GODAN has supported initiatives for clear, consistent and harmonized standards by:

1. Analysing and assessing current agrifood data standards
2. Creating a map of current agrifood data standards
3. Providing recommendations for filling identified data standards gaps

These developments will require close collaboration between providers, users and government and civil society to advance as quickly as possible.

3. Development of clear, consistent and globally harmonized standards for data collection, governance and sharing

Neutral third-party organizations will play an important role in convening different stakeholders and value-chain players to align on clear, consistent and harmonized standards.

Without alignment, traceability could inhibit scaling by imposing operationally and financially burdensome requirements and inconsistent standards across markets. Priority areas for alignment include:

Data-collection requirements. To ensure consistent collection of the most important types of data, global players should align on what data need to be collected to satisfy demand for traceability. Players will also need to align on what platform should be used, the type of technology needed to store the data (e.g. blockchain or another distributed ledger technology) and how data is collected (e.g. using a specific type of sensor for data to be considered valid), among other requirements.

Data-governance and ownership standards. Some supply-chain players, especially individual producers, are sceptical of data-collection requirements. They have concerns about who will own the data, who will have access to it and how it will be used. Therefore, it will be important to develop standards that ensure data privacy is protected, as well as considering who "owns" the data. In addition, special consideration for how consent for data collection is given should be addressed (taking into account differences between population groups, such as literacy).

Data sharing. It will also be important to consider how to "package" a large amount of new data to tell a coherent story, properly informing decisions throughout the system (e.g. how information is communicated to governments as opposed to consumers or the producer). Food value-chain players – especially producers and retailers – who hope to tell a compelling story regarding their food products will need to consider how this "packaging" will interact with pre-existing labels and certifications.

4. Training on traceability requirements and access to advisory services

Helping small-scale producers make the appropriate operational changes to comply with traceability requirements will require effective communication of aligned standards, paired with training and advisory services on how to comply with these standards. In addition to direct training on traceability requirements, value-chain players could consider supplementary resources. In 2000, for example, Egypt successfully launched a virtual extension and research communication network (VERON). This network included a web interface that enabled extension agents to pose questions on behalf of farmers seeking solutions to specific technical questions.[95]

While not easy, there have been proofs of concept that demonstrate how up-front support for small-scale producers can help them thrive in the long term. For example, following the implementation of GLOBALG.A.P. standards in Mali, a non-profit mobile data services operation and a fruit and vegetable export association partnered to support the implementation of standards for farmers in the region. In doing so, they created a web platform that collected information inputted by farmers on their mobile devices. Importers, retailers and customers were willing to pay $0.09 more per pound for the traceable products. The solution resulted in widespread adoption and compliance with the new standards and enhanced the Malian market's reputation for quality produce.[96]

Pursuing these pathways to scale will benefit other stakeholders as well – consistent standards, robust incentive models, technological development and effective training are important enabling priorities across the value chain. These pathways will support other actors who might face risks due to new requirements, like small-scale food processors or distributors who also offer important value to food systems. In addition, these priorities will also be instrumental to support the transition from pilot to fully scaled traceability initiatives for players throughout the value chain.

Section 5

Accelerating Positive Food System Impact

A. The case for multistakeholder collaboration

Full-scale traceability would be difficult for a food value chain player to achieve alone, as barriers to adoption are significant on a large scale (e.g. the financing of capital expenditures and establishment of consistent standards). Collaborations will likely come in one of three forms: horizontal (e.g. the largest global retailers and "brands" work together to align on standards and put pressure on the rest of the supply chain to comply), vertical (e.g. one retailer collaborates with their full supply chain to align on standards) or multistakeholder (downstream competitors collaborate with players from throughout the entire value chain with support from government and civil society). Multistakeholder collaboration is preferable to the other two forms because it helps set consistent standards, taking into consideration the needs and perspectives of the full value chain.

Without multistakeholder collaboration, the impact of traceability could be limited. Traceability requirements could become operationally and financially burdensome, with complex and inconsistent standards, providing limited benefit to consumers and stakeholders alike. For example, if downstream players pursue traceability in silos, food producers will need to comply with several different types of requirements and the associated costs. This risk is already apparent in the proliferation of voluntary market standards for different foods (e.g. organic, GMO-free, fair trade and certified sustainable): if horizontal collaboration between retailers is not deliberately designed to be inclusive, it could exclude small-scale producers from markets entirely.

Collaboration will broadly accelerate and amplify potential impact. Each use case will have different benefits and potential risks for leading players throughout the value chain. At the outset, not all stakeholders are required to set the foundations for standards and eventual collaboration; however, proper representation is important. For example, in the case of consumer credit scoring in the United States, retailers lacked a consistent methodology to evaluate consumers. As a result, cross-cutting national associations were formed that included representatives from both the credit agencies and retailers. These associations built the underlying consumer credit infrastructure that later became a widespread standard.[97]

B. Challenges and opportunities throughout the value chain

The specific traceability challenges and opportunities a stakeholder encounters will differ depending on their role in the value chain. Effective collaboration depends on a mutual understanding of these opportunities, challenges and enabling priorities. Several broad-stroke positions throughout the value chain are a starting point (see summary in Figure 10).

- **Input/retail and distribution.** Traceability could provide input providers with new data that would enable them to better understand the market landscape, including product usage and flows in both developed and developing countries. This data will aid in the development of more tailored advisory services and offerings. In addition, traceability could help address the challenge of counterfeit inputs, helping to validate and authenticate producers.

- **Producers.** Many producers could benefit from the potential of traceability (e.g. process efficiency). This potential value, however, is not always clear. For example, some producers are concerned with how to afford the up-front investment and achieve an economic return in addition to potential data usage issues and the burden of added complexity to operations. As a result, a clear economic value proposition and support on up-front capital expenditures, paired with proper data governance and non-burdensome data collection, will help enable engagement.

- **Trading and primary processing.** Players engaged in trading, moving and processing foods will find value in additional data that will improve understanding of inputs used, product location and flow and end use. This additional data can better inform risk models, trading decisions, operational and logistics choices while unearthing potential data-driven opportunities. In some cases, legacy business opportunities created or sustained by information and data advantages may come under pressure. Traceability and the potential for increased transparency and efficiency, however, are expected to be a net positive for the system.

- **Brands and retailers.** These players have been the leaders of most traceability pilots or initiatives to date. As such, they are able to foresee traceability's potential to create attractive new business opportunities, including those discussed in Section 3 (e.g. meeting consumer demand). In some cases, however, uncertainty remains. This can be due to an inconclusive business case (e.g. consumers' willingness to pay) or the difficulty of communicating the complex story of traceable products, as well as how to effectively incentivize and support the rest of the supply chain in pursuing traceability. Effective strategies to communicate traceability to consumers and

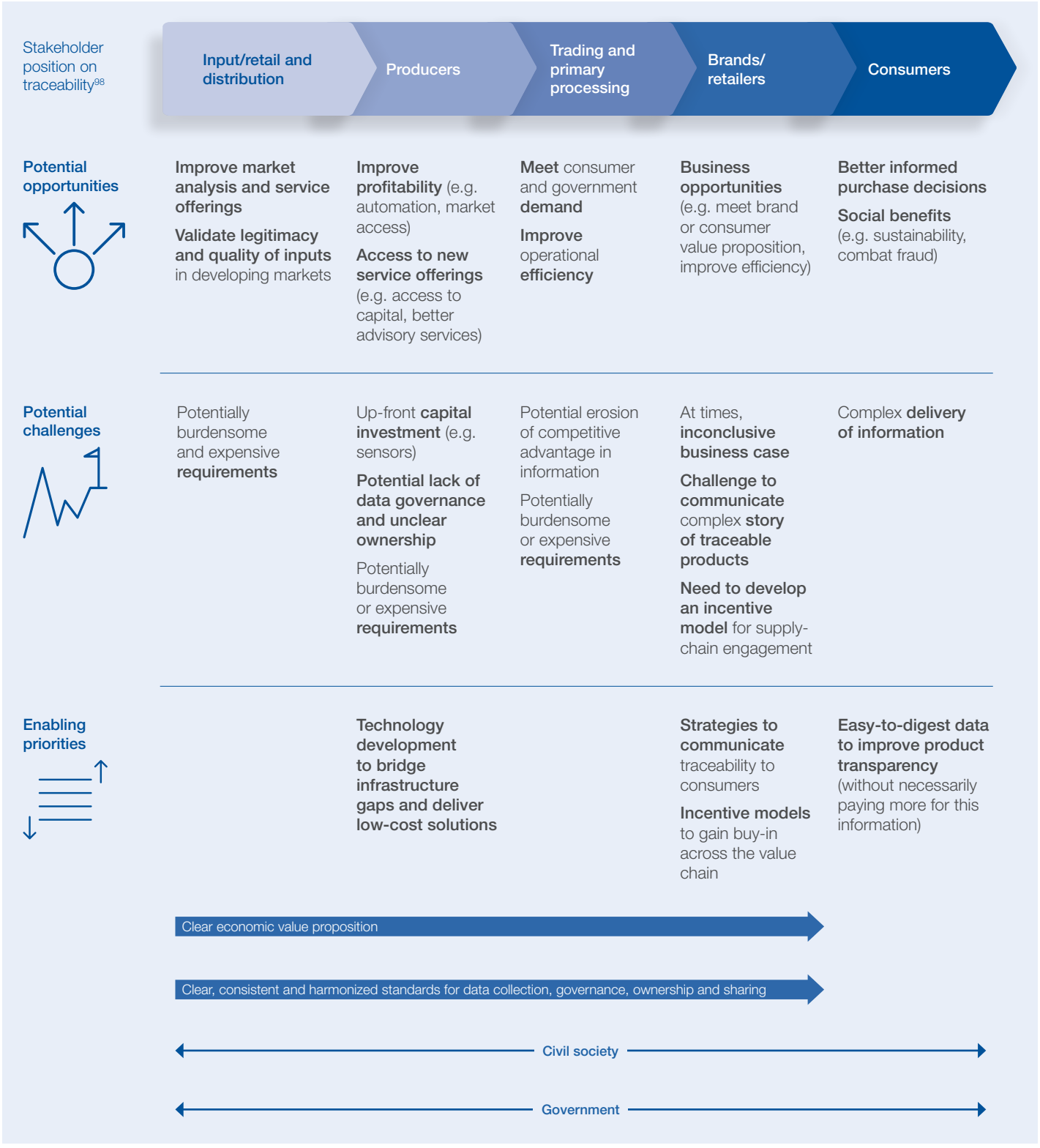
incentive models that support broader ecosystem engagement will be clear enabling factors.

– **Consumers.** Consumers can influence the direction of traceability by communicating their demands for increased transparency into food production as well as the social good that traceability can provide (e.g. supporting sustainability goals). Effective consumer engagement requires that traceability data is communicated in an easily digestible and transparent matter – and that the end product is cost-effective. In addition, the willingness of consumers to pay more could be a significant cause of industry action. That said, the end product will need to remain affordable.

Civil society and the government will also play critical leadership roles in enabling traceability, which is further discussed in subsection 5c.

The need for engagement with traceability initiatives varies throughout the value chain. However, important themes include the need to streamline processes; develop incentives; and align on traceability requirements, standards and processes. To meet these needs, convening of stakeholders, as well as formal partnerships on pilots and initiatives with an emphasis on publicly releasing findings for the benefit of the system as a whole will be valuable.

Figure 10: There are potential opportunities, challenges and priorities throughout the value chain.



C. Stakeholder support to accelerate impact

Stakeholders across the system each have a role to play in supporting and accelerating the positive impact potential of traceability in food value chains.

Governments can help incentivize traceability and support adoption. Where traceability provides a clear societal benefit but has not yet gained buy-in, policy-makers can encourage adoption through policy incentives. To do so, governments will need to consider carefully who is accountable when standards are not met, in addition to the impact of such regulation on supply-chain participants, especially small-scale producers. Cost-benefit analysis regarding the value and potential trade-offs of being able to calculate the "true cost of food" will also likely prove valuable. In addition, governments – especially those in developing countries – can consider methods to support the development of digital and physical infrastructure to make technological adoption feasible for all populations.

Technology companies have the potential to further develop the transformative traceability technologies needed to reduce costs, improve delivery and maximize efficacy. These companies can play an important role in helping to close infrastructure gaps or develop traceability solutions that adapt to developing markets, ensuring traceability is implemented in an inclusive manner. In addition, targeted support from investors could help make such technological development possible.

Retailers, alongside others, can take the lead when convening with other stakeholders to build the right multistakeholder collaborations. Partnering with other stakeholders throughout the value chain to develop pilots will be helpful for alignment and the development of best practices. It will also be important for retailers to work alongside their competitors to support the harmonization of standards and prevent the development of cumbersome silos. Retailers can also play a valuable leadership role in creating inclusive models by considering the developing market context and supporting adoption of small-scale producers.

Agribusiness companies can support the application of traceability for food value chains by coming to the table with an open mind, considering new business opportunities and pushing forward existing commitments. For example, Archer Daniels Midland Company, Bunge Limited, Cargill and Louis Dreyfus Company issued a joint statement in October 2018 in which they said they are investigating methods to "standardize and digitize global agricultural shipping transactions for the benefit of the entire industry". The statement added that the companies "also seek broad-based industry participation to promote global access and adoption".[99] Technology-enabled traceability is a clear link back into this overarching agenda.

Food producers, especially small-scale producers, are potentially at risk of being left behind. That said, traceability could unlock new opportunities for this population, including new market access, improved efficiency and increased access to financing options. As a result, producers should consider what they need to ensure traceability helps – rather than harms – their operations. They can do this by advocating for a seat at the table, ensuring their perspective is considered as traceability standards are developed and poverty is reduced.

Civil society and systems leaders can play the role of convener to ensure all stakeholders have a chance for input when creating standards and requirements. This group, along with donors, can also play a valuable role as catalytic financers, helping support the creation of tools and initiatives for an inclusive model, including advocacy for more digital and physical infrastructure and the application of a digital ID to unlock new financing options.

Creating a transformation agenda to advance a healthy, nutritious, sustainable, efficient and inclusive food system will require unprecedented cooperation and collaboration between organizations, initiatives and actors. A "systems leadership" approach that can engage all stakeholders and align towards a shared purpose is needed to harness the power of emerging technologies and address specific challenges in pain points in food systems (such as traceability). Multistakeholder partnerships are an example of systems leadership in action, promoting a common vision, supporting widespread innovation and action and enabling mutual accountability.

Section 6

Conclusion

Technology-enabled end-to-end traceability in food value chains, coupled with multistakeholder collaboration, has the potential to fundamentally improve food systems. To achieve its full potential, stakeholders will need to come together to enable emerging technologies and to install a broad system and standards. This collaboration should be built on a shared vision and executed with a recognition of the mutual benefits of partnership. Global food-system transformation requires action in the following areas.

- **A multipronged approach focused on the application of emerging technologies across food-system pain points is needed to support transformation.** Fourth Industrial Revolution technologies have the potential to significantly shift today's food system, making it not only healthier but also more nutritious, sustainable, efficient and inclusive. Improved traceability is one of many examples of the pain points addressable by emerging technologies. Traceable value chains could help food systems better meet consumer and cross-value-chain demand for transparency; further enhance the ability to identify, respond to and even prevent food safety issues; support optimization of the supply chain and reduce food loss; and validate sourcing claims to support sustainability goals. In addition, traceability could help empower small-scale producers in developing markets with improved market transparency, income-generating opportunities and access to capital.

- **Emerging traceability technologies could be a powerful tool for small-scale producers; however, without the proper pathways to scale there is risk of such producers getting left behind due to the up-front costs and operational requirements.** Successful development of traceability requires multistakeholder collaboration to address the unique traceability challenges different value-chain players face.

- **Harmonized standards, ongoing technological development to drive down costs, a continued focus on robust economic models and effective communication and training programmes are fundamental to scaling traceability.** Consistent and comprehensive multistakeholder collaboration, supported by robust incentives and commercially viable solutions, would help ensure that traceability is scaled effectively and efficiently.

With the fundamental technologies maturing, technology-enabled end-to-end traceability at scale is within reach – and can be a powerful tool to positively impact food systems. As it matures, traceability will enable broader opportunities, but it will also require deliberate actions to ensure its impact fully advances a healthy, nutritious, sustainable, efficient and inclusive food system.

Annex: World Economic Forum's Innovation with a Purpose Platform

In 2017, the World Economic Forum's System Initiative on Shaping the Future of Food launched Innovation with a Purpose to harness the transformative power of the Fourth Industrial Revolution to better address challenges. The initiative launched a flagship report in January 2018 called *Innovation with a Purpose: The role of technology innovation in accelerating food systems transformation*, which identified the 'Transformative Twelve' – 12 technologies with the potential to positively affect food systems by changing the shape of demand, promoting value-chain linkages and creating effective production systems.

Building on this initial work, in 2019 the Forum is launching Innovation with a Purpose into a platform for multistakeholder collaboration that develops and scales technology solutions for food-systems transformation. Operating as a large-scale partnership aggregator and project accelerator, the platform model will:

- Drive increased investments in inclusive and scalable technology solutions by unlocking business and financing models and incentives, as well as catalytic donor financing
- Promote policy incentives to strengthen and scale the enabling environment
- Mitigate the unintended consequences of technologies on health, the environment, biodiversity and privacy concerns
- Support capacity building, the sharing of knowledge and insights and South-South exchange
- Unlock institutional bottlenecks in support of systemic change

In the first three years, the Platform will follow four main avenues for action:

1. Leadership alignment, agenda setting and commitment to action

The Platform will support new leadership approaches and institutional strategies to develop cross-industry and multistakeholder alliances and collaborations. This will be done through leadership groups catalysed by the World Economic Forum such as the Stewardship Board on Shaping the Future of Food, the Global Future Council on Food Systems Innovation and the Innovation with a Purpose Steering Committee. The Forum will also leverage its convening power, including the Sustainable Development Impact Summit, the Annual Meeting in Davos, regional summits, roundtables and workshops, to develop high-level leadership championship, influence agendas and inspire powerful partnerships.

2. Facilitate a platform ecosystem approach

The Platform will aim to bring about systemic change and increase investments in inclusive and scalable food-system technology solutions by:

- Unlocking business models to support commercially viable solutions that increase investments in food and agriculture-related technology innovations
- Catalysing support for financing mechanisms that accelerate capital flows to innovations by promoting guarantee mechanisms and other blended financing options that aim to de-risk investment activities and promote innovation at scale
- Facilitating support for policy incentives aimed at strengthening and scaling the enabling environment
- Mitigating the unintended consequences of technologies on health, the environment, biodiversity and privacy concerns

3. Develop an action agenda

Advances in technology applications for food and agriculture have made impressive progress, but lack the systemic approach and requisite scale to drive large-scale impact. It will host a portfolio of independent, high-impact and world-leading public-private cooperation projects and in doing so, the Innovation with a Purpose platform will work across Forum Centres, including the Centre for the Fourth Industrial Revolution Network. It will also support affiliated projects led by partners and collaborators that are advancing the same transformative agenda. As of late 2018, the following projects are active or in scoping:

Regional programmes

- Data Solutions Platform in Kenya (in collaboration with AGRA)
- Agricultural drones and data utility platform in Maharashtra, India (led by the Forum's Centre for Fourth Industrial Revolution India)
- Grow Asia digital programme (led by Grow Asia partnership)

Thematic priorities

- Improving Traceability in Food Value Chains (insights report)
- Exploring Pathways for Sustainable Feedstock Production (in collaboration with the Forum's Meat: the Future)

4. Develop insights, support capacity-building and measure impact

The Platform will develop new insights, knowledge and strategies to address key issues and build opportunities for collaboration. This will be done by:

- Developing new insights and understanding related to scaling of technology innovations
- Developing a network of innovators and entrepreneurs and linking them to Forum networks and food-system practitioners
- Convening and promoting multistakeholder dialogues on the role of technology innovations in food systems
- Promoting South-South collaboration, exchange and insights
- Measuring impact and sharing new knowledge

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This report was developed in partnership with McKinsey & Company, led by Lutz Goedde, Sunil Sanghvi, Joshua Katz, Pradeep Prabhala and Annalise McGrail. At the Forum, the project was led by Saswati Bora and Sean de Cleene, with input from Lisa Sweet, Jim Riordan, Maria Elena Varas, Tania Straus and Noopur Desai. Members of the World Economic Forum's Innovation with a Purpose Steering Committee, the World Economic Forum's Stewardship Board on the Shaping the Future of Food, the Global Future Council on Food Systems Innovation and other experts and technology innovators provided substantial input. We also gratefully acknowledge the support of the Rockefeller Foundation and the Wellcome Trust in funding our System Initiative, including work on this report.

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Donors to the System Initiative on Shaping the Future of Food

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