WORLD RESOURCES INSTITUTE

REDUCING FOOD LOSS AND WASTE

Ten Interventions to Scale Impact

With support from

The ROCKEFELLER FOUNDATION

CRAIG HANSON, KATIE FLANAGAN, KAI ROBERTSON, HEIKE AXMANN, HILKE BOS-BROUWERS, JAN BROEZE, CLAIRE KNELLER, DIRK MAIER, CASSIE MCGEE, CLEMENTINE O'CONNOR, STEVE SONKA, TOINE TIMMERMANS, MARTIJNTJE VOLLEBREGT, AND EELKE WESTRA

WRI.ORG

ABOUT THE AUTHORS

Craig Hanson is Vice President for Food, Forest, Water & the Ocean at World Resources Institute (WRI).

Katie Flanagan is an Associate at World Resources Institute.

Kai Robertson is Lead Advisor for the Food Loss & Waste Protocol at World Resources Institute.

Heike Axmann is Project Leader Supply Chain Management at Wageningen University & Research (WUR).

Hilke Bos-Brouwers is Senior Scientist Sustainable Supply Chains at Wageningen University & Research.

Jan Broeze is Senior Scientist at Wageningen University & Research.

Claire Kneller is Head of Food at WRAP Global.

Dirk Maier is a Professor at Iowa State University.

Cassie McGee is a Research Program Manager at Iowa State University.

Clementine O'Connor is Program Officer—Sustainable Food Systems at the United Nations Environment Programme (UNEP).

Steve Sonka is a Fellow at the Ed Snider Center for Enterprise and Markets, University of Maryland.

Toine Timmermans is a Program Manager (Sustainable Food Chains) at Wageningen University & Research.

Martijntje Vollebregt is a Scientist (Sustainable Processing) at Wageningen University & Research.

Eelke Westra is a Program Manager (Postharvest Quality) at Wageningen University & Research.

Design and layout by:
Billie Kanfer
billie.kanfer@wri.org

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The following writing teams drafted each of the "scaling intervention" chapters:

- 1. Lead: Craig Hanson (WRI). Support: Claire Kneller (WRAP), Clementine O'Connor (UNEP)
- 2. Lead: Claire Kneller (WRAP). Support: Craig Hanson and Katie Flanagan (WRI)
- 3. Lead: Craig Hanson (WRI). Support: Toine Timmermans (WUR)
- 4. Steve Sonka (Ed Snider Center, University of Maryland) and Heike Axmann (WUR)
- 5. Dirk Maier and Cassie McGee (Iowa State University)
- 6. Lead: Craig Hanson (WRI). Support: Katie Flanagan and Liz Goodwin (WRI), Claire Kneller (WRAP)
- 7. Lead: Craig Hanson (WRI). Support: Jan Broeze (WUR)
- 8. Craig Hanson (WRI)
- 9. Martijntje Vollebregt and Hilke Bos-Brouwers (WUR)
- 10. Lead: Dirk Maier (Iowa State University). Support: Steve Sonka (Ed Snider Center) and Cassie McGee (Iowa State University)

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FOREWORD

How the world feeds nearly 10 billion people in the year 2050—while supporting economic development and meeting the challenge of climate change—is one of the greatest challenges of our generation. Recent landmark studies such as the World Resources Report *Creating a Sustainable Food Future* have made the case that halving the rate of food loss and waste is a necessary part of meeting this challenge. It can increase food security, raise farmer incomes and lower household bills, and reduce greenhouse gas emissions.

Earlier this year, our institutions published *Reducing Food Loss and Waste: Setting a Global Action Agenda*. As the first part of the agenda, we recommended that countries and companies follow a simple "Target-Measure-Act" strategy: adopt the Sustainable Development Goal target of halving food loss and waste as their own, measure their food loss and waste, and take action on the hotspots identified. Second, we recommended a short-list of "to do's" per each type of actor in the food supply chain. Third, we recommended 10 scaling interventions to increase the impact and pace of these actor-specific interventions.

In this publication, *Reducing Food Loss and Waste: Ten Interventions to Scale Impact*, our institutions delve deeper into the following 10 scaling interventions:

- Develop national strategies for reducing food loss and waste.
- Create national public-private partnerships to tackle food loss and waste.
- Launch a "10 × 20 × 30" initiative to get supply chains working on reducing food loss and waste.
- Invigorate efforts to strengthen value chains to reduce smallholder losses.
- Launch a "decade of storage solutions."
- Shift social norms to make wasting food socially unacceptable.
- Go after the hotspots of food loss and waste-related greenhouse gas emissions.
- Scale up financing for food loss and waste reduction technologies, enterprises, and programs.
- Overcome the food loss and waste data deficit.
- Advance the research agenda on food loss and waste.

We describe what they are, why they are needed, and what the next steps are for getting them going. This publication is intended to inspire leaders within governments, companies, nongovernmental organizations, and research institutions to start to pursue one or more of these interventions—typically in some form of collaboration between sectors. Although it is not an "implementation manual," it recommends basic foundations for these 10 interventions. In short, we lay out a high-level roadmap for these interventions.

We urge you to identify which of these you can help make a reality. Then go get started. There's no time, or food, to waste.

Andrew Steer
President
World Resources Institute

Rajiv J. Shah
President
The Rockefeller Foundation

Steve Sonka
Fellow
Ed Snider Center for Enterprise and Markets, University of Maryland

Dirk Maier
Professor
Iowa State University
Director, Consortium for Innovation in Postharvest Loss and Food Waste Reduction

Mitchell Bernard
Chief Counsel, Interim President, Natural Resources Defense Council (NRDC)

Inger Andersen
Executive Director
UNEP

Louise O. Fresco
President Executive Board
Wageningen University & Research

Marcus Gover
CEO
WRAP

EXECUTIVE SUMMARY

Reducing food loss and waste can help meet the UN Sustainable Development Goals (SDGs) by 2030, contribute to the Paris Agreement on climate change, and sustainably feed the planet by 2050. This report explores 10 "scaling interventions" that have the potential to increase the pace and geographic breadth of efforts to reduce food loss and waste. For each, it addresses what it is, why it is needed, how it works, and what potential next steps are.

Highlights

- Halving the rate of food loss and waste is an important "no regrets" strategy that would contribute to achieving the UN Sustainable Development Goals (SDGs), meeting the goals of the Paris Agreement on climate change, and sustainably feeding the planet.
- This report, based on extensive desk-based research, input from partner organizations, and the authors' firsthand experience, explores 10 "scaling interventions"—first introduced in *Reducing Food Loss and Waste: Setting a Global Action Agenda* (Flanagan et al. 2019a)—to accelerate and spread efforts to reduce food loss and waste.
- Three of these scaling interventions take a "whole supply chain approach" to tackling food loss and waste. They are (1) develop national food loss and waste reduction strategies, (2) create national public-private partnerships dedicated to reducing food loss and waste, and (3) launch a supply chain initiative that encourages retailers to engage their suppliers on food loss and waste reduction.
- Four of these scaling interventions focus on "hotspots" (i.e., stages in the food supply chain or food categories) of food loss and waste. They are (4) invigorate efforts to reduce smallholder losses by strengthening value chains, (5) launch a "decade of storage solutions," (6) shift social norms, and (7) make a concentrated effort to tackle greenhouse gas emissions from food loss and waste.
- Three more of these scaling interventions help create the enabling conditions for food loss and waste reduction. They are (8) scale up financing, (9) overcome the data deficit, and (10) advance a new research agenda.
- Only 11 years remain to achieve the SDGs. Actors ranging from farmers, governments, businesses, consumers, and everyone in between, can have a role to play in implementing the 10 "scaling interventions" outlined in this report. If the world does this, we just might realize a future where the rate of food loss and waste is halved.

ABOUT THIS REPORT

This publication lays out 10 "scaling interventions" designed to accelerate and spread adoption of policies and practices to reduce food loss and waste and help achieve SDG 12.3: "by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" (UN 2017). The present report builds on Flanagan et al. (2019a), which introduced a global action agenda for reducing the rate of food loss and waste. The three-part action agenda involves (a) the Target-Measure-Act approach, (b) an actor-specific to-do list, and (c) 10 "scaling interventions" designed to take the Target-Measure-Act approach and to-do list to scale. After summarizing the first two components of the global action agenda, we expand on the 10 "scaling interventions" by giving more detail and how these 10 interventions can be implemented.

This publication is intended to inspire midlevel managers within governments, companies, nongovernmental organizations, and research institutions to start to pursue one or more of these interventions—typically in some form of collaboration between sectors. Although it is not an "implementation manual," it lays out the basic foundations for these 10 interventions.

This publication was jointly prepared by World Resources Institute (WRI) with support from The Rockefeller Foundation and in collaboration with food loss and waste experts from Iowa State University, the University of Maryland, the Natural Resources Defense Council (NRDC), the United Nations Environment Programme (UNEP), Wageningen University & Research (WUR), and the Waste & Resources Action Programme (WRAP).

BACKGROUND

Reducing food loss and waste is an important strategy for ensuring food security and combatting climate change. Reducing food loss and waste can increase the amount of food harvested that ultimately gets eaten by people. In addition, reducing the rate of food loss and waste by 50 percent would significantly reduce greenhouse gas emissions because more efficient use of food would diminish the need for land conversion for additional food production, slow the rate of increase in fertilizer applications, and reduce methane emissions from food in landfills (Searchinger et al. 2018; Willett et al. 2019). The World Resources Report (Searchinger et al. 2019) and the EAT-Lancet Commission (Willett et al. 2019) both identify cutting food loss and

waste rates in half as a critical element in achieving a sustainable future.

WHAT IS THE FOOD LOSS AND WASTE CHALLENGE?

A significant amount of food intended for human consumption is never eaten. According to the only global data available (FAO 2011), approximately one-third of all food intended for human consumption is lost or wasted between the farm and the plate.

The world is calling for reducing the rate of food loss and waste by 50 percent. The Sustainable Development Goals (SDGs) call for ending poverty and hunger, protecting the planet, and ensuring prosperity for all. SDG 12 seeks to "ensure sustainable consumption and production patterns." The third target under this goal, Target 12.3, calls for halving food loss and waste by 2030 (UN 2017).

WHAT SHOULD BE DONE ABOUT IT?

Flanagan et al. (2019a) proposed a three-part agenda for tackling food loss and waste (and meeting SDG Target 12.3): (a) the Target-Measure-Act approach, (b) an actor-specific to-do list, and (c) 10 scaling interventions designed to rapidly scale the deployment of the Target-Measure-Act approach and of the to-do list.

This publication expands on these 10 scaling interventions by providing a more detailed explanation of what each one entails, why it is important, and what next steps are needed to implement it. Three of the scaling interventions take a "whole supply chain" approach, four of them target specific hotspots of food loss and waste, and three more enhance enabling conditions for reducing food loss and waste.

Whole supply chain approaches

- *Develop national strategies for reducing food loss and waste*. Increase the number of countries with national strategies, as these can be an important catalyst for Target-Measure-Act at the country level—aligning public policy, private sector action, and farmer-to-consumer behavior toward a shared goal.
- *Create national public-private partnerships*. Increase the number of country-level public-private partnerships dedicated to achieving SDG 12.3.
- *Launch a "10 × 20 × 30" supply chain initiative*. Launch a voluntary private sector campaign where at least 10 corporate "power players" commit to Target-Measure-Act themselves and then engage their own 20 largest suppliers to do the same and achieve a 50 percent reduction in food loss and waste by 2030.

Hotspot-specific approaches

- *Invigorate efforts to strengthen value chains to reduce smallholder losses*. Invigorate efforts to help smallholder farmers reduce food losses during production and storage.
- *Launch a "decade of storage solutions."* Kick-start a focused collaboration among storage providers, cold chain alliances, financiers, and governments to rapidly get income-sensitive, climate-smart storage technologies into the hands of farmers and distribution networks around the world.
- *Shift social norms*. Leveraging the latest findings of behavioral science, engage grassroots campaigns, social media, religious communities, and others to make "wasting food" as unacceptable as littering now is in many countries.
- *Go after GHG emissions reductions*. Use sector-led programs to tackle food loss and waste from beef, dairy, and rice head on, and get the reduction of food loss and waste into nationally determined contributions to the Paris Agreement on climate change.

Enabling approaches

- *Scale up financing*. Develop funds and financing products dedicated to investing in innovation and scaling up enterprises, technologies, and programs that would reduce food loss and waste.
- *Overcome the data deficit*. Over the next five years, a concentrated push to measure food loss and waste is needed to overcome this data deficit in time to support achievement of SDG 12.3.
- *Advance the research agenda*. Engage in more research to answer multiple "next generation" questions that would, in turn, help refine food loss and waste reduction strategies and advance implementation of the global agenda.

For all of the above, monitoring and evaluation systems are needed to assess the interventions' efficacy and enable midcourse correction.

A CALL TO ACTION

Implementing the 10 scaling interventions is necessary and urgent. Only 11 years remain before the SDGs are due, yet food loss and waste is still commonplace. Governments, businesses, farmers, consumers, and everyone in between needs to play a role in accelerating the global action agenda for reducing food loss and waste. As with food, there is little time to waste.

INTRODUCTION

Figuring out how the world can adequately and nutritiously feed nearly 10 billion people by the year 2050 in a manner that advances human well-being while also reducing the food system's impact on the environment, particularly on climate change, is one of the grand challenges of this half century.

As identified by World Resources Institute (WRI), the World Bank, the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP) (Searchinger et al. 2018, 2019), addressing this challenge entails implementing a "menu of solutions" that simultaneously (a) closes the gap between the food needed by 2050 and that available today, and (b) reduces greenhouse gas (GHG) emissions from business-as-usual agriculture and related land-use change by 2050 in order to meet the Paris Agreement on climate change. One critical menu item for achieving both is to reduce the current rate of food loss and waste by 50 percent. Recent modeling[1] found that doing so would close the gap between the amount of food needed to adequately feed the planet in 2050 and the amount of food available in 2010 by more than 20 percent (Figure 1). Modeling also found that a 50 percent reduction in the rate of food loss and waste would reduce the food system's projected business-as-usual GHG emissions in 2050 by 10–14 percent (Figure 2).[2] Reducing food loss and waste, therefore, would have a very big impact—being one of the most impactful items on the "menu of solutions." This finding is similar to those of other recent studies, including the EAT-Lancet Commission report (Willett et al. 2019) and the Intergovernmental Panel on Climate Change report on Climate Change and Land (IPCC 2019).

In *Reducing Food Loss and Waste: Setting a Global Action Agenda* (Flanagan et al. 2019a), we proposed a suite of recommendations for how the world can cut the rate of food loss and waste in half. The present report, *Reducing Food Loss and Waste: Ten Interventions to Scale Impact*, begins by summarizing key aspects of Flanagan et al. (2019a) and then follows up on it by elaborating on 10 interventions designed to accelerate and spread adoption of measures (e.g., policies, practices, investments) that can reduce food loss and waste (see Box 1 for elaboration on the research methods for this publication). For each intervention, this report explores questions such as the following:

- What is it?
- Why is it needed?
- How does it work?
- What are possible next steps?

We hope that these 10 interventions will help catalyze ambition, mobilize action, and accelerate progress toward cutting the rate of food loss and waste in half—to the benefit of people and the planet.

Figure 1 | **Reducing Food Loss and Waste Can Play an Important Role in Closing the Food Gap between 2010 and 2050 without Expanding Cultivated Area**

Note: Includes all crops intended for direct human consumption, animal feed, industrial uses, seeds, and biofuels.
Source: Searchinger et al. (2018).

BOX 1 | RESEARCH METHODS FOR THIS PUBLICATION

The first section of this publication summarizes key findings of *Reducing Food Loss and Waste: Setting a Global Action Agenda* (Flanagan et al. 2019a), a report released in mid-2019 with the same lead authors as the present publication. Since the lead authors are the same, we repeat (at times word-for-word) with permission of the authors some of the text from that report. This section has a gray background.

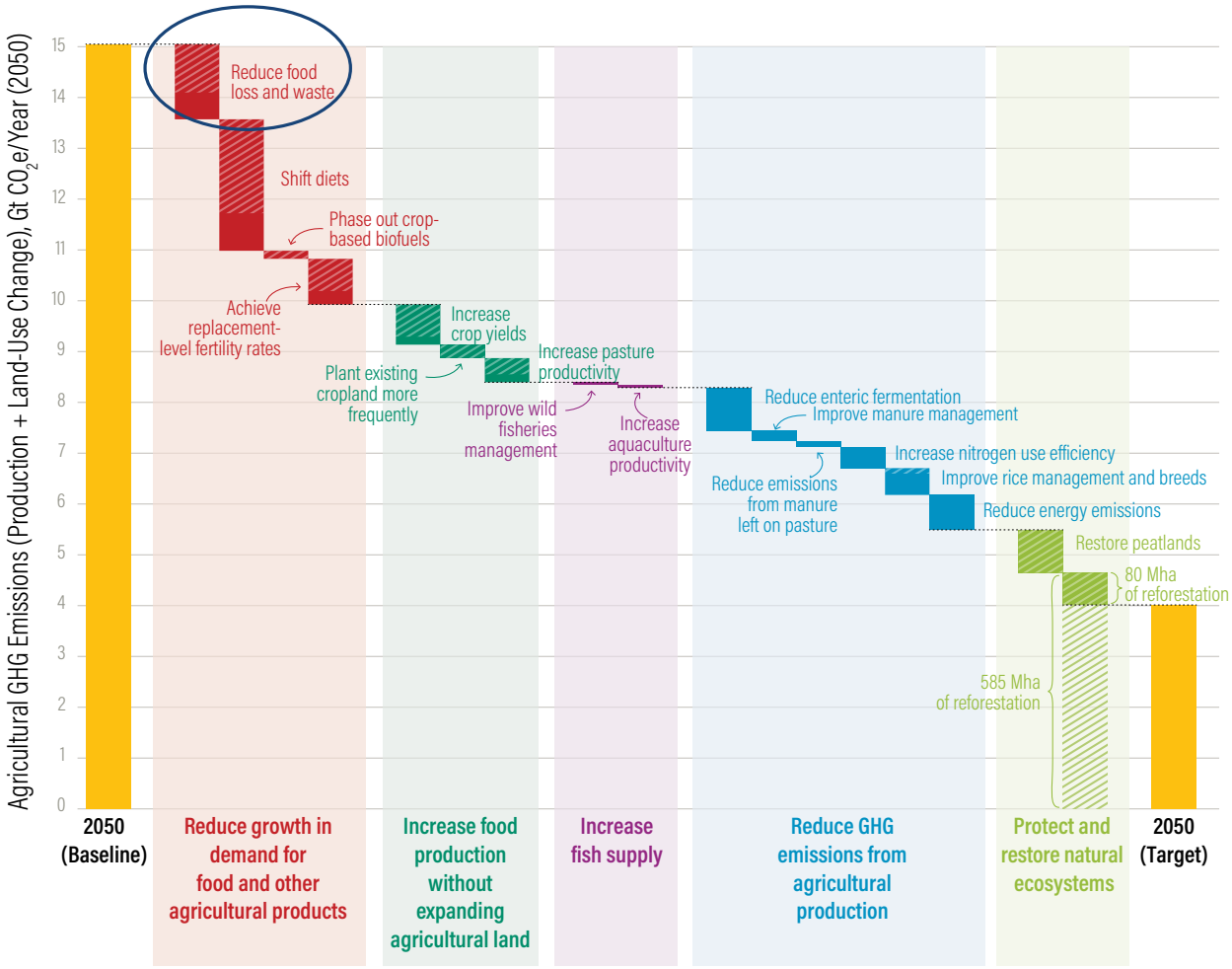
The rest of this publication explores in more depth the 10 scaling interventions first introduced in Flanagan et al. (2019a). Perspectives on the 10 scaling interventions were developed by a literature review and author insights from years of food loss and waste reduction fieldwork, research, and interviews/discussions with industry leaders, other researchers, and practitioners. Those with whom the authors had discussions or interviews about one or more of the scaling interventions include leaders from the African Union Commission, Consumer Goods Forum, FEMSA Foundation, Global Food Cold Chain Council, IKEA Food, members of the Courtauld Commitment (see http://www.wrap.org.uk/food-drink/business-food-waste/courtauld-2025), Nestlé, Postharvest Education Foundation, Olam, Rabobank, ReFED, Royal DSM, Sodexo, Tesco, University of Nairobi, U.S. Department of Agriculture, U.S. Environmental Protection Agency, Walmart Foundation, World Bank, and WWF. In addition, the need for multiple such interventions has been identified during discussions with members of the Champions 12.3 coalition (see www.champions123.org for a list).

When perspectives were gathered in an interview, these were open-ended and unstructured, focusing on three themes: Why is the intervention important? What is the status to date? What are needed next steps? Although the authors had already described the interventions in Flanagan et al. (2019), we sought additional perspectives on the value of the intervention, what recent developments might support it, who needs to be involved, what process steps are next, and related information.

Much of the original thinking about the 10 scaling interventions came from the authors themselves, particularly the teams who wrote each intervention. Interviews helped inform, substantiate, and/or challenge the emerging recommendations of each author group.

Where possible, perspectives were informed by examples of smaller-scale implementation of the intervention and the track record of those examples. This is the case, for instance, with intervention #2 on public-private partnerships and intervention #3 on 10 × 20 × 30. For other interventions, the recommendations are derived from expert observations of where a "gap" is that needs to be filled. This is the case, for instance, with intervention #8 on financing, #9 on the data deficit, and #10 on the research agenda.

Figure 2 | **Reducing Food Loss and Waste Could Eliminate ~1.5 Gt of the Projected 15 Gt of Greenhouse Gas Emissions from Agriculture and Land Use in 2050 (CO_2 Equivalent)**



Note: Solid areas represent agricultural production emissions. Hatched areas represent emissions from land-use change.
Source: Searchinger et al. (2018).

SETTING A GLOBAL ACTION AGENDA

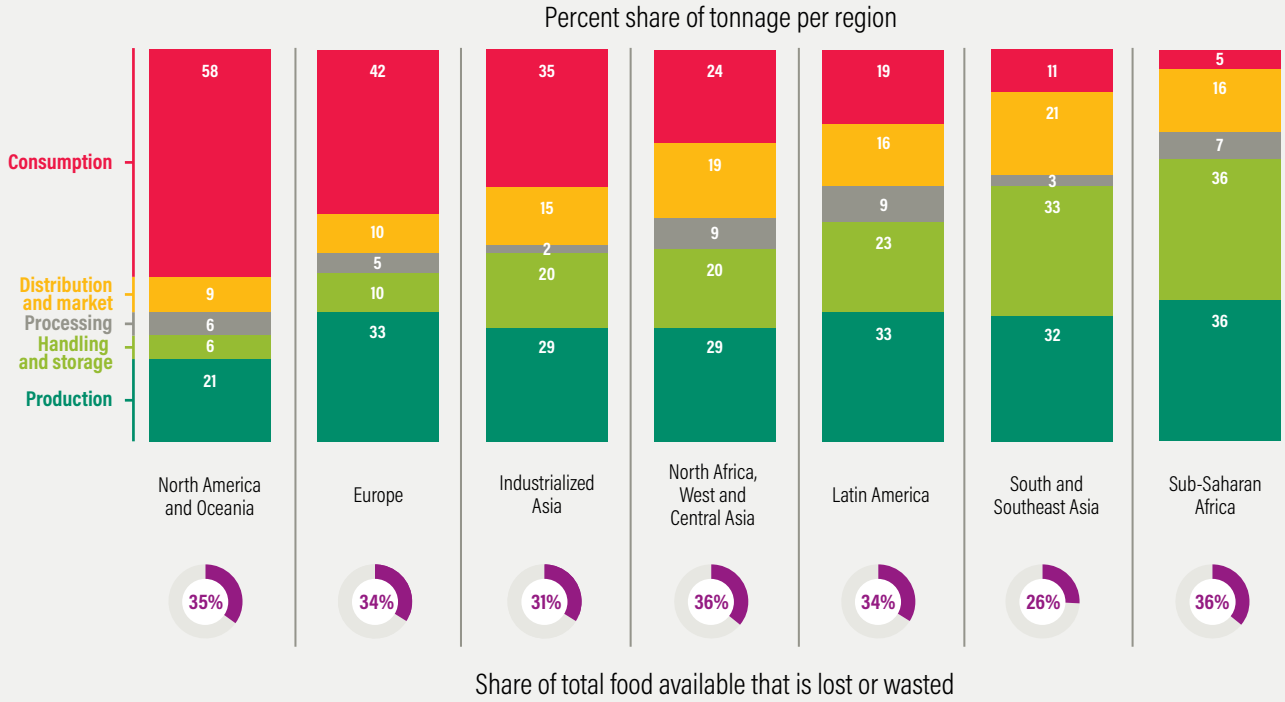
This chapter consists of abridged text directly from Flanagan et al. (2019a). Use of the same text has been approved by the authors of Flanagan et al. (2019a); they are the same lead authors and contributors as this current publication. This synthesis is intended to summarize the findings of that report in order to set the foundation for exploration of the 10 scaling interventions. Readers who have already read that report in its full length may want to skip to the next chapter.

What is the food loss and waste challenge?

A significant amount of food intended for human consumption is never eaten. In 2011, the Food and Agriculture Organization of the United Nations (FAO) launched a landmark publication, *Global Food Losses and Food Waste: Extent, Causes and Prevention* (FAO 2011), with the headline finding that one-third of all food is lost or wasted between the farm and the plate. Our assessment of more subcontinental and commodity-specific studies conducted since then suggests that the FAO data are broadly correct (Flanagan et al. 2019a).

The distribution of food loss and waste across the food supply chain varies by region of the world. Food loss and waste at the point of consumption in homes and restaurants appears to be a hotspot of food loss and waste in high-income regions, whereas losses during handling and storage are a hotspot in low-income regions. On-farm production losses (i.e., during and just after harvest) are an issue in all regions (FAO 2011) (Figure 3).

Figure 3 | **Distribution of Food Loss and Waste by Region and Stage in the Food Supply Chain, 2007**



Notes: Values displayed are of food loss and waste as a percent of food supply, defined here as the sum of the "Food" and "Processing" columns of the FAO Food Balance Sheet. Numbers may not sum to 100 due to rounding.
Source: WRI analysis based on FAO (2011).

The world is calling for halving the rate of food loss and waste. In September 2015, nations of the world formally adopted a set of 17 Sustainable Development Goals (SDGs) as part of the 2030 Agenda for Sustainable Development—global goals to end poverty and hunger, protect the planet, and ensure prosperity for all. SDG 12 seeks to "ensure sustainable consumption and production patterns." The third target under this goal, Target 12.3, calls for halving "per capita global food waste at the retail and consumer levels and reduc[ing] food losses along production and supply chains, including post-harvest losses," by 2030 (UN 2017).

Why does it matter?

Food loss and waste matters in terms of the environment, economy, food security, jobs, and ethics:

- *The environment:* The food that is lost and wasted each year accounts for an estimated 8 percent of annual GHG emissions (FAO 2015), consumes a quarter of all water used by agriculture (Kummu et al. 2012), and requires an agricultural area the size of China (FAO 2013).
- *The economy:* The annual market value of lost and wasted food is estimated at an astounding $940 billion globally (FAO 2015).
- *Food security:* More than 1 billion metric tons of food per year is never consumed in a world where one in nine people are still undernourished (FAO et al. 2018).
- *Jobs:* Reducing food loss and waste could play a modest role in job creation across the supply chain, ranging from smallholder processing facilities close to the farm to technology start-up companies that help redistribute food that would otherwise be wasted (Flanagan et al. 2019a).
- *Ethics:* Reducing food loss and waste is considered by many people as simply "the right thing to do" (Flanagan et al. 2019a).

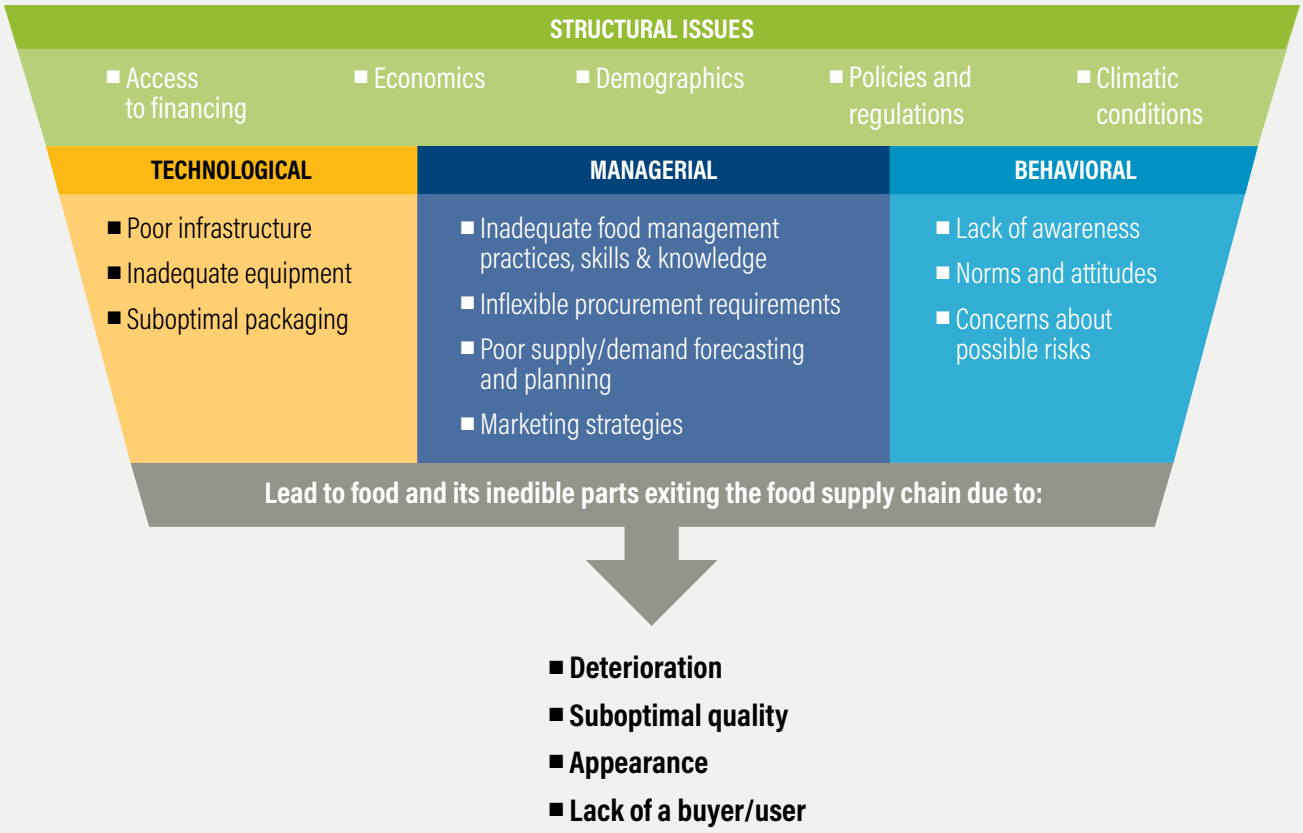
The benefits of reducing food loss and waste can be significant. For instance, reducing the current rate of food loss and waste by 50 percent by 2050 would have the following results:

- It would close the gap between food needed in 2050 and food available in 2010 by more than 20 percent (Searchinger et al. 2019).
- It would avoid the need to convert an area of natural ecosystems roughly the size of Argentina (the eighth-largest country in the world) into agricultural land between 2010 and 2050 (Searchinger et al. 2019).
- It would lower GHG emissions by 1.5 gigatons (1.5 billion metric tons) of carbon dioxide equivalent (Gt CO_2e) per year by 2050, an amount more than the recent energy- and industry-related emissions of Japan (Searchinger et al. 2019).

What causes food loss and waste?

Understanding why food loss and waste occurs (whether intentionally or not) is important to successfully reducing it. The most immediate reasons food leaves the human food supply chain (the "direct causes") tie back to concern about a food's safety or suitability for consumption. Food may deteriorate or be considered of suboptimal quality, or there may be no perceived use or market for it due to the food's appearance, excess supply, seasonal production fluctuations, or other issues. Leading to these direct causes are a number of "underlying drivers" (Flanagan et al. 2019a). These can be technological, managerial, behavioral, or structural in nature. The technological drivers are poor infrastructure, inadequate equipment, and suboptimal packaging. The managerial drivers are inadequate food management practices, skills, or knowledge; inflexible procurement practices; poor supply and demand forecasting and planning; and marketing strategies. The behavioral drivers are norms and attitudes, lack of awareness, and concerns about possible risks. The structural drivers are conditions in demographics, climate, policies and regulations, economics, and financing that lead to food loss and waste. These 15 underlying drivers need to be addressed if food loss and waste is to be reduced (Figure 4).

Figure 4 | **Why Food Is Lost or Wasted Is Due to Multiple Underlying Drivers**



Source: Flanagan et al. (2019a).

The underlying drivers of food loss and waste are closely interrelated (Flanagan et al. 2019a). An instance of food loss or waste is often driven by more than one driver (e.g., rice losses may occur due to inadequate storage bags, which, in turn, may be caused by a grower's lack of access to credit to purchase better bags). Moreover, while an underlying driver may affect one stage of the food supply chain, the generation of loss and waste might actually occur at a different stage. For instance, orders modified last-minute by food retailers at the distribution and market stage of the food supply chain can result in fruits and vegetables being left on the farm field, leading to losses during production.

Among the various underlying drivers, some are more relevant in certain regions (Flanagan et al. 2019a). For example, lack of infrastructure is typically a more significant driver in low-income countries, whereas social norms and attitudes such as the acceptability of not eating all the food on one's plate are often a driver in high-income countries. Reducing food losses close to the farm (during production as well as handling and storage) can be a result of "good economic development." As economies develop, food loss may give way to food waste closer to the plate, as the underlying drivers shift.

What should be done about it?

Flanagan et al. (2019a) proposes a three-part agenda for tackling food loss and waste, and for meeting SDG Target 12.3.

Target-Measure-Act. Governments and companies should pursue a simple but effective "Target-Measure-Act" approach to reducing food loss and waste:

- **SET TARGETS.** Targets set ambition, and ambition motivates action. Governments and companies should therefore adopt an explicit food loss and waste reduction goal aligned with SDG 12.3—a 50 percent reduction by 2030 relative to a recent year baseline.

- **MEASURE YOUR FOOD LOSS AND WASTE.** The adage "what gets measured gets managed" holds true for food loss and waste as well. Quantifying food loss and waste within borders, operations, or supply chains can help decision-makers better understand how much, where, and why food is being lost or wasted. This information provides an evidence-based foundation for prioritizing interventions to reduce food loss and waste, and helps entities monitor whether they are on track to realizing their target. Governments and companies should therefore start to measure their food loss and waste and monitor progress over time.

- **TAKE ACTION.** What ultimately matters is action. However, there is no proverbial "silver bullet" action for reducing food loss and waste. Rather, reducing it at scale will require numerous actors in the food supply chain to implement a variety of context-specific interventions.

Actor-specific interventions. Figure 5 summarizes a priority "to-do list" for each type of actor in the food supply chain that can help kick-start efforts to reduce food loss and waste. Governments, companies, farmers, citizens, and others should immediately get moving on implementing their respective to-do list.

Scaling interventions. Most of the specific interventions on the to-do lists are already technically possible. The problem is that too few actors are deploying them. Why? In some cases, it may be lack of awareness, concern, or focus regarding food loss and waste. In others, it may be lack of ability or resources (e.g., technical, financial). And in still others, it may be lack of collaboration across a large number of actors needed to effect change. What is needed is a series of "scaling interventions" that addresses these bottlenecks and takes a systems approach.

To address this, Flanagan et al. (2019a) proposed 10 such scaling interventions (Table 1) that have the potential to accelerate and broaden deployment of the Target-Measure-Act approach and of the actor-specific interventions. Three of them take a whole supply chain approach, four of them target specific hotspots of food loss and waste, and three more enhance enabling conditions for reducing food loss and waste. They may not constitute a comprehensive set, but they are a good starting point for making progress.

The rest of this publication explores each of these 10 interventions.

Figure 5 | **Priority "To Dos" by Actor (Not Exhaustive)**

PRODUCTION | HANDLING AND STORAGE | PROCESSING AND PACKAGING | DISTRIBUTION AND MARKET | CONSUMPTION

Crop farmers

- Improve harvesting practices (e.g., ensure product is harvested at the right maturity and use appropriate harvesting equipment to maximize yield while minimizing crop damage).
- Improve skills or use tools to better schedule harvesting (including accessing better data on weather).
- Engage customers (e.g., wholesalers, retailers) to communicate implications of order changes.
- Engage customers to explore changes in quality specifications to enable more of what is harvested to be sold.
- Identify financially viable alternative markets or use for crops otherwise left in the field (e.g., value-added processing, donation, secondary surplus markets).

Fishers

- Use fishing gear designed for target species to reduce bycatch.
- Identify (or create) markets for unavoidable bycatch (e.g., animal feed or processed products).

Ranchers and animal farmers

- Build capacity in practices to reduce losses (e.g., reduce milk spills, minimize contamination).
- Implement best practices in animal welfare to avoid stress and injuries that can reduce the shelf life of meat from animals.

PRODUCTION | **HANDLING AND STORAGE** | PROCESSING AND PACKAGING | DISTRIBUTION AND MARKET | CONSUMPTION

Primary producers

- **Crop farmers:** Improve training in best practices (e.g., handling to reduce damage, drying, fumigation treatments, and on-farm processing). Establish aggregation centers that provide adequate storage and preservation options, such as cooling chambers.
- **Fishers:** Improve temperature management, handling, and preservation techniques (e.g., fenced-off landing beaches or drying racks to improve the quality of fish and to minimize losses).
- **Ranchers and animal farmers:** Improve handling and preservation options (e.g., establish milk collection centers with cooling tanks). Improve conditions during transportation of food-producing animals from farm to markets.

Packinghouses

- Adopt best practices to provide the clean, cool, and/or dry conditions required to reduce postharvest losses.
- Reexamine handling and storage practices to reduce damage (e.g., use liners in wood and basket containers, reduce the size of sacks or crates to minimize product damage).
- Build near-farm facilities to convert unmarketable crops and by-products into value-added products.

Storage providers

- Use storage containers that protect against temperature variations, humidity and precipitation, and insect and rodent infestation.
- Adopt low-cost storage and handling technologies (e.g., hermetic grain storage bags, plastic or metal silos, plastic crates) that prevent spoilage and increase shelf life.
- Work with intended users and community experts to design and produce locally relevant storage solutions.

Transportation and logistics providers

- Improve handling practices during loading and unloading.
- Use technology innovations to improve the flow of information (e.g., about road and traffic conditions, as well as timing of pickup and delivery) to optimize movement of food.
- Introduce (or expand) energy-efficient, clean, low-carbon cold chains from farm to wholesalers.
- Work upstream with customers to provide planning tools and handling and storage technologies that help them reduce losses.
- Create access to alternative markets for products that cannot be marketed.

Figure 5 | **Priority "To Dos" by Actor (Not Exhaustive) (Cont'd)**

PRODUCTION | HANDLING AND STORAGE | PROCESSING AND PACKAGING | DISTRIBUTION AND MARKET | CONSUMPTION

Processors and manufacturers

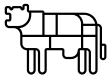
Operations-related:

- Improve training of staff to reduce technical malfunctions and errors during processing.
- Reengineer production processes and product design to reduce waste during product line changeovers.
- Introduce software and related information and communications technologies to optimize operations (e.g., to identify waste, track temperature and ensure freshness, assess ripeness, better balance demand and supply forecasts, and accelerate delivery of food).

Customer-related:

- Use product sizes and packaging that reduce waste by consumers (e.g., accommodate desire for smaller or customizable portions).
- Standardize date labels (e.g., eliminate "sell by" and use only "use by" for perishable items and "best before" for others) to reduce consumer confusion.
- Develop new food products or secondary uses (e.g., animal feed or other value-added products) from what cannot be marketed (e.g., spent grains, fruit trimmings, vegetable peels).
- Seek donation of excess food that is still safe to consume (e.g., revise vendor agreements with retailers to allow for donation instead of mandatory destruction).

Slaughterhouses



- Ensure that proper temperature management conditions are maintained.
- Follow best practices in cleaning and sanitation to reduce losses due to contamination.
- Fully leverage potential for using animal by-products to safely manufacture other products (e.g., animal feed supplements).
- Identify and address management practices that lead to avoidable losses (e.g., using remote video auditing to assess whether best practices are being implemented).

Packaging providers

- Invent, design, produce, and mainstream packaging options or coatings (e.g., resins used on pouches or on foods) that extend a product's shelf life (although consideration should be given to the impact of the packaging, and efforts should be made to create reusable and recyclable packaging.
- Offer packaging that is resealable to allow for incremental consumption and to extend how long the remainder of a product stays suitable for consumption.
- Provide commercial customers with a greater variety of packaging sizes to help shoppers purchase the amount appropriate for their needs.
- Adjust packaging so it is easier for consumers to empty all the contents.

Figure 5 | **Priority "To Dos" by Actor (Not Exhaustive) (Cont'd)**

PRODUCTION | HANDLING AND STORAGE | PROCESSING AND PACKAGING | **DISTRIBUTION AND MARKET** | CONSUMPTION

Wholesalers 	■ Build capacity for better handling and storage practices to reduce mistakes that result in food loss. ■ Expand cold storage systems during wholesale and logistics to protect products vulnerable to heat damage. ■ Find food rescue partners or establish online marketplaces that facilitate sale or donation of rejected shipments or short-life products. ■ Use backhauling (or other logistics solutions) to enable return of reusable storage containers or rescue of surplus food for people in need. ■ Invest in technologies to track temperature and ensure freshness, streamline routing, track movement of goods in and out of warehouses, and monitor food loss and waste.
Retailers (formal) 	**Operations-related:** ■ Improve training of staff in temperature management, product handling, and stock rotation. ■ Optimize inventory management systems (and increase flexibility in supplier contracts) to better match forecasting and ordering. ■ Review cosmetic specifications and accept a wider diversity of produce. **Consumer-related:** ■ Enable consumers to purchase smaller or customized portions (e.g., through bulk bins or staffed seafood and meat counters). ■ Adjust promotions to avoid excessive purchase of additional items (e.g., offer half off or mix-and-match deals rather than two-for-one offers). ■ Redesign in-store merchandising to avoid excessive handling of products by consumers (e.g., sort by stage of maturity), and to achieve the desired appearance of abundance but with less damage and excess product (e.g., through smaller bins and bowls). ■ Educate consumers about better food management (e.g., proper storage, meal planning, understanding date labels, safe food handling, cooking tips).
Retailers (informal) 	■ Participate in groups or associations of informal operators to access guidance and training in best practices in food handling and storage. ■ Take advantage of municipal support to access clean water, storage areas, equipment that improves food safety, and training in how to reduce food contamination. ■ Use practices that minimize damage such as handling produce gently, stacking properly (e.g., to avoid bruising delicate produce), marking cases to track inventory, and rotating stock following a "first-in–first-out" method. ■ Ensure that displays allow air to be circulated and temperature conditions to be appropriate for product to remain fresh (e.g., high-ethylene producers should be kept away from ethylene-sensitive commodities). ■ Avoid sprinkling unclean water on products (to minimize wilting and shriveling) as such practices result in unsafe foods shunned by buyers.

Figure 5 | **Priority "To Dos" by Actor (Not Exhaustive) (Cont'd)**

	PRODUCTION	HANDLING AND STORAGE	PROCESSING AND PACKAGING	DISTRIBUTION AND MARKET	CONSUMPTION
Policymakers 	■ Embed into agricultural extension services (and in farmer subsidy programs) food loss reduction awareness, technical assistance, and financial aid. ■ Develop, facilitate, promote, and/or improve climate-smart infrastructure (e.g., roads, electricity, irrigation, community storage) and access to it, especially for smallholder farmers who live far from markets. ■ Increase investment in agricultural research related to postharvest loss and provide incentives for the adoption of postharvest technologies (e.g., zero-rates tax on imported postharvest technologies, incentives for local manufacturers of postharvest technologies, subsidies for postharvest technologies). ■ Implement policies to prevent unfair trading practices (e.g., last-minute order cancellations and unilateral or retroactive changes to contracts). ■ Remove barriers to food redistribution via policies (e.g., liability limitations, tax breaks) that make it easier for food suppliers to donate safe (but unsold) food to charities or to those in need. ■ Support policies to standardize food date labeling practices to reduce confusion about product safety and quality, and improve consumer understanding of the meaning of date labels. ■ Include food waste reduction lessons in school curricula and include food waste reduction training in public procurement programs. ■ Provide municipal support for informal retailers to access clean water, storage areas, equipment that improves food safety, and training in how to reduce food contamination. ■ Make measurement and reporting of food loss and waste by large companies mandatory. ■ Tax food waste.				
Financiers 	■ Increase the number of philanthropic institutions funding food loss and waste prevention activities. ■ Create financing instruments and product lines (e.g., funds, bonds, loans) dedicated to reducing food loss and waste. ■ Increase start-up financing for new technologies and business models that would reduce food loss and waste, as well as financing to scale up proven technologies and models. ■ Increase development cooperation between high-income and low-income countries targeting food loss and waste. ■ Introduce "pay-as-you-go" programs to make technologies affordable for smaller operations (e.g., for solar-powered refrigeration units and mobile processing).				
Innovators and intermediaries (e.g., brokers, consolidators, digital solution developers) 	■ Develop and improve availability of processing and preservation facilities (including aggregation centers and mobile low-carbon options). ■ Develop alternative outlets during peak season through organizing export opportunities to markets with other seasonalities. ■ For unmarketable crops, improve flow of information to find alternative buyers, promote financially viable alternative markets, or develop new outlets (e.g., as processed foods, industrial products, animal feed). ■ Apply innovations to reduce delays for imported products during the point of exit and entry, which extends the shelf life of perishable products. ■ Leverage technology and digital solutions to rethink and better coordinate key processes between suppliers and customers in a more organized and informed way.				
Researchers 	■ Research new and innovative technologies to preserve food quality and extend shelf life. ■ Develop innovative products from perishable food commodities, such as fruits and vegetables, to promote whole food utilization. ■ Undertake research to fill data gaps and standardize reporting of food loss and waste data in order to better compare results, create benchmarks, and provide clearer direction for stakeholders. ■ Assess impact of interventions to improve evidence base of what works and the return on investment. ■ Develop sector-specific guidance that provides the motivation and technical information for businesses to take action (e.g., promote industry roadmaps for food loss and waste reduction).				
Civil society 	■ Raise awareness and shift social norms so that food loss and waste is considered "unacceptable" for all, including higher-income consumers. ■ Encourage public and private sector leaders to pursue the Target-Measure-Act strategy. ■ Act as a channel for the sharing and reporting of food waste data and progress.				

Source: Flanagan et al. (2019a) based on Canali et al. (2014); CEC (2017, 2018, 2019); Clowes et al. (2018a, 2018b, 2019); Food Loss and Waste Protocol (2016); Global Knowledge Initiative (2017); Gooch et al. (2019); Gunders and Bloom (2017); Hegnsholt et al. (2018); HLPE (2014); ReFED (2016); and WWF-US (2018).

Table 1 | **Ten Scaling Interventions**

	INTERVENTION	DESCRIPTION
Whole supply chain approach	1. Develop national strategies for reducing food loss and waste	Increase the number of countries with national strategies, as these can be an important catalyst for Target-Measure-Act at the country level—aligning public policy, private sector action, and farmer to consumer behavior toward a shared goal.
	2. Create national public-private partnerships	Increase the number of country-level public-private partnerships dedicated to achieving SDG 12.3.
	3. Launch a "10 × 20 × 30" supply chain initiative	Launch a voluntary private sector campaign where at least 10 corporate "power players" commit to Target-Measure-Act themselves and then engage their own 20 largest suppliers to do the same and achieve a 50 percent reduction in food loss and waste by 2030.
Specific hotspots approach	4. Invigorate efforts to strengthen value chains to reduce smallholder losses	Energize efforts to help smallholder farmers reduce food losses during production and storage.
	5. Launch a "decade of storage solutions"	Kick-start a focused collaboration among storage providers, cold chain alliances, financiers, and governments to rapidly get income-sensitive, climate-smart storage technologies into the hands of farmers and distribution networks around the world.
	6. Shift social norms and behavior	Leveraging the latest findings of behavioral science, engage grassroots campaigns, social media, religious communities, and others to make "wasting food" as unacceptable as littering now is in many countries.
	7. Go after greenhouse gas emissions reductions	Use sector-led programs to tackle food loss and waste from beef, dairy, and rice head on, and get the reduction of food loss and waste into nationally determined contributions to the Paris Agreement on climate change.
Enabling conditions approach	8. Scale up financing	Develop funds and financing products dedicated to investing in innovation and scaling up enterprises, technologies, and programs that would reduce food loss and waste.
	9. Overcome the data deficit	Over the next five years, a concentrated push to measure food loss and waste is needed to overcome this data deficit in time to support achievement of SDG 12.3.
	10. Advance the research agenda	Engage in more research to answer multiple "next generation" questions that would, in turn, help refine food loss and waste reduction strategies and advance implementation of the global agenda.

Source: Author analysis.

INTERVENTION 1

Develop and Implement National Strategies for Reducing Food Loss and Waste

The first scaling intervention is to increase the number of countries with national strategies for reducing food loss and waste.

What is it?

A national strategy for reducing food loss and waste is a plan of action for achieving an overall prevention and reduction of food loss and waste within national borders. This plan includes a suite of programs, policies,[3] practices, incentives, and/or other related measures to influence the actions of farmers, companies, consumers, and political bodies in order to achieve the reduction target.

Why is it important?

Since national governments are the entities that committed themselves to the SDGs, it is logical that national governments should have strategies for achieving the various SDG targets. A national strategy has the power to align public policies with private sector actions, farmer practices, and consumer behavior toward a common target—since governments cannot achieve the SDGs on their own. But to be effective and not just a document sitting on a shelf, a national strategy needs to be politically supported, backed by financial resources, and monitored for follow through. Moreover, the convener (e.g., government agency, national nonprofit) of the entities developing the national strategy should feel accountable for execution of the strategy. The few countries that appear to be making significant progress on tackling food loss and waste (e.g., the United Kingdom, the Netherlands) have national strategies in place (Flanagan et al. 2019b).

What should a national strategy include?

As articulated in Flanagan et al. (2019a), the Target-Measure-Act approach can be helpful in framing a food loss and waste reduction strategy, and includes national strategies. The "Target" here is SDG 12.3, to which a national strategy should commit. "Measure" means that the strategy should define what "counts" as food loss and waste, how it should be measured, and the periodicity of measurement. For a nation to "Act" most effectively, its strategy should describe who needs to do what, including specifying which of the actor-specific interventions described in Figure 5 are to be prioritized. National strategies should seek to engage nearly all relevant actors within a nation. Table 2 outlines features that we recommend be included in a national strategy on food loss and waste reduction, based on contents of already existing national strategies and on our perspectives.

What is the status to date?

As of August 2019, only a few countries had developed national strategies to reduce food loss and waste. Some of these strategies tackle food loss and waste across the whole supply chain, and contain many of the key recommended features listed above. For instance, the United Kingdom's "Food Waste Reduction Roadmap" includes

activities, milestones, and guidance for the private sector to Target-Measure-Act on food waste. The Netherlands has developed a national strategy, "United against Food Waste," for achieving SDG 12.3; it involves four action pillars: private sector engagement, consumer awareness, policy changes for a circular economy, and monitoring. Germany recently approved its National Strategy for Food Waste Reduction, which addresses political frameworks, food sector business process optimization, behavior change, and digital solutions for logistics. Australia recently created a national strategy that adopts a target in line with SDG 12.3, sets a timeline for generating an estimate for food loss and waste in the country, establishes a voluntary agreement to engage businesses along the supply chain, and is supported by initial funding of 1.3 million Australian dollars over two years (Australian Government n.d.).

National strategies that cover specific stages of the food supply chain or specific commodities exist or are under development in a number of countries. For example, a national strategy to reduce postharvest losses of grains is being developed in Uganda, and a roadmap to reduce postharvest losses is being developed for Vietnam. Although these strategies do not tackle food loss and waste across the entire food supply chain, they target the hotspots of losses in those specific countries (Flanagan et al. 2019b).

What are possible next steps?

If SDG Target 12.3 is to be met, many more nations will need to create national food loss and waste reduction strategies that include, at a minimum, the design parameters outlined above. Just as important, these strategies need to be accompanied by adequate financing and political support for implementation. Most nations around the world need to develop such strategies, since few to date have them.

As we first noted in Flanagan et al. (2019a), Africa provides an immediate opportunity for progress. The African Union's Continental Post-Harvest Management Strategy encourages member states to develop national strategies on postharvest food losses and also encourages member states to report progress on targets set out in the Malabo Declaration, including a target to halve postharvest losses. So there is political buy-in at a broad level. Thus far five member states—Ethiopia, Kenya, Tanzania, Zambia, and Zimbabwe—have taken steps to create national strategies, supported by the African Union, FAO, and The Rockefeller Foundation (FAO 2018a). But this means that 50 African countries have not. Supporting these nations in developing their own strategies is a window of opportunity.

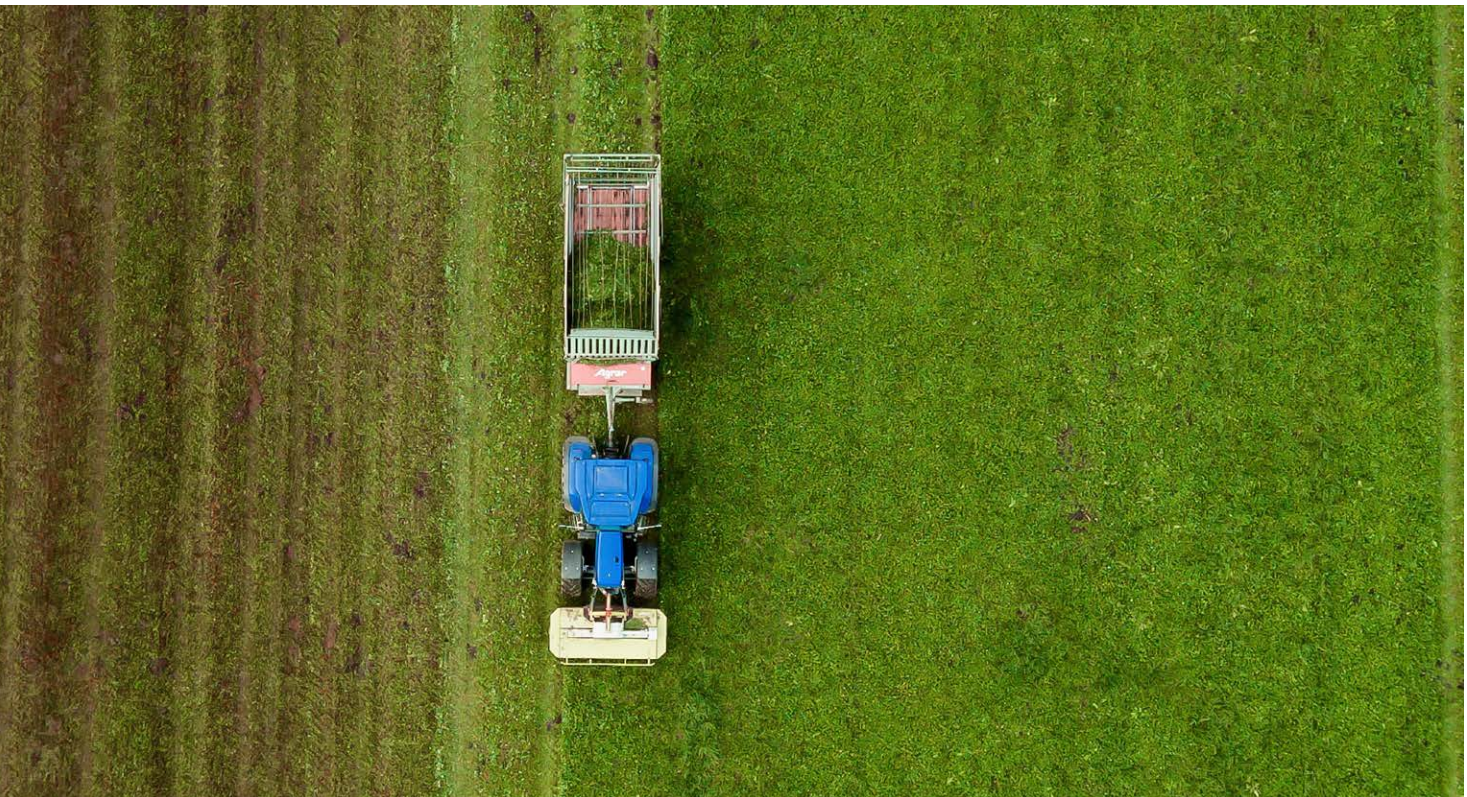


Table 2 | **Recommended Features to Include in a National Food Loss and Waste Reduction Strategy (Not Exhaustive)**

THEME	FEATURE	COMMENT
Target		Set a target consistent with SDG 12.3 (50 percent reduction by 2030). As suggested in *Reducing Food Loss and Waste: Setting a Global Action Agenda* (Flanagan et al. 2019a), the authors recommend that the 50 percent reduction apply to both food losses and food waste, and cover from the point that crops and livestock are ready for harvest or slaughter through to the point when they are ready to be ingested by people.
Measure	Scope	Select the scope of what should be measured. The scope includes what types of material are to be considered "food loss and waste," what destinations of that material are to be considered "food loss and waste," and the geographic and organizational boundaries to consider (e.g., food loss and waste that occurs within national boundaries). Champions 12.3 published a guidance note that recommends the best practice for countries in achieving SDG 12.3 (Hanson 2017), advising that the "halve per capita" apply not just to food waste (as written in SDG 12.3) but also to food losses (i.e., preretail food waste). Moreover, the guidance note recommends that the scope cover from the point that crops and livestock are ready for harvest or slaughter through to the point that they are ready to be ingested by people. Chapter 1 in Flanagan et al. (2019a) provides some recommendations on setting a scope.
	Methods	Recommend which quantification methods public, private, and research sector actors should use. Given the complexity of the issue and variations in data and resource availability, no single method will likely be appropriate. The FLW Standard (Food Loss and Waste Protocol 2016) outlines 10 quantification methods (or combinations of them) that are possible.
	Base year	Select a year for the first quantification of food loss and waste against which the reduction target will be applied and future progress measured. Ideally this year would be as close to 2015 (the start of the SDGs) as possible in light of data availability.
	End year	Select the final year of quantification. Ideally this should be 2030 in order to match the time period of SDG 12.3.
	Milestones	Recommend some measurable milestones of progress along the way between the base year and the end year. These milestones might include percentage of reduction to date, share of private sector engaged, number of new public policies implemented, and so on.
	Frequency	Determine how many quantifications will occur between the base year and the end year. Optimal periodicity of quantification is between every other year and every five years (in order to allow actors to take corrective action after seeing results).
	Entities	Recommend which entities should measure their food loss and waste. At a minimum, the national government should measure food loss and waste that occurs within national borders. This can be done with assistance of national research institutions and/or FAO and UNEP. Cities should consider measuring. Likewise, large companies active in the national food supply chain should measure their food loss and waste.
	Public reporting	Require that the results of each measurement be publicly reported in order to raise awareness of the issue, celebrate progress, enable benchmarking, and motivate further action where progress is not being made. Stakeholders will appreciate transparency on the issue, and this can foster greater collaboration and joint problem-solving.
Act	Actors-specific interventions	Based on country-specific evidence and conditions, articulate which of the actor-specific interventions described in Figure 3 are to be prioritized, supported, and realized. In other words, give initial recommendations on interventions that actors can take during harvesting, storing, processing, marketing, and consuming food.
	Public policies	Articulate which public policies are to be implemented to support food loss and waste reduction. In addition, articulate the process by which public policy impacts will be evaluated and refined over time.
	Public-private partnerships	Recommend the formation of a public-private partnership to help with implementation of many aspects of the strategy. Articulate aspired membership and activities of the partnership. See scaling intervention #2 in this publication for more details.
	Investment	Recommend the amount, type, and sources of investment needed to implement the strategy.

Source: Author analysis.

INTERVENTION 2

Create National-Level Public-Private Partnerships

The second scaling intervention is to develop and implement national-level public-private partnerships (PPPs) dedicated to reducing food loss and waste.

What is it?

In a public-private partnership, relevant government agencies collaborate with relevant nongovernmental actors (e.g., companies, research institutions, civil society organizations) to jointly tackle an issue of joint interest—typically an issue where both public and private actors are needed to effect change. A national-level public-private partnership on food loss and waste is one such partnership where participants share a common ambition to reduce food loss and waste within the country. Participants are ideally national agriculture and environment agencies, food-related businesses (e.g., producers, manufacturers, retailers, restaurants, hospitality companies) active in the country, nongovernmental organizations that work on food loss and waste, and research institutions that bring topical expertise.

Why is it important?

Public-private partnerships are an important approach to tackling food loss and waste for several reasons:

- ***They bring the private sector and public sector together.*** Reducing food loss and waste requires private actions complemented by supportive public policies (Flanagan et al. 2019a). No single institution can drive a 50 percent economy-wide reduction on its own. The private sector is particularly critical in markets where it is a major player in food production, distribution, and sales. The public sector can provide policies, infrastructure, and incentives to facilitate private sector actions.
- ***They facilitate action across the entire food supply chain.*** Reducing food loss and waste often requires a "whole food supply chain" approach (Flanagan et al. 2019a). Their memberships enable public-private partnerships to reach all the way "up" the supply chain to farmers and all the way "down" the supply chain to consumers.
- ***They can tailor generic solutions to local implementation.*** National-level public-private partnerships help address hotspots of food loss and waste by enabling generic interventions (e.g., increase adoption of low-cost storage technologies) to be tailored to the national context and hotspots. This implies that a public-private partnership need not "begin with the answers." Rather, the partnership can implement a process by which members jointly figure out the interventions that are most appropriate for their national context.
- ***They enable sharing of strategies and best practices between actors who face similar issues.*** The precompetitive sharing and joint problem-solving that occurs in a public-private partnership can accelerate

implementation of food loss and waste reduction measures, and can make them more cost-effective.

- ***They are demonstrating success.*** For example, the Courtauld Commitment in the United Kingdom has driven total avoidable food waste (post–farm gate) down by 19 percent since 2007 (WRAP 2018). Countries making the most progress to date on food loss and waste reduction appear to be those with public-private partnerships (e.g., the United Kingdom, the Netherlands) (Flanagan et al. 2019b).

What is the status to date?

National-level public-private partnerships focused on reducing food loss and waste have begun to emerge over the past decade. The first such partnership was the Courtauld Commitment, launched in the United Kingdom in 2005. The partnership has led to measurable improvements in food waste levels among companies and households in the United Kingdom, with a ratcheting up of ambition over the years. Its pioneering success has helped inspire public-private partnerships on this issue elsewhere. For instance, in 2016, the U.S. Department of Agriculture and U.S. Environmental Protection Agency engaged 20 food retailers and manufacturers with operations in the United States to form the Food Loss and Waste 2030 Champions (USDA 2018). In 2018, the Pacific Coast Collaborative invited leaders from the food product and retail industries to collaborate and convene with West Coast jurisdictions to commit to reducing wasted food 50 percent by 2030 (Pacific Coast Collaborative 2018).

In 2018, the Netherlands launched "United against Food Waste," a public-private partnership to deliver on the Dutch national goal to halve food waste by 2030. Over the subsequent four years, the Dutch Ministry of Agriculture, Nature and Food Quality will provide €7 million to the initiative to support innovation, research, monitoring, and education (Flanagan et al. 2019b). Also in 2018, a coalition of companies, government agencies, and nongovernmental organizations launched the "Food Loss and Waste Action Partnership–Indonesia" dedicated to dramatically reducing Indonesian food loss and waste (Flanagan et al. 2018). The latter is the first such public-private partnership outside Europe and North America. Future public-private partnerships are under discussion in a few other countries, too, such as Sweden and South Africa.

What are possible next steps?

We recommend that public-private partnerships dedicated to reducing food loss and waste become established in more countries. In fact, if such partnerships emerged in the following additional countries, then the world's 20 largest agriculture exporters would be covered, representing nearly half of the world's population: Argentina, Belgium, Brazil, China, France, India, Italy, Malaysia, New Zealand, Poland, Thailand, and Turkey (FAO 2018b).

The countries most amenable to establishing such public-private partnerships may be those with domestic operations of some members of the Consumer Goods Forum and/or the Global Agribusiness Alliance. These business associations already have their own global food loss and waste reduction targets aligned with SDG 12.3, and many members have already started measurement and action in at least some of their operations (CGF 2018). Therefore, the domestic operations should (in theory) already have corporate headquarter support for engagement in a national public-private partnership.

There are many ways one can set up a public-private partnership. One blueprint for doing so prepared by the Waste & Resources Action Programme (WRAP) and the European Union's project Resource Efficient Food and Drink for the Entire Supply Chain (REFRESH) involves five steps (Figure 6):

1. *Find an appropriate convener*. The lead organization or convener should be an independent, trusted organization that can convene businesses, government agencies, civil society, and research institutions (as needed) and recruit members from across the food supply chain. Examples include nongovernmental organizations, research institutions, and philanthropies.
2. *Set ambitious targets*. The targets should be aligned with SDG 12.3 and be shared by all participants.
3. *Identify sources of funding*. It will take human and financial resources to operate

the partnership. Start-up funding needs to be secured and a long-term funding strategy should be developed.

4. *Measure and take action*. Participants need to measure their food loss and waste in order to set a base year and to identify hotspots. Based on these data, participants then need to identify the actions required to reduce the hotspots. This should be followed by implementation.
5. *Evaluate progress*. Data should be collected and publicized periodically to help track progress, identifying successes as well as areas where progress is falling behind.

The steps are iterative, with the evaluation of progress feeding into new action planning.

A caveat

Those seeking to establish public-private partnerships on food loss and waste will need to address two challenges that have been experienced by partnerships to date (REFRESH and WRAP Global 2019). The first is competition for decision-maker time. Both governments and businesses face multiple priorities. Conveners of a partnership need to make an effort to get food loss and waste high enough on the list of issues garnering management attention. Making the business case for addressing food loss and waste (see Hanson and Mitchell 2017) and/or tying food loss and waste reduction to other business and government priorities (e.g., climate change, food security) can be a means of doing so. For example, Ethiopia's Ministry of Industry and the Industrial Parks Development Corporation have invested in the creation of a number of agro-processing parks, which were identified as one way to spur economic growth in the country. These agro-processing facilities are expected to play an important role in linking farmers to processing plants and therefore in reducing postharvest losses (Export.gov 2018).

The second challenge is the need for funding and in-kind commitment to operate the partnership. Ideally, the evidence of real financial savings from food loss and waste reduction at the corporate and government level should help convince the businesses and government agencies involved to contribute funds to the operation of the partnership. For example, evidence from Hanson and Mitchell (2017) shows that of 1,200 business sites across 700 companies that implemented food waste reduction programs, half yielded at least a $14 return for every $1 invested. Likewise, philanthropic and development assistance financing are candidates for cosupported public-private partnerships (see intervention #8 below).

Figure 6 | **Five Steps to Setting Up a Public-Private Partnership**

Source: REFRESH and WRAP Global (2019).

INTERVENTION 3

Launch a "10 × 20 × 30" Supply Chain Initiative

The third scaling intervention is to launch an initiative to leverage the power of supply chains to engage more companies in the Target-Measure-Act approach.

What is it?

Since the publication of Flanagan et al. (2019a), a 10 × 20 × 30 initiative has been launched (WRI 2019). It is a voluntary private sector effort in which at least *10* of the world's largest food retailers and food providers commit to the Target-Measure-Act approach themselves and then each engages at least *20* of its priority suppliers to do the same, with a shared goal of halving their food loss and waste by 20*30*. The 10 would provide their suppliers guidance on how to raise internal organizational awareness, technical assistance on measuring and taking action on food waste, and a means of sharing experiences to advance joint learning. Each cohort of 20 suppliers will be implementing the Target-Measure-Act approach.

The 10 × 20 × 30 initiative leverages the supply chain power of a few companies. Large food retailers and providers have market positions where they have many suppliers, relatively few competitors, and many customers. This is essentially a supply chain "pinch point" with market power. Thus, a handful of retailers and providers can catalyze change "up" the supply chain and across geographies.

Why is it important?

The initiative is important for several reasons. First, too few companies have yet internalized SDG 12.3 relative to the scale of the challenge. As of mid-2019, approximately 30 large food and agricultural companies have a food loss and waste reduction target consistent with SDG 12.3 (Flanagan et al. 2019b). Second, the 10 × 20 × 30 approach could make it in a supplier's interest to take food loss and waste reduction seriously. Third, food loss and waste data collected to date by suppliers to companies such as Tesco indicate that much more food loss and waste occurs upstream of food retailers and manufacturers. The hotspots are not the retail store or manufacturing facility but rather production before that, such as on-farm, in storage, or during handling (Tesco 2019). Therefore, one of the biggest impacts a food retailer or provider can have on food loss and waste is to engage and help its suppliers to reduce it.

Retailer-supplier engagement to date suggests that the 10 × 20 × 30 approach could be influential. The initiative is inspired by what food retailer Tesco pioneered in 2017, when 27 of its major suppliers committed to Target-Measure-Act (Flanagan et al. 2019b). All of these suppliers adopted the

target, completed their base-year food loss and waste inventories, publicly reported the results, and started exploring actions within one year of the start of the program. This is an indication that the market power of the entity requesting the commitment—and the training provided to the suppliers—can lead to follow through.

The 10 × 20 × 30 initiative could have impact across multiple dimensions. First, it could increase the number of companies pursuing the Target-Measure-Act approach, since each member would be engaging at least 20 others. Having the 10 come from a variety of geographic markets would reduce overlap in supply chains and thereby increase the number of suppliers engaged. Theoretically, up to 200 additional companies would become engaged. This is a significant increase from current levels.

Second, 10 × 20 × 30 could accelerate progress on food loss and waste reduction due to increased collaboration between buyers and producers in the supply chain. The approach is inherently collaborative. Among other things, the food retailers and providers would provide tools for measuring food loss and waste, tips on strategies that have proved effective elsewhere, and a forum for their suppliers to learn from the retailer or manufacturer, from each other, and from external experts. Likewise, 10 × 20 × 30 provides a platform where a supplier can explain to the retailer which of the latter's practices trigger food loss and waste in the supplier's operations. This mutual sharing and capacity-building can help companies learn faster and adopt proven practices.

Third, 10 × 20 × 30 could get more private sector involvement in tackling on-farm and near-farm losses. One of the hotspots identified in Flanagan et al. (2019a) is food losses during production (in many countries) as well as during handling and storage (especially in low-income countries). One way of motivating action among food producers, and of bringing financial and capacity-building resources to them, is for their downstream buyers to be engaged in a supply chain program focusing on food loss reduction. Whereas food loss reduction near the farm in low- and middle-income regions has tended to be the purview of government agencies and philanthropic efforts, 10 × 20 × 30 would engage the private sector as well.

Fourth, this approach could help companies who are part of the Science-Based Targets Initiative[4] meet their voluntary pledges. Reducing a company's food loss and waste within its own operations could contribute to Scope 1 emissions reductions, while reducing it within a company's supply chain could contribute to Scope 3 emissions reductions. Thus, 10 × 20 × 30 could be part of, or "nest" within, a company's wider greenhouse gas mitigation program.

What are possible next steps?

The 10 × 20 × 30 initiative was launched in September 2019. Convened by WRI, the founding food retailers and providers are AEON, Ahold Delhaize, Carrefour, IKEA Food, Kroger, METRO AG, Pick n Pay, the Savola Group, Sodexo, Tesco, and Walmart. Founders include 6 of the 10 largest food retailers in the world, the world's second-largest food service provider, and leading food retailers in regions such as southern Africa and the Middle East. Combined, participants operate in more than 80 countries. Technical support will be provided by WRI, WRAP, and UNEP (WRI 2019).

The next step is for these major food retailers and food providers to engage at least 20 of their priority suppliers. These could be "own-label" suppliers or "independent brand" ones. They could be the 20 largest, among 20 of the largest, or 20 prioritized based on most popular products sold, and so on. For each of the retailers and providers, engagement involves these actions:

- Requesting that its priority suppliers adopt the SDG 12.3 target (50 percent reduction by 2030), start measuring their food loss and waste, and take action to reduce the hotspots.
- Convening the suppliers to provide background information about SDG 12.3, a training package on how to measure their food loss and waste, and guidance or tips on common approaches to reduce food loss and waste relevant to their contexts. Such basic training packages have been pioneered by Tesco.
- Setting expectations, such as when baseline measurement is to be completed and published, how progress will be monitored, and how insights on what is working (and not) are generated and shared.

INTERVENTION 4

Invigorate Efforts to Reduce Smallholder Losses by Strengthening Value Chains

The fourth intervention emphasizes the underappreciated role of value chains in reducing smallholder farmer food losses during production and storage.

What is it?

Reducing smallholder losses involves implementing on-farm practices and improving collaboration along the value chain. In other words, smallholders can benefit both from on-farm use of technologies and practices that reduce food loss and from loss reductions downstream from the farm. Effective implementation requires well-functioning upstream value chains to support on-farm use and practices consistent with the market needs of downstream value chains.

Why is it important?

Managing postharvest loss (PHL) is a challenge endemic to agricultural and food systems. Time and resources are devoted to producing an attractive field of grain or an orchard of trees brimming with fruit. But for consumers to benefit (including the family of the smallholder farmer) that produce must be harvested, stored, transported, and processed within systems that may operate over several months and considerable distances. Without appropriate care and attention, losses can be distressingly high. The well-being of smallholders can be disadvantaged by losses both on the farm and beyond the farm gate.

Flanagan et al. (2019a) identifies key characteristics of settings where PHL would be minimized:

- Access to low-cost technologies such as improved harvesting equipment, storage units, cold or dry storage, and low-tech food processing units.
- Access to improved knowledge and skills in harvesting and storage.
- Access to small-scale appropriate financing to support use of these technologies.
- Aggregation capabilities at the smallholder level that provide operational and economic efficiencies.

Each of these characteristics requires involvement of actors in addition to the individual smallholder farmer. Smallholder farmers typically rely upon suppliers to provide key inputs and sell portions of their output in downstream value chains. However, they also typically do not know the quantity and quality that the market requires.

How is it done?

Each of the three types of value chains can help smallholders reduce losses in its own way:

a. A value chain that provides key **technologies** and supporting **practices** can enable smallholder farmers to minimize postharvest losses.

b. A relatively **simple commodity** chain can transport a smallholder's products to users who desire a relatively homogeneous output (more typical for staple crops).

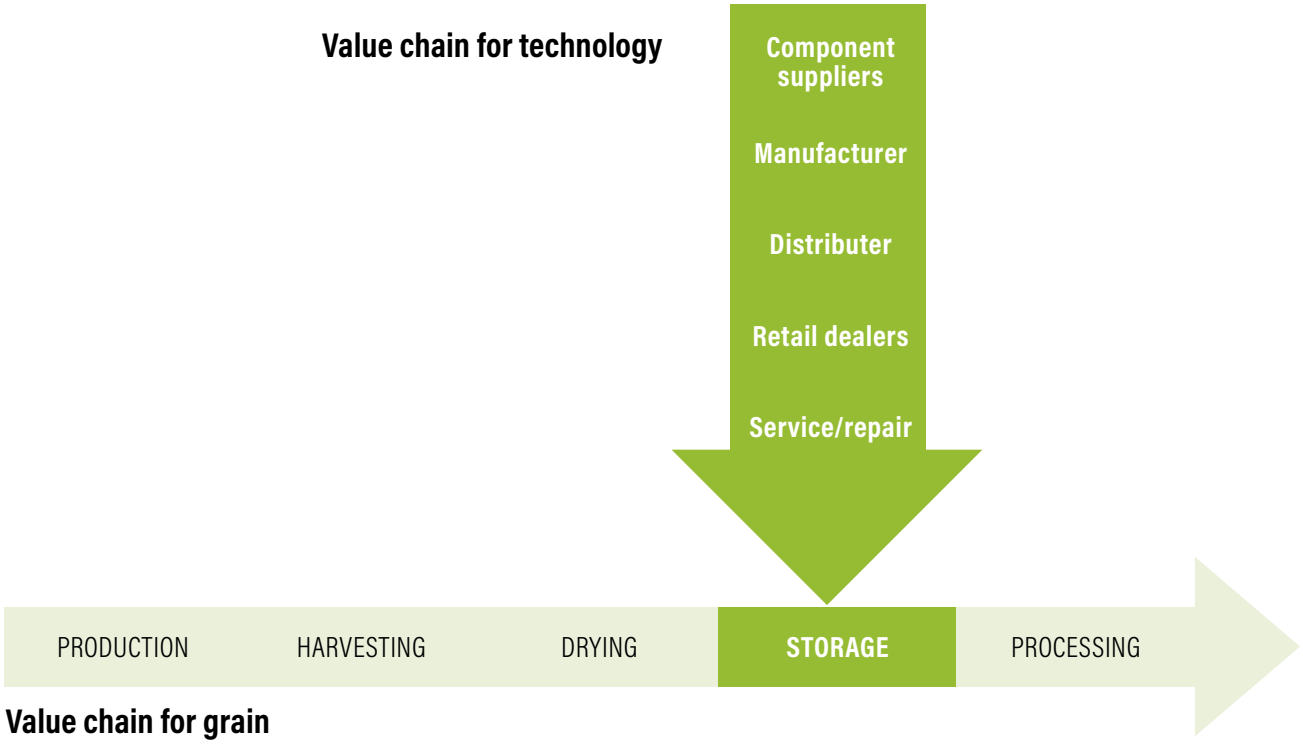
c. A more **complex commodity** chain can allow users to operate in differentiated markets that require agricultural products with differing quality attributes (more typical for perishables).

Figure 5 illustrates the roles of value chains types A and B above. The horizontal arrow refers to the value chain for a staple agricultural commodity (type B). That chain is shown as extending from production to the eventual end-user market. An example intervention might focus on improving storage at the smallholder farmer level. This could be done through use of hermetic storage bags, small metal silos in the farm household (see Box 3), or community storage systems.

For the smallholder farmer producing a staple such as maize, family consumption may be the end use. Improved storage allows smallholder farmers to escape the trap of having to sell their output at harvest when prices are low and then having to purchase that staple later in the year when prices are high. For instance, one study in Kenya found that farmers who used metal silos spent less on insecticides and were able to store maize for an average of nine weeks longer than nonadopters, meaning they were able to sell their surplus maize when prices were higher as opposed to directly after harvest, when prices tend to be low (Gitonga et al. 2013).

An underappreciated aspect of agricultural systems is shown in Figure 7 by the arrow in dark green. The arrow depicts the value chain for the *technology* of interest. Note there are two value chains in

Figure 7 | **Illustration of Value Chain for PHL Technology and Value Chain for Staple Agricultural Commodity**



Source: Sonka et al. (2018a).

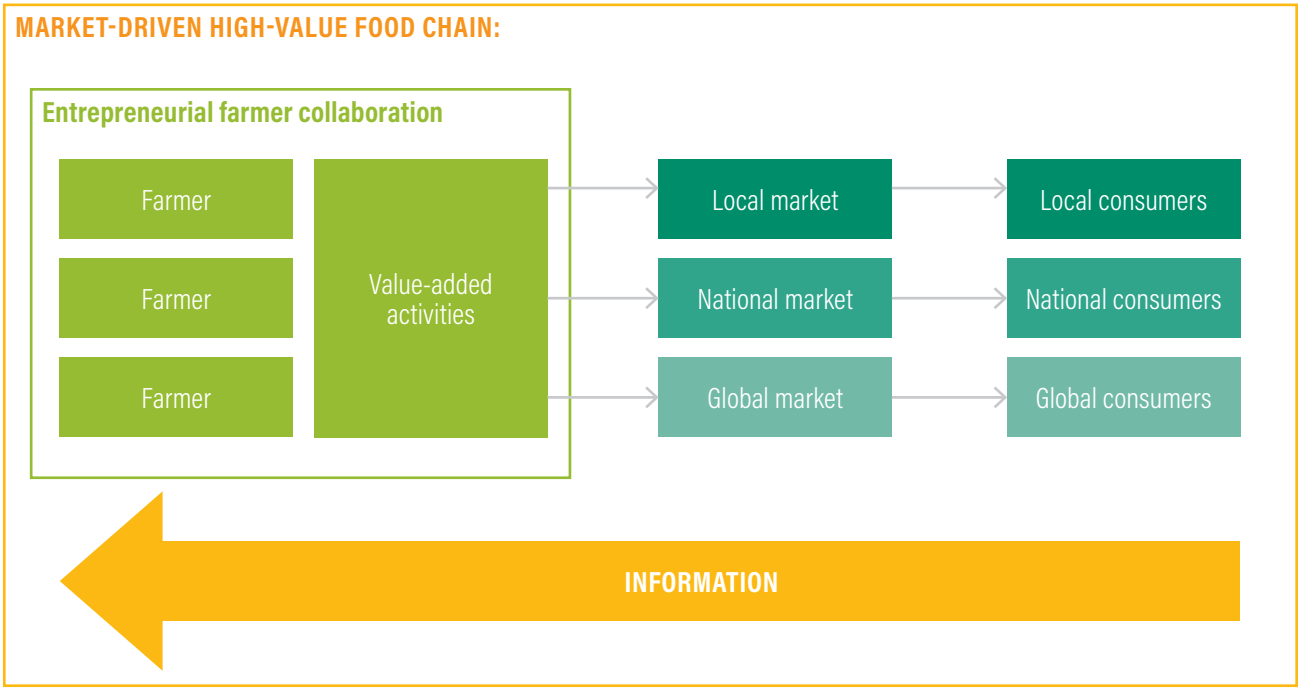
Figure 7: one for the agricultural commodity (grain) and one for the technology (value chain type A) that enables improved storage—bags, silos, or community storage. The components of the technology supply chain encompass more than the physical elements of production and delivery. Included are key market-place mechanisms such as service, user support, and product improvement over time. These mechanisms are vital if scaled adoption is to occur. Unfortunately, this value chain, although essential, is often overlooked despite being a key component of the business case for all actors.

The staple crop value chain of Figure 7 illustrates a "push" market system, where the existence of the output pushes the market system to use the product. An alternative is the "pull" approach, where the needs of the downstream users pull products with differentiated attributes through the market system. Such a setting is more applicable to fruit and vegetable markets. Relative to smallholder farmers, the differing requirements and opportunities of the type B versus type C value chains also have not been widely recognized.

Figure 8 illustrates the pull characteristic of such markets (value chain type C). At the right side of the figure, differing consumers and markets are identified. Note that the key distinctions here are not only matters of geography. Consistent supply of quality and quantity is also essential. Typically, export markets that serve global consumers require that the product arrive with little deterioration, despite the distances and time involved. However, local markets, often in rural villages, may require minimal effort to provide acceptable products.

To optimize value chain performance, the smallholder farmer should take actions consistent with the needs of the end-user market. If the product is not carefully handled during harvest, downstream actors typically cannot repair a product damaged at the farm level. Conversely, actions that a smallholder farmer might take to meet specific high-end export market requirements may not be economically rewarded in local or low-end processor markets.

Figure 8 | **Illustration of a Pull-Oriented Value Chain for Agricultural Products**



Source: Guo and Axmann (n.d.).

As the horizontal bar in Figure 8 indicates, information is essential to this value chain. To foster a system where smallholder actions serve the needs of particular downstream markets, alignment is needed to incentivize appropriate actions without causing unnecessary ones by smallholder farmers. In some settings, contract arrangements provide value chain alignment. However, contracts also can impose rigidities inconsistent with the uncertainties inherent in agriculture (Sonka forthcoming). Advances in information and communication technologies have the potential to better align actions of smallholder farmers and downstream actors. More work is needed to improve such coordination that can reduce PHL as the collaboration achieves increased efficiency.

The case studies in Box 2, Box 3, and Box 4 highlight the role of value chain development. The Kenya example in Box 2 shows how coordinated actions can lead to a more effective pull-type value chain (type C) to serve new food markets, which in this case also required enhancements to the farm input value chain (type A) to be effective. The case studies in Box 3 and Box 4 illustrate the need for an effective input supply value chain (type A) where the more subsistence setting kept the downstream value chain from being a substantial factor in reducing loss.

BOX 2 | CASE STUDY: POTATOES IN KENYA

In Kenya, the potato is an important food crop, second after maize, and a typical smallholder crop. Wageningen University & Research (WUR) documented the extent of potato losses and assessed viable strategies to reduce losses and extend the harvest window. Furthermore, WUR guided a lead company in redesigning a more effective potato value chain.

The study of potato losses showed that although farmers participating in the project were commercially oriented, they lacked awareness of the volume of postharvest losses throughout the value chain. While farmers could pinpoint hotspots for postharvest losses, they could not trace them back to the root causes. Up to 65 percent of recorded damage and loss in potatoes occurred postharvest. Key factors driving loss included inappropriate harvesting tools, insufficient training, lack of grading, and ineffective storage facilities. In addition, potatoes were marketed through a fragmented chain characterized by many handlers, minimal cooperation, and no integration, which resulted in unnecessary supply risks and quality losses.

In the second phase of the project, Wageningen evaluated potential solutions. To reduce postharvest loss, improved practices were needed—such as regular availability of certified seeds, use of machinery during harvesting, implementation of grading criteria, and provision of storage facilities. Strengthening market linkages required stimulating and enhancing cooperation and coordination between the different actors and shortening the value chain to benefit farmers. The introduction of standardized bags, along with per-weight payment and the expansion of contract farming were identified as opportunities to support the market linkages of smallholder farmers.

In the program's implementation phase, the business case was built around a lead company organizing the chain, traders and farmers who benefit from use of appropriate practices, and improved market linkages. The most effective intervention required an integrated approach with intervention at crop and postharvest levels. Using only one of those interventions would not have produced the desired result.

Storage financing was enabled by cooperation between entrepreneurs, small and medium-sized farmers, input providers, restaurants, banks, nongovernmental organizations, and traders. The result was a bankable business plan for midtech storage of 500 metric tons, supplying potatoes to a processing unit in need of high-quality, year-round raw material. The processing unit converts potatoes into fresh French fries and supplies them predominantly to local restaurants. This sector is growing fast in Kenya, but to take advantage of this opportunity, suitable processing varieties and a supply that is consistent in quantity and quality throughout the year are necessary.

This example from the potato sector in Kenya demonstrates that losses at the smallholder level can be reduced successfully by a market-driven design of value chains.

Source: Axmann et al. (n.d.).

BOX 3 | CASE STUDY: MAIZE IN CENTRAL AMERICA

Over a 20-year period, the Postcosecha program, conducted by the Swiss Agency for Development and Cooperation (SDC) fostered and facilitated the successful adoption of approximately 670,000 metal silos by smallholder farmers in four Central American countries. Metal silos helped 415,000 rural households preserve about 380,000 tons of grain each year, accounting for approximately 21 percent of annual grain production in the countries.

The program's extensive replication across Central America attests to its success. In addition, a careful postprogram review showed that the production and adoption of metal silos continued after the program was completed in 2003. Three sources of benefit were achieved: reduced grain loss, better selling price, and less need to buy high-priced grain during the off-season for family consumption. The estimated benefit-cost ratios to the program's farmer participants ranged from 2:3 to 3:5, and the internal rate of return ranged from 47 percent to 95 percent.

Postcosecha developed and supported a market environment to facilitate adoption of the metal silo technology. In fostering the demand for metal silos, SDC actively engaged stakeholders from both the public and private sectors. The program also helped establish the value chain to supply metal silos. SDC trained more than 2,000 tinsmiths in the techniques of metal silo production and in the concepts necessary to run a business. Trained tinsmiths were able to start their own metal silo businesses and thus became an essential link in the value chain, ensuring the future supply of metal silos.

Source: Fischler et al. (2011).

BOX 4 | MAIZE IN TANZANIA

A food staple of major importance for Tanzania's economy, maize is cultivated by most farmers, both to ensure household food sufficiency and to sell, with maize occupying 45 percent of the country's cultivated land (Ipsos Tanzania n.d.).

Starting in 2016, the YieldWise Initiative has introduced smallholder farmers to a series of postharvest loss-reducing technologies, including mechanized dehusking, mechanized threshing, tarp use, and improved storage practices. By the end of 2016, more than 25,000 smallholder farmers had been trained in the use of at least one of these technologies.

Over the project's duration, postharvest losses were substantially reduced. For example, while the beneficiary farmer group reported losses of 19 percent, losses in the control farmer group exceeded 39 percent, meaning that the YieldWise beneficiary farmers' losses were approximately half those of the control group. Beyond these benefits, farmers who adopted improved storage technologies such as hermetic bags and plastic silos reported improved quality of maize stored for consumption, with maize remaining free from pesticides, aflatoxin, and damage by pests (WFP 2019).

Source: Flanagan et al. (2019a).

What are possible next steps?

Sustained loss reductions require well-functioning upstream value chains that support on-farm use of good technologies and practices, and these practices need to be consistent with market needs. Matching market needs to the available supply might also reveal that, in fact, the market cannot absorb what is produced by the smallholders at that moment. We suggest the following solutions:

- Grow produce with an extended shelf life and therefore a longer sales window.
- Find new market outlets.
- Introduce value-added products.
- Produce other crops for which there is market demand.

We recommend a four-step process. First, **understand the root causes of losses.** This should be done in a market-driven approach that looks beyond the current status quo of a value chain. It is also important to rigorously examine consumer needs and market opportunities that require interventions, instead of focusing on interventions that only are feasible from a technical point of view. For example, in the case study in Box 2, crates likely could have been provided to reduce bruising in transport. This might well have resulted in marginal improvement. The case study demonstrated the value of looking to market possibilities that, through processing, extended the shelf life of potatoes.

In some cases, exploring the root cause of losses may show that well-intended loss interventions in the existing chain do not solve the problem. Reduction in food losses can become waste if the market is unable to absorb more of the same product. Longer and/or different sales windows and outlets might be more sustainable solutions in this situation. Examining the root causes of losses can also reveal unintended consequences. For example, while smallholder farmers may adopt hermetic storage bags for home consumption, value-added taxes increase the cost of the bags, which inhibits their use for transport and storage in the supply chain. A result is unnecessary use of pesticides on grain destined for urban consumers.

Second, **recognize that the "hotspots" associated with excessive postharvest loss tend to be more of a symptom than a cause.** Fixing the symptom (for example, by just providing hermetic storage bags or cooling chambers) is not likely to achieve sustained, scaled improvement. For example, in the case study in Box 3, the pilot efforts showed that metal silos reduced loss but did not achieve scaled adoption. Scaled adoption did not occur until the Postcosecha program developed an endogenous supply chain for metal silos. As noted in Figure 7, an effective value chain provides a range of services and support along with the physical product. These capabilities are essential for scaled, sustained adoption of technologies over time. While donor provision of technologies may be necessary in a demonstration mode, success will not be achieved until an on-going value chain is established to support and scale technology implementation.

Third, **design interventions to match the complexities of downstream value chains**, especially for perishables. In these settings, market needs must drive the design of the supporting value chain, including the contributions of smallholder farmers. An effective value chain has high-, mid-, and low-end market outlets so that produce that does not fully meet upper- or middle-class specifications remains in the food supply chain and is not wasted. Similarly, loss reducing actions of smallholder farmers should be designed to align with those needs.

In agricultural settings with strong government institutions and markets, the prior three steps tend to be identified and turned into opportunities by private sector actors (Sonka et al. 2018b). However, smallholder farmers and excessive postharvest loss are more common in economic environments where institutions and markets are relatively weak. In the fourth step, therefore, **civil society and nonprofit actors, as well as academia, should catalyze postharvest loss reduction** by initiating the development of locally driven value chains.

INTERVENTION 5

Launch a "Decade of Storage Solutions"

The fifth scaling intervention is to kick-start a focused collaboration among storage providers, cold chain alliances, financiers, and governments to get income-sensitive, climate-smart storage technologies into the hands of farmers and distribution networks around the world. In short, it is to make the 2020s a decade of mainstreaming storage solutions.

What is it?

Food losses during handling and storage can result from any number of factors, including careless handling, pests, inadequate reduction of heat and moisture during drying and before storage, vibration of vehicles on bad roads, lack of cold chain infrastructure, delays at border crossings, and disruptions due to weather, among others (Flanagan et al. 2019a). Relevant interventions tend to address the underlying drivers of poor infrastructure, inadequate equipment, inadequate implementation of practices, insufficient skills and knowledge, inflexible procurement requirements, lack of access to affordable financing, and climatic conditions.

Storage solutions include the first critical postharvest steps, immediately after a crop is harvested in the field, and are deployed throughout the supply chain to preserve a crop until it is consumed or utilized. Storage technologies and practices are intended to preserve crop quantity and quality, and to extend a crop's shelf life from field to plate (or trough). They include drying (e.g., sun, solar), handling (e.g., carrying, transport), and storage (e.g., hermetic, cold) solutions. Some occur immediately after harvest (e.g., solar drying), some occur multiple times along the supply chain (e.g., trucking), and some once more before use (e.g., home refrigerator).

A number of solutions for drying, handling, and storage of crops to reduce food loss and waste across the supply chain are emerging (Flanagan et al. 2019a). These include low-cost technologies such as hermetic bags to store grains and reusable plastic crates to transport fresh produce. Both are gaining traction in sub-Saharan Africa. Investments in storage infrastructure are growing, too. They include modern warehouses to aggregate grain bags from farmers for "bulk" sales to anchor buyers or cooling sheds to aggregate fresh produce from farmers for "bulk" sales to exporters.

How does it work?

Reducing food loss and waste during postharvest handling and storage requires supply chain actors to implement a number of priority solutions (Flanagan et al. 2019a).[5] For example, *crop farmers* need improved training in best practices such as handling produce to reduce damage, drying grain to the moisture content necessary for safe storage, and transporting crops to minimize loss due to spillage along rough roads. They also need access to aggregation centers that provide adequate storage and preservation options, such as cooling chambers. It is critical for *storage providers* to facilitate access to low-cost, locally relevant storage and handling technologies that prevent spoilage, increase shelf life, and protect against temperature variations, humidity and precipitation, and insect and rodent

infestation (e.g., hermetic grain storage bags, plastic or metal silos, stackable plastic crates).

Fishers need access to better drying racks that allow for temperature management and quality preservation, and that are secured on fenced-off landing beaches to avoid theft. *Ranchers* and animal source food producers need access to improved handling and preservation options for meat, eggs, and milk, such as milk collection centers with cooling tanks. They also need to improve conditions during transportation of food-producing animals from farms to markets.

Packinghouses need to adopt best practices to provide clean, cool, and/or dry conditions required to preserve perishable produce. Handling and storage practices need to be reexamined to reduce postharvest loss and damage. Consideration should be given, for example, to using liners to pad wood basket containers and reducing the size of sacks or crates to minimize product damage during stacking. Reverse supply chain logistics should be established to return poor quality and heavily damaged produce determined as unmarketable to livestock farmers for use as feed, thus reducing food loss and waste.

Transportation and logistics providers need to adopt improved handling practices during loading and unloading, and reusable crates that do not collapse during transport. Technology innovations and digital solutions exist to improve the flow of information (e.g., on road and traffic conditions, assigned pickup and delivery times, or what is in the truck load) to optimize movement of food upstream and provide access to alternative markets for products that cannot be marketed. Ideally, more energy-efficient, low-carbon footprint cold chains are implemented and expanded at key points in the supply chain from farms to wholesalers to reduce food spoilage and loss.

Additionally, *financiers* and financial service providers need to introduce "pay-as-you-go" programs to make handling and storage technologies affordable for smaller operations, especially those in rural locations. The use of drying, handling, and storage technologies is seasonal and depends on the crop cycle. Thus, financing instruments (e.g., endowed funds, near-prime-interest-rate loans, index insurance) are needed that calculate risk of investment and its return over the crop cycle period rather than the calendar year. Start-up financing for new technologies (e.g., solar-powered refrigeration units) and business models (e.g., fee-for-service mobile crop processing units), as well as financing to scale-up proven technologies and models (e.g., The Rockefeller Foundation's YieldWise model), are needed that would reduce food loss and waste.

Policymakers and governments need to develop, facilitate, promote, and/or improve climate-smart infrastructure (e.g., roads, electricity, irrigation, community storage, internet) and access to it, especially for smallholder farmers who live far from markets. They also need to increase investment in applied agricultural research related to postharvest loss, and incentivize the private sector (including smallholder farmers and farmer-owned enterprises) to adopt postharvest practices and technologies. Innovative approaches include zero-rate taxes on imported postharvest technologies that are proven and practical, and incentives for local manufacturers to adapt existing postharvest technologies for local solutions.

Why is it important?

Data sources beyond FAO (2011) indicate that storage of crops and finished foods is often a hotspot of food losses. For example, an assessment of 45 different crops over 100 regions of India found that poor storage was a hotspot across the food supply chain of losses for cereals, pulses, oilseeds, fruits, vegetables, and poultry (Jha et al. 2015). The main driver of these storage losses is lack of cold chain infrastructure, especially in villages. APHLIS (2016) indicates that, for nine cereal crops across eight countries in sub-Saharan Africa, handling and storage was the stage with the highest share of losses in 2016 (8 percent of total crop produced). However, fresh produce suffers even higher losses, especially during processing and packaging (Sheahan and Barrett 2017).

More recent research on food loss measurements for 20 hand-harvested crops in 123 fields conducted on California farms in 2016 and 2017 indicates that on average 31.3 percent of marketable yield remained in fields after harvest. Adding to that, walk-by (unharvested) field losses of 2.4 percent resulted in a food loss total of 33.7 percent (Baker et al. 2019). This is substantially higher than what has been reported and assumed for higher income

economies, but, based on our experience, it may well represent the economic optimum based on supply and demand as well as buyer and consumer preferences. It is therefore important to keep the local crop context in mind when assessing hotspots because food loss rates are highly variable and depend on crop, labor availability, market prices, and buyer and consumer preferences.

Studies are confirming that investing in technologies and practices to reduce food losses near the farm are generating financial returns. For instance, in West and Central Africa hermetic storage bags prevented grain losses and generated a 29 percent internal rate of return for farmers over a five-year period (Sonka et al. 2015). Adopters also spent less on chemical protectants and fumigants and were able to store maize longer than nonadopters. Thus, they were able to sell their surplus maize when prices were higher rather than directly after harvest, when prices tend to be low (Sonka et al. 2015). In Uganda, cold storage units on biogas-powered tricycles carry 300 kilograms (kg) (Global Knowledge Initiative 2017). According to its designers, the biogas-powered tricycle is a more flexible delivery vehicle in congested urban traffic and will provide more than a 15 percent return on investment in the second year of use (Bayer Foundations 2017).

At the local level, improving storage facilities can reduce food losses and increase the amount of food available for farmers to consume or to sell in markets. One study found that the use of hermetic storage technologies for grains in two regions in Tanzania led to a 33 percent reduction in the number of food-insecure households during the lean season. Hunger levels dropped by one-third immediately after farmers began using the improved storage technologies (WFP 2019). Reducing food losses during handling and storage can also increase incomes, which could be used by farmers to pay for family needs such as more nutritious food, education of children, and access to better health care (HLPE 2014). In India, precooling and cold storage facilities for banana growers reduced losses by 20 percent and resulted in farmers being paid three-times-higher prices for their produce (Danfoss 2019).

What is the status to date?

Some technologies and practices have gained traction and become commercially viable. For example, since their introduction in 2007, 20 million Purdue Improved Crop Storage (PICS) bags have been distributed across Africa (Baributsa 2019). These bags, made of woven polypropylene, have two plastic film liners and, when properly sealed, provide a hermetic, airtight environment. Biological activity inside them, primarily due to insect respiration, reduces oxygen concentration, eventually asphyxiating insects. PICS bags are sold in at least 18 African countries and commercially produced under license by plastic film manufacturers in several countries. Inspired by the success of the PICS bags, at least five other commercial manufacturers of hermetic bag storage technology products are in business in Africa, Central America, and South and Southeast Asia. The Postharvest Loss Alliance for Nutrition in Nigeria (PLAN-N) is working with the Lagos government and the Nigerian Ministry of Agriculture to promote the use of plastic crates to reduce tomato losses during postharvest handling and transportation. More than 80,000 of these crates have been purchased. Together they can hold 1.6 million kg of fresh tomatoes that are now more likely to reach the consumer (GAIN Health n.d.).

In 2018, the Indian government and the National Cold Chain Development Board funded the development of more than 2,000 fruit and vegetable packinghouses by 2021 (Kulkarni 2017). In Kenya, a new smallholder aggregation and processing center for mangoes has been established. The facility is equipped with low-cost storage technologies that enable farmers to aggregate their produce and negotiate better prices. It is equipped with juice processing and drying facilities that allow farmers to transform fresh mangoes into value-added products, such as pulp, juices, and dried chips, that fetch a better price at market (Ambuko 2019).

In 2018, the "One District, One Warehouse" project was launched by the Ghanaian government. The initiative aims to build 50 units of 1,000-metric-ton warehouses in selected districts that will provide storage for farmers and their produce (GhanaWeb 2018). AgResults, which uses "pay-for-results"

competitions to incentivize private investment in agricultural innovations, worked in Kenya to incentivize the private sector to develop and sell on-farm storage devices. By 2018, it had reached nearly 329,000 smallholder farmers and sold over 1 million improved storage devices, resulting in approximately 413,000 metric tons of improved storage capacity (AgResults 2018).

The rapid advance of communication and information technologies is providing digital service platforms. One example is the mobile app Cheetah, which allows food growers and transporters to share information about delays, vehicle breakdowns, detours, and traffic congestion. This information is used to reroute delivery vehicles in real-time, allow traders to plan ahead for alternative routes to markets, identify infrastructure bottlenecks and future improvement needs, and provide more accurate data on postharvest losses during handling and transportation (Cheetah 2018).

Funded by The Rockefeller Foundation, the YieldWise Initiative—a partnership including the private sector, government, and academic institutions—has supported more than 200,000 farmers in Kenya, Nigeria, and Tanzania to improve

- access to appropriate loss reducing technologies;
- access to finance by collaborating with financial institutions to develop affordable credit products that can be accessed by farmers and farmer-based organizations;
- aggregation and training of farmers and other supply chain actors in postharvest management and development of local aggregation centers; and
- access to markets by stimulating demand and engaging actors across the diverse ecosystem of buyers (Pyxera Global n.d.).

Multiyear results have been encouraging, with catalytic demonstrations for maize, mangoes, and tomatoes indicating loss reduction of between 20 and 30 percent, while more farmers are being connected to market channels and given assured markets for their produce. The three YieldWise Initiative projects have significantly advanced the use of postharvest loss reduction technologies and practices, and enhanced the well-being of individual smallholder farmers, their families, and their communities (Pyxera Global n.d.).

What are next possible steps?

As next steps, we suggest that the 2020s become a "decade of storage solutions." This entails collaboration by storage solution providers, the Global Cold Chain Alliance, the Global Food Cold Chain Council, financiers, governments, and academic institutions to get income-sensitive, climate-smart storage technologies into the hands of farmers, farmer-owned enterprises, small and medium-sized enterprises, and distribution networks (as well as households) around the world. The world needs to better understand the urgent need for better storage. To improve the understanding, use, and effectiveness of storage technologies, we recommend the following near-term steps:

- Encourage entities, such as the newly established Consortium for Innovation in Postharvest Loss and Food Waste Reduction, to step forward to lead this decade of storage solutions.
- Raise awareness about which storage technologies and practices are available and are appropriate for which conditions via media, public and private sector–led outreach programs, and other avenues.
- Build capacity or "know-how" for using these technologies via aggregated smallholder farmer training.
- Stimulate private sector investment to increase access to technologies, akin to prize competitions such as AgResults, which uses "pay-for-results" competitions to incentivize the private sector to invest in agricultural innovations. An AgResults project in Kenya, for instance, sold more than 1 million improved storage devices, resulting in approximately 413,000 metric tons of improved storage capacity (AgResults 2018).
- Introduce special credit interest rates, government subsidies, and/or "lease-to-own" programs to lower the cost of financing closer to prime interest rates.
- Connect market-facing anchor buyers (with their technical know-how, scale demand, and financial resources) and small and medium-sized enterprises with smallholder farmers to enable the approaches above.
- Be sure to assess the trade-offs between improved storage and the use of plastics.[6]
- Accompany implementation with research to assess the effectiveness of these recommendations.

INTERVENTION 6

Shift Social Norms and Behaviors

The sixth scaling intervention is aimed at shifting people's norms and behaviors in order to deter the wasting of food in consumption settings such as restaurants and the home.

What is it?

Many possible routes exist to changing people's behavior. These include giving people information about an issue, explaining the benefits of changed behavior, adjusting the consumption environment so that change becomes easier, making the desired change the default option, introducing legislation to encourage or mandate the desired change, and leveraging social influence to change behavior (Michie et al. 2013). This scaling intervention is focused on shifting social norms and attitudes, an approach identified as showing potential but currently underresearched with respect to food waste (Stöckli et al. 2018). Shifting social norms may be achieved via a range of actions that target social influences on behavior.

By "shifting social norms and attitudes" (hereafter sometimes shortened to "norms"), we mean creating a society in which wasting food is not acceptable, leading to behavior change as a result. In other words, people living in societies where this social norm is currently weak (most commonly in countries and cities of relative affluence) in the future would consider it "unacceptable" to throw away edible food and therefore not do it. This shift is akin to how people in many cultures today feel that littering is unacceptable, whereas decades ago littering was commonplace.

Why is it important?

The scaling interventions above would reach many actors in the food supply chain, yet few of them would directly engage people as they buy, prepare, and eat food in or out of the home. As countries develop and urbanize, the locus of food loss and waste appears to "shift" downstream toward the consumption stage of the food supply chain, meaning that food waste in the home, office, and restaurants will likely become a growing problem (Flanagan et al. 2019a).[7]

As we discussed in Flanagan et al. (2019a), a common theory as to why this is the case is that the "value of food" declines and food is no longer considered scarce as countries develop. The average household in the United States, for example, spent 43 percent of its income on food in 1945 but just 9 percent in 2015 (USDA ERS 2019). It is therefore no surprise, according to this theory, that food waste in the household is so high in the United States, because wasting food is now relatively cheap. By contrast, in Cameroon—a country with estimated low rates of waste at the consumption stage of the food supply chain—food comprises 46 percent of total household expenditures (USDA ERS 2019).

Raising the price of food would have negative impacts for the poor and few, if any, politicians would support such an approach. So what can be done to address food waste at the consumption stage? One approach is to raise awareness of the issue, ringing the proverbial alarm bell about the amount consumers waste and communicating the financial costs to households (and wider environmental and food security impacts). However, behavioral science indicates that, while education campaigns may raise awareness of an issue, increasing knowledge by itself does not necessarily translate into changed behavior (Samson 2015).

Other factors play a role in shifting behavior. Examples include the current attitudes a person holds, whether there are any barriers that prevent someone from adopting a new behavior, and social norms—the informal rules that govern our behavior (Michie et al. 2013). With regard to social norms, people tend to behave in a way that they think other people behave, or how they think one ought to behave (Bicchieri 2016). Successful behavior change efforts can leverage social norms to change individual behaviors, for example, by telling people about the behavior of others. For instance, in one study, energy consumption was reduced most significantly when normative messages such as "most people in your community are finding ways to reduce energy at home" were used, as opposed to messages that focused on environmental benefits (Nolan et al. 2008). Such messages create the impression of a new social norm, which makes certain behaviors more acceptable or even expected in the mind of the individual.

Changing the current social norms which lead to behaviors that increase food waste, such as the reluctance by people in some societies to take home leftovers from a restaurant, may be a way to reduce food waste in consumption settings (Hamerman et al. 2018). However, other factors may impact the efficacy of this change effort, such as how easy or difficult it is to adopt the desired new behavior, how the person thinks peers will perceive him or her, and who the messenger is (Samson 2015). Therefore, shifting social norms may require a number of additional steps, such as publicizing compelling role models (e.g., famous or respected people), making individual food waste more publicly visible to others, providing people with tools to make preplanning of food purchasing easier, or giving people tips on how to properly store food (D. Vennard, WRI, personal communication, 2019).

What should it include?

Emerging evidence suggests that integrated approaches to reducing food waste at the consumption stages are the most appropriate (Reynolds et al. 2019; van der Werf and Gilliland 2017). These may include communications, tips, and resources to support food-waste-preventing behavior, as well as tools to help people assess their own food waste. We therefore suggest that any intervention aiming to shift social norms on food waste develop an evidence-based strategy that addresses what we call the "4 Ms": Messages, Messengers, Modes, and Means (which includes tips and tools).

Messages

Developing a suite of messages will be an important element in interventions that aim to influence social norms about wasting food. Which types of messages are most effective likely will vary by audience and culture. For instance, WRAP had some success more than a decade ago with messaging around the personal financial implications of household food waste (e.g., "You can save almost £60 a month by throwing away less food") (WRAP 2013). This may have been particularly effective because the campaign ran during the Great Recession. Another form of historic messaging has had a moral character (e.g., "Eat everything on your plate since there are starving children elsewhere"). For other issues, messaging that highlights social influences or trends (e.g., "more and more people are doing *X* today") have had impact. Too little research has been conducted, however, on whether messages that leverage social influence work with food waste (which largely occurs in the privacy of the home), and which messages (and under which conditions) have had the most impact.

An approach that appears to have had impact, albeit on a different issue, has been to use powerful imagery that has moral overtones. Cases in point include the television series *Blue Planet II* and its now famous images of a sea turtle trapped in plastic netting and albatrosses with shards of plastic in their gut, as well as a YouTube video of a sea turtle with a straw stuck in its nose, which has been viewed almost 40 million times.[8] These images likely played a big role in catalyzing the modern ocean plastics movement. They are simple, touch human emotions, and send an unambiguous moral message about human behavior. Could the food waste agenda find a similar image?

Messengers

The intervention will need to identify the messengers most likely to influence people's behavior. One lesson from behavioral science is that people tend to model their behavior on that of people they identify closely with or hold in esteem (Bicchieri 2016). Therefore, those seeking to reduce consumer food waste should carefully consider the appropriate messengers (who will likely differ from market to market). These could range from children (who can influence their parents) to sports stars to online influencers to religious leaders (Box 5). Entities that serve as intermediaries between people and the food they consume—such as like hotels, restaurants, and retailers—can serve as messengers as well. These intermediaries have direct channels to communicate with food purchasers just before they purchase food.

Modes

The intervention will need to identify which forms of communication would be most effective, and how that communication should be timed. More traditional efforts at shifting behavior on other issues have relied on radio, television, and printed media to engage audiences. But such approaches can be expensive and untargeted. One mode worth more exploration is social media. Several social movements have started on social media, including #MeToo and the #ALSIceBucketChallenge. Food

BOX 5 | ENGAGING RELIGIOUS COMMUNITIES

As discussed in *Reducing Food Loss and Waste: Setting a Global Action Agenda* (Flanagan et al. 2019a), there is an ethical case for reducing food loss and waste:

"The importance of not wasting food is highlighted by several of the world's major religions. The Qur'an states this most explicitly: 'Do not waste. He does not love the wasteful.' The importance of preventing food waste has also been expressed in ethical terms by Pope Francis, whose *Laudato Si'*, an encyclical on the environment, states that 'whenever food is thrown out it is as if it were stolen from the table of the poor' (Francis 2015). Judaism condemns wastefulness in principles such as ***bal tashchit*** ('Do not destroy'), which essentially prohibits any wasteful negative effects on the natural environment. At many Buddhist retreats, Buddhists follow the practice of eating meals 'orioki' style, taking 'just enough' food. Hinduism teaches that no one should be hungry and that people should help those who are hungry; Mahatma Gandhi once said that 'God comes to the poor in the form of food' (Food Waste Weekend 2018)."

With 84 percent of the global population identified as "religious" (Hackett et al. 2015), there is a currently untapped opportunity for faith leaders to engage on this issue—urging the faith community to reduce food loss and waste on ethical and religious grounds. It is no surprise that many food rescue organizations have roots in the faith community. However, engagement needs to go beyond food redistribution, with faith leaders more proactively integrating "waste no food" messages into their teachings and communication with members. One "big idea" would be to organize an interfaith campaign on reducing consumer food waste among the world's largest religions. Such an interfaith effort could reach billions of people.

In late 2019, The Rockefeller Foundation and the Pontifical Academy of Sciences hosted a conference at the Vatican on the topic of food loss and waste. The aim of this conference was to develop a coordinated communication effort to raise the profile of food loss and waste in the media and mobilize civil society and faith communities to embed food loss and waste reduction efforts with their followers.

Source: Flanagan et al. (2019a).

retailer ASDA, for example, conducted a campaign via Facebook in which it got customers to publicly post their recipes for leftovers (Young et al. 2017). Food waste reduction could leverage social media as well, particularly as an approach to engage younger generations most comfortable with social media. Their behaviors could be influenced today so that, as they grow up, "not wasting food" is considered the norm.

Moreover, social media might be able to help overcome one challenge that the effort to shift norms about food waste is likely to face, invisibility. It is hard to create a normative behavior if that behavior is invisible (e.g., conducted in the privacy of one's own home or the relative privacy of one's table at a restaurant), because there is less chance that another person can observe what one is doing. Adherence to social norms is driven in part by people not wanting to be seen behaving outside that social norm (Bicchieri 2016). Making food waste more socially visible might be a key element to shifting norms. There have been some attempts at using social media to make food waste in the home more public. For example, both the Grumpy Bin and BinCam apps take photos of food that has been thrown in a person's trash and share these photos on Facebook. In the case of Grumpy Bin, the photo is accompanied by a sarcastic comment about the waste. In the case of BinCam, the photo triggers scores, rewards, and/or penalties. These interventions found that technological interventions can have an impact, although these do not necessarily persist over time (Stökli et al. 2018).

Means

The intervention will need to identify approaches and prompts that help consumers implement the desired changed behavior; messages alone are likely to be insufficient. For example, one study found that people are more likely to take home leftovers from a restaurant when waiters *offer* customers a "doggy bag" or "take home bag." The fact that the waiter offered it establishes the behavior of using such bags as the norm (Hamerman et al. 2018). It also can trigger conformity effects: people may have a desire to comply with the waiter's offer in order to be liked by the waiter or be held in esteem by fellow diners. Another nudge is to not have trays in buffets, which forces the consumer to use a plate instead and thereby avoid "hoarding" behavior (Lipinski et al. 2013). Another study found that informing diners (verbally or via signs) at a buffet that they are able to return for seconds reduced food waste by just over 20 percent (Kallbekken and Sælen 2013). Educating children in schools may be another approach to consider, especially since children can pressure parents into changing in-home behaviors (S. Gaiani, FAO, personal communication, 2019).

More research is needed into how social norm interventions can be effective in the home, where food is wasted out of sight of others. However, some promising ideas used for other issues could be applied. For example, in Nova Scotia, the amount of waste sent to the landfill was reduced by over 30 percent after residents were required to put their household trash in a clear bag, making it visible to neighbors (White et al. 2019). This type of intervention could be applied to food waste bags (where separate collections exist).

What are possible next steps?

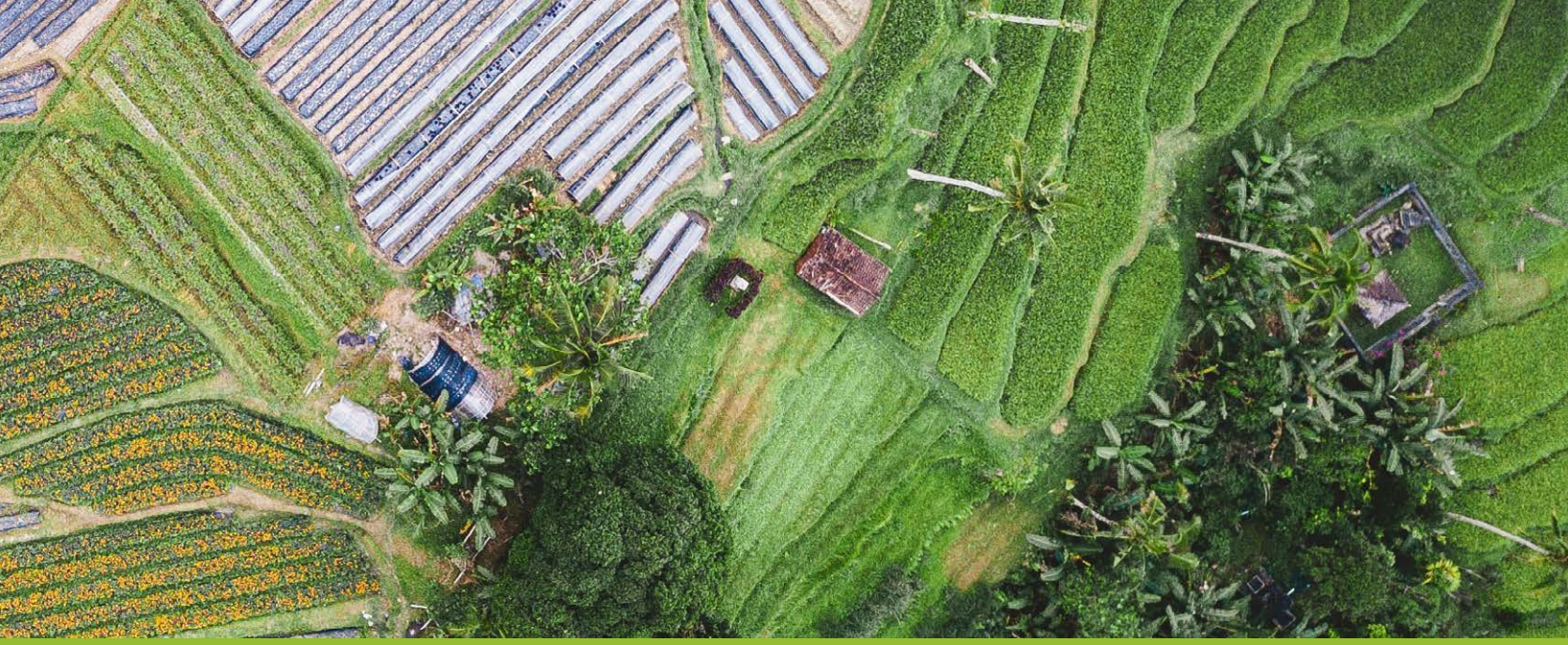
We recommend that nongovernmental organizations, government agencies, or combinations of both develop efforts with the culturally relevant combination of the "4 Ms." At least three next steps might help accelerate this:

- ***Increase research and funding.*** There is a dearth of evaluations of the effectiveness of various campaigns and efforts to shift social norms and behaviors about food waste. Much of the evidence that does exist is focused on reducing food waste in public settings, such as restaurants, rather than in the home (Stöckli et al. 2018; Reynolds et al. 2019). More quantified studies are needed. Underpinning this lack of research is a lack of funding to do so. Although investment in this area is growing, much more is needed.
- ***Launch pilots.*** After the evidence base of what works in what contexts is made more robust, we recommend that pilot projects be launched in cities and countries to test on a bigger scale what messages, messengers, means, and modes work in different contexts. A city could provide an ideal pilot site, considering the role cities play in waste collection and the fact that most urban areas tend to have higher rates of food waste in the home compared to rural areas. A pilot could bring together various actors who could influence behavior, including local government, retailers, religious leaders, and celebrities in order to provide them with the skills, knowledge, and motivation to shift the norms of the groups of people they have influence over.
- ***Scale up grassroots movements.*** In a number of countries, bottom-up, domestic-led campaigns by civil society organizations such as Feedback (United Kingdom), Stop Wasting Food (Denmark), and Save the Food (United States) have raised public awareness of food waste and developed messengers whom the public respects or listens to (e.g., celebrity chefs) in an effort to start shifting norms and behavior (Ipsos Public Affairs 2019). Going forward, we recommend the creation of more grassroots movements like these in more countries. These movements will need to know which combinations of the "4 Ms" are most effective. One way to achieve this would be for grassroots organizations with a track record of success to convene civil society organizations from more than 100 countries and provide training. In this manner, transferring practices and messages can be done at scale and can be tailored to local conditions.

INTERVENTION 7

Go After Greenhouse Gas Emissions Reductions

The seventh scaling intervention is to target food loss and waste as a means of reducing greenhouse gas (GHG) emissions.



What is it?

This intervention calls for two approaches. First, catalyze programs led by industry to tackle loss and waste in the food categories with the highest climate footprints (e.g., beef, dairy, rice). Second, get countries to focus on reducing food loss and waste as a way to contribute to achieving climate goals, for instance by getting food loss and waste reduction into nationally determined contributions (NDCs) to the Paris Agreement on climate change.

Why is it important?

Targeting greenhouse gas emissions reductions is an important strategy for food loss and waste reduction for at least two reasons. The first is political. In many countries, climate change garners more government attention, focus, and financing than other sustainability issues. Moreover, funding for climate change in domestic programs and international development assistance in many countries has increased in recent years (Global Finance Landscape 2018).

The second reason is physical. Food loss and waste is a significant contributor to human-caused GHG emissions. According to FAO analysis, global food loss and waste directly and indirectly accounted for about 4.4 gigatons of GHG emissions per year in 2011 (FAO 2015). This is equivalent to about 8 percent of GHG emissions worldwide. If food loss and waste were its own country, it would be the world's third-largest emitter, surpassed only by China and the United States (Figure 9).

The greenhouse gas emissions associated with this food loss and waste come from a variety of sources, such as

- on-farm agriculture emissions—such as from the digestive systems of cows, manure from livestock, on-farm energy use, and fertilizer emissions—for producing food that is ultimately lost or wasted;
- the production of electricity and heat used to manufacture and process food that is ultimately lost or wasted;

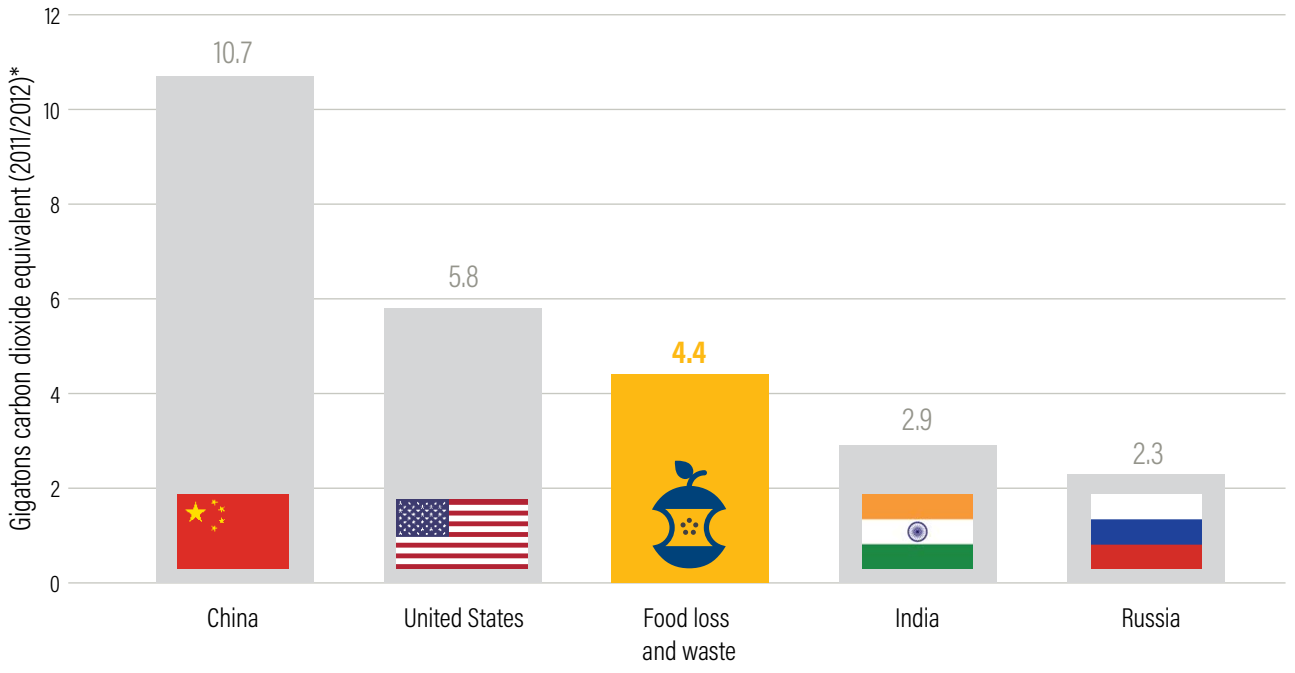
- the energy used to transport, store, and cook food that is ultimately lost or wasted;
- the landfill emissions from decaying food; and
- the emissions from land use change and deforestation associated with producing food that is ultimately lost or wasted (Searchinger et al. 2019).

From a climate perspective, all food loss and waste is not created equal. Meat (in particular ruminant meat such as beef) has by far the highest GHG footprint per kilogram of food, followed by dairy (Ranganathan et al. 2016). This is because nearly 50 percent of direct agricultural production emissions are caused by ruminants (i.e., cattle, goats, sheep) via enteric fermentation (i.e., methane generated in their stomachs) and their manure (Figure 10). Additional emissions are associated with land-use change to create pastures for beef cattle and dairy cows. Among plant-based foods, rice has a high footprint, given the methane released from paddies. In fact, in 2010 about 16 percent of all direct agricultural production emissions came from growing rice (Searchinger et al. 2019). Other analyses arrive at similar conclusions, highlighting bovine meat, dairy, and rice as the top GHG emitting food categories (Figure 11). Thus, ton per ton, losing or wasting any of these food categories has an outsized climate impact.

What are possible next steps?

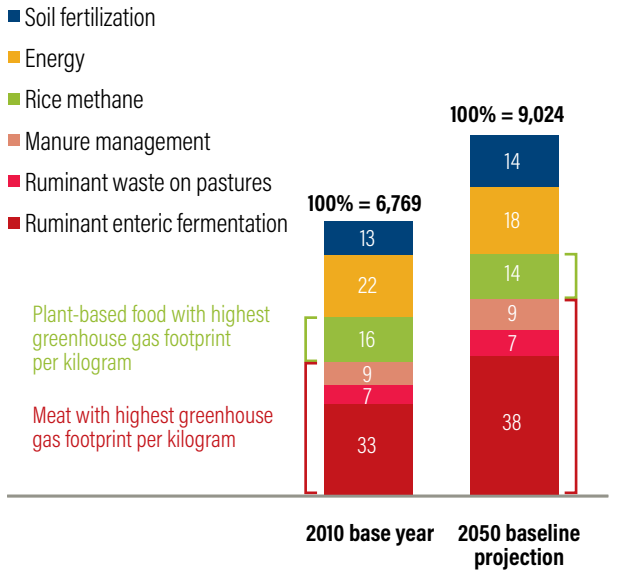
We recommend industry programs targeting the food categories responsible for the most greenhouse gas emissions. For example, the Sustainable Rice Platform—which brings together many of the world's largest rice producers—recently committed to take a Target-Measure-Act approach to SDG 12.3 and will engage growers to halve on-farm and near-farm rice losses (Flanagan et al. 2019b). We encourage the Global Dairy Platform—an associa-

Figure 9 | **Greenhouse Gas Emissions by Country vs. Food Loss and Waste**



* Figures reflect all six anthropogenic greenhouse gas emissions, including those from land use, land-use change, and forestry (LULUCF). Country data is for 2012 while the food loss and waste data is for 2011 (the most recent data available.) To avoid double counting, the food loss and waste emissions figure should not be added to the country figures.
Source: CAIT (2015); FAO (2015).

Figure 10 | **Annual Direct Agricultural Production Emissions (Excludes Land-Use Change) Million Metric Tons CO_2e**



Note: The 2050 baseline projection contains a number of assumptions, which are listed in the source. Numbers may not sum to 100 due to rounding.
Source: Searchinger et al. 2018.

tion of dairy suppliers around the world—to start a similar program, engaging dairies and processors with awareness-raising, food loss measurement tools, guidance on which interventions to implement, case examples of successes, a loss and waste reduction reporting platform, and periodic assessments of progress. For beef, a natural convener of an SDG 12.3 program would be the Global Roundtable for Sustainable Beef, which convenes many of the world's largest beef processors.

We recommend that governments incorporate food loss and waste reduction into national climate strategies, particularly in their NDCs to the Paris Agreement on climate change. An NDC consists of the pledges a country makes to the Paris Agreement to reduce its national GHG emissions. These pledges include an articulation (with varying degrees of specificity) of measures to be pursued by that country and actors within it. NDCs can be influential because they help set a country's priorities with respect to national climate change strategy, policies, and investments.

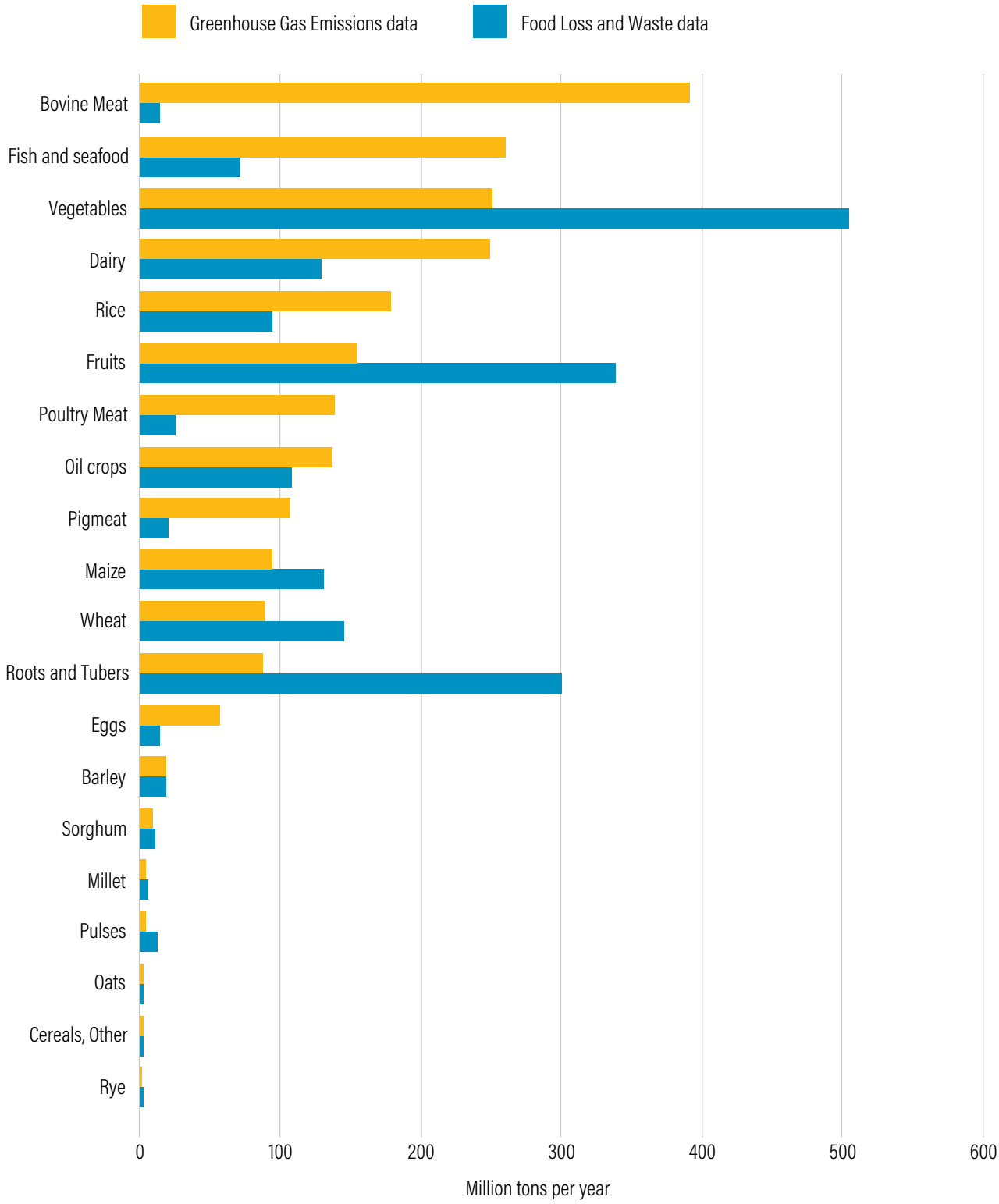
As of August 2019, only about a dozen countries had included some form of food loss and waste reduction in their NDCs, most of them in Africa. These are Belize, Bhutan, Burkina Faso, Chad, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Honduras, the Maldives, Rwanda, and Uganda (Climate Watch 2019). We recommend that more countries do so. Priority countries include major beef and dairy producers (e.g., Argentina, Australia, Brazil, EU members, the United States) and major rice producer and consumer countries (e.g., China, India, much of Southeast Asia). We also recommend that countries with large greenhouse gas emissions from organic material (much of it food) in landfills add "reducing organic material in landfills" to their NDCs, too.

The year 2020, a milestone in the Paris Agreement's five-year cycles of ratcheting up ambition, is an important political window of opportunity for doing this. At the UNFCCC Conference of Parties that December, nations are supposed to articulate how they are enhancing their NDCs. A push from government agencies, political bodies (e.g., African Union Commission), and civil society organizations could encourage more governments to add food loss and waste strategies to NDCs. Fortunately, plenty of technical support is available to help countries in this effort. Initiatives such as the NDC Partnership can help countries strengthen their NDCs and find the technical and financial support they need to implement new ambitions on food loss and waste reduction.

Caveat

The greenhouse gas intensity of the solution matters. From a climate perspective, it is important to assess potential trade-offs between the life-cycle GHG emissions associated with the food loss and waste to be reduced versus the life-cycle emissions generated by the proposed solution. In fact, every consideration about a food loss and waste solution should factor in such life-cycle GHG implications. Some solutions for reducing food loss and waste induce GHG emissions through energy use and packaging production. For instance, cold storage powered by a coal-fired power plant might actually have higher emissions per ton of food saved than the emissions associated with that ton of food being lost or wasted. Solutions with a net *reduction* in GHG emissions should be prioritized. Box 6 profiles one example where the food loss and waste reduction solution leads to even more GHG emissions for some foods, while in the other example the solution is a net benefit to the climate.

Figure 11 | **Global Food Loss and Waste and Associated Greenhouse Gas Emissions by Food Category (2013)**



Note: Estimates of global postharvest food loss and waste and associated greenhouse gas emissions are based on FAOSTAT production data and aggregated estimates from Porter et al. (2016).
Source: Guo et al. (2019).

BOX 6 | ASSESSING LIFE-CYCLE GREENHOUSE GAS EMISSIONS AND TRADE-OFFS

CASE 1. Vegetables and meat in the Netherlands

Food loss and waste of refrigerated perishables like cut vegetables and meat in supply chains is largely due to expiration at the end of shelf life (Mercier et al. 2017). Lowering refrigeration temperatures can extend the shelf life of these products, reducing losses. This reduction will lower greenhouse gas (GHG) emissions related to the food that otherwise would have been lost. However, applying a lower refrigeration temperature along the chain uses more energy over an extended period.

By modeling such a scenario for cut salad and beef (both with a shelf life of nine days) for a typical supply chain in the Netherlands, Broeze et al. (forthcoming) found that

- losses in shelf life due to exceeding the expiration date are reduced from 3.0 percent to 0.5 percent;
- average period in shelf life is extended from 40 to 45 hours;
- total refrigeration energy use is about doubled;
- for beef the total GHG emissions per kg sold is reduced from 25.4 to 24.8 kg CO_2e per kg meat; and
- for cut salad the total GHG emissions per kg sold is increased from 0.53 to 0.55 kg CO_2e per kg salad.

Thus, lowering refrigeration temperatures in this context was effective for reducing net GHG emissions for beef but not for salad.

CASE 2. Cassava in Africa

Supplying cassava to a centralized starch factory is accompanied by high losses because of the crop's vulnerability and perishability. Developed by Wageningen University & Research, a mobile processing unit capable of visiting (smallholder) farming communities may solve that problem by converting the crop to a stable cake or flour. Table B6.1 summarizes a comparison of this mobile processing unit versus the status quo of centralized (distant) processing and imported maize flour. The mobile unit significantly reduces GHG emissions.

TABLE B6.1. COMPARISON OF GREENHOUSE GAS EMISSIONS FOR DIFFERENT CHAIN CONFIGURATIONS FOR SUPPLYING STARCH TO A CENTRAL LOCATION

	GHG EMISSION SOURCE	PROCESSING TO CAKE IN MOBILE FACTORY	PROCESSING TO FLOUR IN MOBILE FACTORY	PROCESSING TO CAKE IN CENTRAL FACTORY	REFERENCE: IMPORTED MAIZE FLOUR
Kg CO_2 e per kg crop	Agricultural production	0.04	0.04	0.04	0.38
	Collection transport	0.03	0.03	0.15	0.07
	Emissions allocated to waste/losses	0.01	0.01	0.08	0.00
	Processing energy and packaging use	0.02	0.06	0.01	0.03
	Transport to starch factory	0.06	0.03	0.00	0.07
	Total	**0.16**	**0.17**	**0.28**	**0.55**
	Total (per kg starch)	**0.72**	**0.75**	**0.97**	**1.1**

Source: Broeze et al. (forthcoming).

INTERVENTION 8

Scale Up Financing

The eighth scaling intervention is to ramp up financing for food loss and waste reduction.

What is it?

Scaling up financing for food loss and waste reduction involves increasing the amount of financing available for programs, technologies, and enterprises that prevent or reduce food loss and waste. Such financing could be in the form of grants, government subsidies or incentives, development assistance, near-prime-rate-interest loans, or commercial investments. In our view, scaling also needs to improve the "bankability" or "investment readiness" of reduction programs, technologies, and enterprises.

Why is it important?

This scaling intervention is important for at least three reasons. First, too little money is making it into food loss and waste reduction. The amount of public, private, and philanthropic investment in reducing food loss and waste currently is quite small relative to the demands for achieving SDG 12.3. For example, innovations in food storage technologies in Africa and rollout of food waste reduction technologies in Europe need more financial support (Flanagan et al. 2019a). This increase in financing is needed in a variety of forms. Some solutions are very early in development and thus need grant, de-risked, or venture capital investment. Other solutions have been successfully piloted but now need more commercially oriented capital to go to scale (Flanagan et al. 2019a). Of course, the types of needed investments will vary in low-, middle-, and high-income countries. For example, investment in technologies to reduce food loss and waste in low- and middle-income countries should be sensitive to the needs of smallholder farmers.

Second, more financing is needed *directly* targeting technologies, enterprises, and programs that focus on the reduction of food loss and waste. Doing so might require a shift in funding priorities. To date, much funding that affects food loss and waste arguably is focused on broader goals (e.g., rural infrastructure, electrification) that in turn may have a knock-on positive effect on reducing food loss and waste. But those effects might be quite diluted. More impact might be achieved, arguably, if more investments *directly* targeted food loss and waste (e.g., storage technologies, storage warehouses, new food processing systems, enterprises focused on food loss and waste reduction).

Third, more candidate investments need to be investment-ready. Interviews with financial institutions indicate that ideas that cross prospective financiers' desks may be promising but often lack a credible approach to convert them into a viable

business case or investment. They may lack good business plans, strategies for getting to scale, or clear customers; they may not have a high enough return on investment; or they may be experiencing a combination of these shortcomings. In other words, there is a shortage of "bankable" projects.

What are possible next steps (per type of financier)?

In the following, we suggest what various sources of financing could do to help scale investments in food loss and waste reduction.

Private philanthropy

We recommend that private philanthropy (e.g., foundations, individual benefactors) increase grant-making to food loss and waste initiatives. Despite all the social and environmental benefits of reducing food loss and waste, author research into foundation grant-making finds that fewer foundations are investing in this thematic area than in areas such as climate change and forest conservation. We recommend that more philanthropies add the reduction of food loss and waste to their portfolios. Reducing food loss and waste could support any number of thematic areas that foundations target, such as climate change, food insecurity, and rural economic development.

Development banks

We recommend that development banks, both multilateral and domestic, consider creating financial instruments dedicated to food loss and waste. The World Bank, for instance, recently launched a $1 billion sustainable development bond focused on reducing food loss and waste (World Bank 2019). Interviews with several managers at development banks have noted, however, that their banks are "client driven" or "demand driven." Thus, unless the client country asks for financial (and associated technical) assistance from the bank on a particular issue, it is difficult to direct financing toward that issue. This pattern holds for food loss and waste as well. Thus, before development banks can increase financing of food loss and waste reduction, countries must first ask for such funds. Pursuit of scaling interventions 1 (national strategies), 2 (public-private partnerships), 5 (storage solutions), and 7 (greenhouse gas emissions reductions) can help countries increase their focus on food loss and waste reduction and put the issue "on the agenda" when they engage with multilateral and domestic development banks.

National governments

As we discussed in Flanagan et al. (2019a), many of the benefits of reducing food loss and waste are aligned with a national government's economic, food security, and environmental objectives. Therefore, we recommend that national governments increase their interest in investing in food loss and waste reduction efforts. As recommended in scaling intervention 1, the best practice is to ensure that there is committed national funding to support the development and rollout of national food loss and waste reduction strategies. As scaling intervention 7 suggests, food loss and waste reduction is a legitimate use of a government's climate financing and investments (whether domestic or international). Moreover, redirecting even a small portion of the nearly $600 billion in annual agricultural subsidies (Searchinger et al. 2019) to support on-farm or near-farm food loss reduction could boost food loss reduction efforts. National governments are already starting to invest in food loss and waste reduction. For example, in 2019 the U.S. Agency for International Development awarded $3 million to Purdue University to develop market-driven value chains that reduce postharvest losses. In 2018, the Dutch Ministry of Agriculture, Nature, and Food Quality announced that it had reserved €7 million for projects combatting food waste between 2018 and 2021 (Purdue University 2019).

Private financial institutions

There can be a financial business case for food loss and waste reduction technologies, programs, and enterprises (Hanson and Mitchell 2017). One could argue that private financial institutions such as commercial banks, investment banks, and investment funds should increase their investments in food loss and waste reduction technologies and businesses. One approach is to create a special program to target such investments. Another is to launch "investment roundtables" or competitions that bring together financiers and innovators in an efficient process to match investments with promising technologies and enterprises. For example, in 2018, Rabobank hosted "Food Loss Challenge—Asia," an investment competition for start-up enterprises focused on food loss reduction (Rabobank 2019). These types of investment roundtables should be scaled up.

Private companies

Given that a lot of the world's food enters the private sector at some point in the food supply chain, private sector food companies have an important role to play in reducing food loss and waste. This role includes investments in food loss and waste reduction. In 2019, for instance, Sodexo (one of the world's largest food service companies) invested in scale-based food waste measurement technologies across 3,000 of its sites to better understand what and how much food was being wasted, as well as what it cost, in order to motivate and inform strategies for food waste reduction (Sodexo 2019). Olam, one of the world's biggest food producers and traders, has created an internal fund of $500 million to support projects that enhance sustainability within its operations and business dealings (Olam International 2018). Food loss reduction programs and technologies are eligible for these funds. More companies should make such investments in food loss and waste reduction.

What are possible next steps (crosscutting)?

Here are some initial suggestions on scaling financing for food loss and waste reduction that cut across sources of financing.

Blended finance

We recommend that financial institutions launch blended funds dedicated to food loss and waste. Blended finance brings together grants or near-prime-rate-interest loans with more commercially oriented lending in order to de-risk investments. Such funds could involve development banks, commercial banks, and philanthropic institutions. Such funds have already been established. For example, the ABC Fund, initiated by the International Fund for Agricultural Development and supported by the European Union, the Africa Caribbean Pacific Group of States, the Government of Luxembourg, and the Alliance for a Green Revolution in Africa, will deploy loans and equity investments in rural small and medium-size enterprises and financial institutions in developing countries. The fund will also support farmers through technical assistance to improve yields (Next Billion 2019).

Project preparation facilities

Increased support is needed to make projects investment-ready given the apparent shortage of "bankable" projects. Project preparation facilities could address this problem—identifying candidate food loss and waste investments, screening the candidates, and helping prepare a subset or "pipeline" to become "investment-ready" with strong business plans and financial projections. The technical assistance provided could cover aspects such as building a customer base, creating pro forma financial plans, and developing project financing.

INTERVENTION 9

Overcome the Data Deficit

The ninth scaling intervention is to overcome the dearth of data about food loss and waste and thereby strengthen the development and implementation of food loss and waste reduction strategies.

What is it?

With regard to food loss and waste reduction, the "data deficit" refers to the current state of data on food loss and waste levels around the world. While there are a growing number of efforts to quantify the amount of food loss and waste and to use similar methodologies, a critical need remains for more and better measurement of food loss and waste (Xue et al. 2017). As we found in Flanagan et al. (2019a), many of the various studies currently available use different scopes. This makes results difficult to compare. Too few use direct measurement. For example, a meta-analysis of postharvest loss studies from around the world from 2006 to 2017 found that the methods used to measure quantitative losses included surveys via interviews and questionnaires (41 percent) and mixed methods (37 percent), while only 7 percent were direct measurements alone (Kitinoja et al. 2018). Another study (Sheahan and Barrett 2017) similarly found that only 20 percent of food loss and waste studies evaluated used empirical field data.

This ninth proposed scaling intervention is a concentrated push over the next five years by governments, companies, UN agencies, and research institutions to generate new quantified data that are more consistent and comprehensive in terms of the geographies, stages of the food supply chain, and food categories covered.

Why is it important?

Availability of reliable and consistent data is a key ingredient for effective deployment of the Target-Measure-Act approach and effective implementation of the actor-specific interventions. This is because quantifying food loss and waste within borders, operations, and/or supply chains can help decision-makers better understand *how much*, *where*, and *why* food is being lost or wasted. Doing so enables identification of "hotspots" that may provide the largest opportunities for (and thus benefits of) reduction. Such information provides the evidence base for developing and prioritizing reduction strategies and interventions. Measurement also is necessary if entities are to know whether or not they are on track to realizing reduction targets. Alongside gathering other information, measurement can inform an important part of evaluations designed to understand which interventions are having an impact and why.

What is the status to date?

The world is not "starting from scratch" when it comes to quantification of food loss and waste. Significant progress has been made over the past decade in the following areas:

- ***FAO data***. FAO's *Global Food Losses and Food Waste* (2011) report was the first to estimate food loss and waste throughout the food supply chain for the entire world. The UN organization's *State of Food and Agriculture* (FAO 2019b) report focuses on food loss and includes quantifications of food losses from the farm to (but not through) retail for a number of countries.
- ***Food Loss Index and Food Waste Index***. To assist governments with monitoring progress toward SDG 12.3, UN agencies have been developing national-level estimates of food loss and food waste. FAO has been leading the development of a Food Loss Index that will estimate food losses occurring within a country from farm gate up to, but not including, the retail level. The estimate for a country is based at a minimum on data for losses among 10 key food commodities produced in that country (Fabi and English 2018). In late 2018, the Food Loss Index was approved by the Inter-agency and Expert Group (IAEG) on SDG Indicators as an official indicator for UN SDG monitoring (FAO n.d.a). In complementary fashion, the UN Environment Programme has been leading the development of a Food Waste Index (UNEP n.d.). This index will be used by governments to estimate food waste within each country from its manufacturing, retail, hospitality, food service, and consumer sectors. The Food Waste Index will go before the IAEG for approval in 2019.
- ***European Union reporting***. The European Union generated estimates of food loss and waste levels for member states, with its first baseline report in 2010 (Monier et al. 2010). It provided more comprehensive estimates in 2016 (Stenmarck et al. 2016). In 2018, the European Parliament and European Council adopted a revised Waste Framework Directive, and in 2019, the European Union's Delegated Act defined what needs to be measured as "food waste" at each stage of the food supply chain and how this measurement should be performed. Member states are expected to put in place a monitoring framework with 2020 as the first year of data—in order to report food waste levels to the European Commission by mid-2022 (European Commission 2019).
- ***Country measurement***. As of early 2019, a number of countries were measuring food loss and/or waste within their borders. These include Australia, Canada, Denmark, Estonia, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, Saudi Arabia, Slovenia, Spain, the United Kingdom, and the United States—nations that are home to 12 percent of the world's population (Flanagan et al. 2019b).
- ***Company measurement***. In 2015, only a handful of companies were measuring and publishing their food loss and waste, but by early 2019 at least 30 companies in the Forbes Global 2000 were doing so (Flanagan et al. 2018).
- ***The Food Loss and Waste Accounting and Reporting Standard ("FLW Standard")***. Published in 2016, the FLW Standard offers globally consistent requirements and guidance on *what* to measure and *how* to measure it when it comes to food loss and waste (Food Loss and Waste Protocol 2016).[9]

- ***The Food Waste Atlas***. Launched in 2018, the Atlas is an online repository of publicly available food loss and waste data wherein users can search for quantifications by food category, location, and stage in the supply chain (e.g., amount of tomatoes lost per year in Spain during storage) (Flanagan et al. 2018).[10]
- ***The FLW Value Calculator***. Launched in 2018, the calculator is an online tool that helps companies, governments, and others quantify the environmental and nutritional impacts of food loss and waste by geography and selected food commodities. These impacts include greenhouse gas emissions, water usage, macronutrients, and micronutrients associated with the food that is lost or wasted (Flanagan et al. 2018).[11]
- ***African Post Harvest Loss Information System (APHLIS)***. APHLIS offers estimates of food losses where direct measurements are not available. These estimates are based on existing scientific literature and presented in a transparent manner. Estimates are provided as maps or tables and can be downloaded. APHLIS covers cereals but in 2019–20 will be adding legumes, roots, and tubers (B. Tran, University of Greenwich, personal communication, 2019).
- ***Other quantification methods***. Developed by FAO, the Food Loss Analysis Case Study Methodology enables researchers to quantify losses and identify where in the food supply chain these losses occur (FAO n.d.b). Likewise, the International Food Policy Research Institute (IFPRI) and the Consultative Group on International Agricultural Research (CGIAR) have developed an approach to quantifying food losses involving surveys for selected commodities in specific countries (FAO 2019b). In January 2018, the African Union Commission published the first Biennial Review Report, which tracks progress toward achieving the 2025 Malabo goals, including the goal on reducing postharvest losses, through the African Agricultural Transformation Scorecard (African Union 2018).

What are possible next steps?

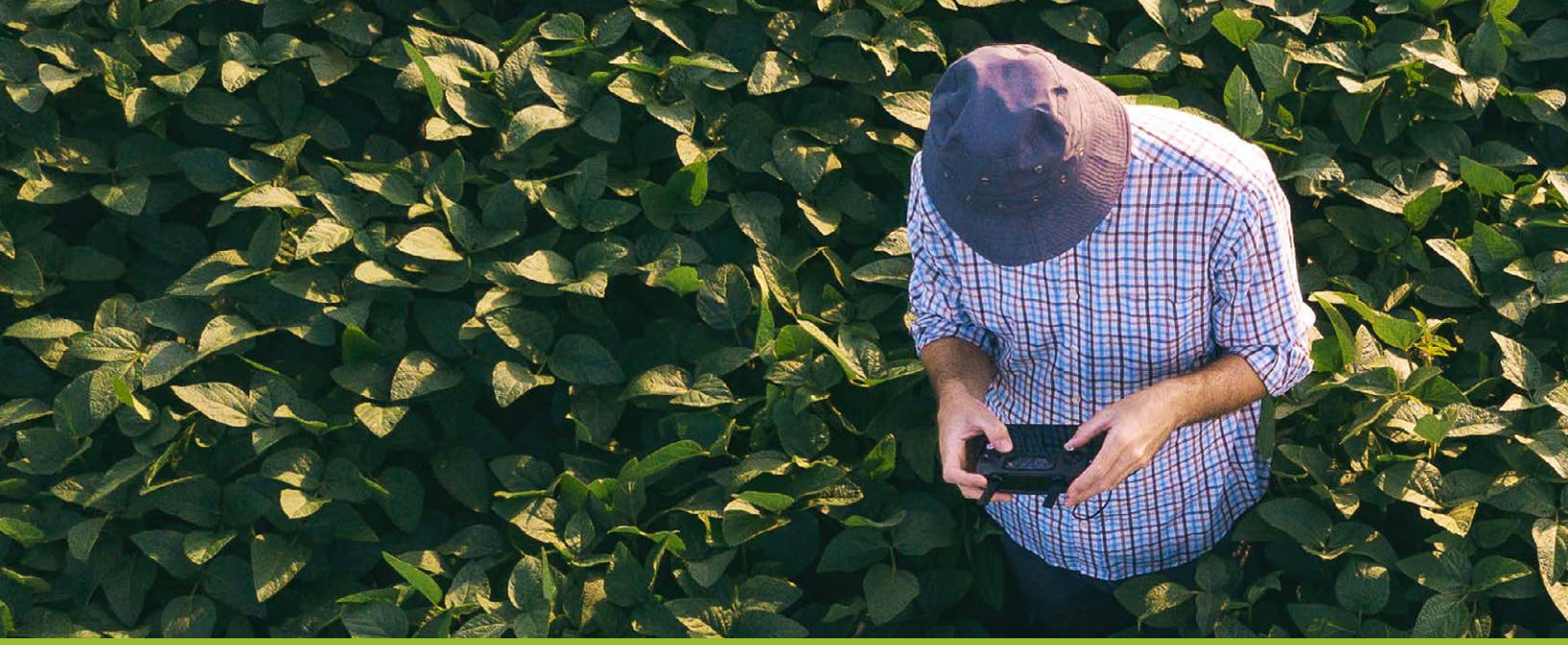
A lot of this progress has set the foundation for good measurement. We now see the need to build on these foundations and make actual quantification more widespread. Over the next five years, a concentrated push to measure and record for public use food loss and waste quantities would overcome the data deficit in time to support achievement of SDG 12.3. We recommend that this concentrated push consist of the following actions:

- ***Utilize emerging common definitions and methodologies***. To accurately assess progress toward SDG 12.3, measurement should be conducted according to common definitions of food loss and waste, as well as common measurement methodologies. This makes comparison between different studies possible and allows for benchmarking of individual entities such as food companies or entire countries, which can in turn further motivate entities to take action to reduce food loss and waste. The FLW Standard can provide guidance for quantifying and reporting on food loss and waste that ensures clarity and comparability. The Food Loss Analysis Case Study Methodology, developed by FAO, provides a methodology that allows users to identify the amount of losses and the underlying drivers for a particular commodity at critical loss points in a given country (FAO 2019a).
- ***Roll out the Food Loss Index and Food Waste Index***. FAO and UNEP need to spearhead country-level estimates of food loss and waste, respectively, using these new indices. If conducted in 2020, 2025, and 2030, these indices would provide a harmonized baseline, a midperiod check-in, and an end-of-period assessment. This approach would enable the world to know whether or not SDG 12.3 has been achieved.

- ***Improve measurement of on-farm losses***. Some quantifications of food losses (e.g., Food Loss Index and end yield measurement) exclude food that is lost during harvest, is unharvested, or is left on the field. This exclusion occurs because data collection often starts at the farm gate. But a number of studies indicate that a lot of food gets lost between harvest and the farm gate (see Feedback 2018; Johnson et al. 2018; and WRAP 2019). Therefore, national (and corporate supply chain) measurement should start to include and publicize these pre–farm gate losses.
- ***Get 1,000 companies to begin quantifying food loss and waste***. Getting 1,000 large and midsized companies around the world in the food sector quantifying and reporting on their food loss and waste would be a dramatic ramp-up of private sector quantification. These companies should be measuring and reporting their food loss and waste within their own operations across all their geographic locations. One way to achieve these numbers of companies mimics the 10 × 20 × 30 approach, wherein larger companies challenge their suppliers to quantify their own food loss and waste and provide technical assistance in doing so. Besides getting more entities to measure, this approach can lead to more transparency within the supply chain, which can open doors to dialogue between suppliers and customers that enable chain-wide efforts to reduce food loss and waste.
- ***Incentivize measurement***. To get entities to measure, some may need incentives. One approach would be for development banks or bilateral development cooperation agreements to provide financial and technical support to low-income countries to conduct food loss and waste measurements. Alternatively, measurement of food loss and waste could be a requirement for farmers, businesses, and governments that receive funding from banks for agriculture-related projects. A more aggressive approach would be for governments to require all food companies above a certain annual revenue or all food companies receiving government contracts to measure and report their food loss and waste.
- ***Increase funding for measurement and data***. It takes people and time to effectively quantify food loss and waste at the site, company, or country level. This means money. Too little money is dedicated by companies and countries toward measurement, despite proven positive returns on investment from measuring and taking action on food loss and waste (Hanson and Mitchell 2017). Much more funding should be allocated to measurement by philanthropic foundations, companies, government agencies, and project financiers over the next five years in order to make major progress on closing the data deficit.

- ***Leverage modern information and communication technology (ICT)***. Companies such as Winnow (2019) and LeanPath (2019) are pioneering approaches that combine image-recognition software and artificial intelligence to rapidly and inexpensively quantify food waste in the commercial kitchen environment. Adapting this approach such that the weight and/or share of food that is lost in the field could be detected by one or two smart-phone photographs is one concept to evaluate for reducing the costs (and simplifying the generation) of food loss and waste data across a variety of contexts. The combination of mobile phones, algorithms, artificial intelligence software, and other ICT developments could revolutionize the generation of food loss and waste data and thus help rapidly close the data deficit. The ICT revolution has yet to hit the "Measure" aspect of food loss and waste.

- ***Report completed inventories***. As all of these countries and companies measure their food loss and waste, they should post the results on the Food Waste Atlas. Such transparency would enable easier identification of success stories and benchmarking. More important, it would make data available that others might use; one need not conduct original research on, for instance, the amount of rice lost during harvesting in India if someone else has already recently conducted that research and posted it on the Atlas. Making data publicly available is critical to closing the data deficit. A company concerned about sharing sensitive information or confidentiality can anonymize its name in the system.



INTERVENTION 10

Advance the Research Agenda

The 10th scaling intervention is to further research on food loss and waste.

What is it?

Advancing the research agenda is about addressing numerous "next generation" research questions that would, in turn, help refine food loss and waste reduction strategies and address remaining (usually nontechnical) bottlenecks for scaling solutions. The underlying question to be answered is, How can the world systematically achieve scaled, sustained adoption of food loss and waste reduction technologies, practices, and policies that are technologically appropriate, provide positive returns (economic, environmental, and social), and can significantly move the needle when adopted?

Why is it important?

Although a range of investable solutions and a body of knowledge already exist on food loss and waste, more research is still needed to support overall achievement of SDG 12.3 (Spang et al. 2019). Most scaling interventions would benefit from additional systems-based, multidisciplinary research to help hone the strategies as well as monitoring and evaluation to determine whether the interventions are having the intended impacts (especially in terms of benefiting smallholder farmers and small and medium-sized enterprises).

What are possible next steps?

We recommend that public and private institutions add to their research agendas a number of research questions in order to refine strategies for reducing food loss and waste and advance implementation of the global agenda. Table 3 lists some of the key questions identified by the authors.

Table 3 | **Important Questions for Reducing Food Loss and Waste (Not Exhaustive)**

CATEGORY	QUESTIONS
Technology: Food loss	Which available technologies offer the biggest promise (in terms of impact, scale, and market readiness) for food loss reduction at the "production," "storage and transportation," and "processing and packaging" stages of the food supply chain? How does one accelerate their scaling? What research into novel and emerging technology innovations that reduce losses during transportation of fresh produce, postpone spoilage, preserve food quality, and extend product shelf life through packaging should be prioritized and incentivized? Which public and private actions will best foster the creation of effective markets to provide existing and new technologies to reduce food loss?
Technology: Food waste	Which available technologies offer the biggest promise (in terms of impact, scale, and market readiness) for food waste reduction at the "market" and "consumption" stages of the food supply chain? How does one accelerate their scaling? What research into novel and innovative value-added products from perishable food commodities—fruits, vegetables, seafood, dairy—to promote whole food utilization and healthy foods, and reduce food waste, should be prioritized and incentivized? Which public and private actions will best foster the creation of effective markets to provide existing and new technologies to reduce food waste?
Cold chains	How can the world accelerate deployment of climate-smart cold chains (precooling, cold storage, transportation, freezing) in low-income countries?
Economics	What sector-specific guidance that provides the motivation and technical information for businesses to take action (e.g., promote industry roadmaps for food loss and waste reduction) needs to be developed? What quantitative research on the relationship between the reduction of food loss and waste, on the one hand, and job creation and improved rural livelihoods, on the other, needs to be pursued? Which pricing signals and incentive structures (or lack thereof) are driving the economics of food loss and waste? Is the world simply producing too much food for it not to be lost or wasted? Which interventions to reduce food loss and waste would provide (or are providing) the biggest return on investment?
Finance	Which types of financing (from microfinancing to multilateral development bank financing) are needed to scale up adoption of leading food loss and waste reduction practices and technologies? What are reasonable loan interest rates and return on investment rates that value chain actors can afford? What effect would reduction of high loan default rates typically faced by domestic banks have on loan interest rates charged to smallholder farmers, aggregators, and other value chain actors?
Public policy	Which inclusive, cost-effective public policies (e.g., regulations, standards, incentives) hold the most promise for reducing food losses in low-income countries? Which inclusive, cost-effective public policies (e.g., regulations, standards, incentives) hold the most promise for reducing food waste in middle- and high-income countries? Which vexing food system bottlenecks for scaling innovative food loss and waste solutions that are usually nontechnological (e.g., access to markets, enabling policies, access to creative and affordable financing, enabling environments) need to be prioritized and incentivized?

Table 3 | **Important Questions for Reducing Food Loss and Waste (Not Exhaustive) (Cont'd)**

CATEGORY	QUESTIONS
Smallholders	Which specific types of infrastructure, technical assistance, and/or financial assistance do farmers in low-income countries need to implement technologies and practices that would dramatically reduce on-farm and near-farm losses? Which are already working? How does one effectively build capacity for smallholders to implement food loss reduction technologies and practices (e.g., preservation and processing at aggregation sites)?
Consumers	What can the latest findings and insights from economics and the social and behavioral sciences tell us about how to shift social norms and consumers' long-term behavior when it comes to food waste? How can grassroots campaigns, social media, religious communities, and others be engaged to make "wasting food" as unacceptable as littering now is in many countries?
Other actors	What role can cities, communities, and civil society play in reducing food loss and waste? Which educational approaches can higher education institutions facilitate to foster, inform, and motivate a future generation of leaders with the skill and motivation to achieve dramatically lower levels of food loss and waste?
Measurement	How can the time and cost of measuring food loss and waste be reduced? What do the new quantifications of food loss and waste (e.g., by companies, by countries) that are becoming public tell us about the hotspots and trends in food loss and waste? How can inclusion of "not harvested" crops left in the field be assessed to close the data gap between on-farm and farm gate information that government agencies currently tend to ignore? How are qualitative losses, such as micronutrient (e.g., vitamin and mineral) losses, best measured? What research should be undertaken to fill data gaps and standardize reporting of where food is lost and wasted in order to better compare the evidence base on results, create benchmarks, and provide clearer direction to stakeholders for prioritizing effective food loss and waste reduction strategies and interventions?
Monitoring and evaluation	Which monitoring and evaluation approaches should be set up to evaluate the efficacy of the nine scaling interventions above (and enable course corrections)? What do evaluations of the nine scaling interventions above tell us about what works and what does not?

Source: Author analysis.

Addressing these questions is an important task for public and private research institutions over the coming decade. These institutions need funding support to do so. Many of these questions are multi-disciplinary in nature and thus require multiple disciplines to collaborate. Moreover, researchers need to dedicate energy and resources in communicating the outputs of their research, and getting the outputs into the hands of those who need them.

Dr. Akinwumi Adesina, president of the African Development Bank, refers to the "Scaling Up Triangle" when speaking about new ways to create impact. The three sides of the triangle are "strong and sustained political will," "suitable policy incentives," and "the power of science and technology" (Cooley and Howard 2019). The research agenda for reducing food loss and waste encompasses all three. Advancing this research agenda is an urgent need because the clock is ticking when it comes to the SDGs. To close the gap and achieve lasting, systemic change we must "(1) design interventions with scale in mind and with clear scaling strategies; (2) assess and address obstacles to scalability; and (3) actively manage the pathway to scale" (Cooley and Howard 2019).

A Call to Action

SDG 12.3 is a historic opportunity for the world to realize the numerous food security, economic, and environmental benefits of halving food loss and waste by 2030. These benefits support many other SDGs and the Paris Agreement on climate change. Momentum is growing, but the world has much more to do. At the time of this writing, only 11 years remain to achieve the SDG targets.

This publication has explored 10 scaling interventions that could accelerate adoption of the Target-Measure-Act approach to reducing food loss and waste and accelerate adoption of actor-specific interventions across supply chains and geographies. Governments, businesses, farmers, consumers, and everyone in between will need to play their relevant role in implementing these 10 scaling interventions. And they need to do so now because, just like food, there is little time to waste.

ENDNOTES

1. The modeling was led by WRI and the French Agricultural Research Centre for International Development (CIRAD) and supported by the World Bank, UN Environment, the UN Development Programme, and the French National Institute for Agronomic Research (INRA). See Searchinger et al. (2019).

2. The modeling for Figures 1 and 2 was conducted out to 2050 in order to indicate the relative scale of impact of a wide variety of strategies on ability to achieve a sustainable food future (reducing food loss and waste being one of the strategies). Elsewhere, this report discusses reducing food loss and waste by 50 percent by 2030 in order to meet the target set by the Sustainable Development Goals.

3 Chapter 4 of Flanagan et al. (2019a) gives a number of candidate public policies.

4. See www.sciencebasedtargets.org for more information about the initiative.

5. This entire section is a synthesis of interventions profiled in Flanagan et al. (2019a).

6. For more information on this issue, see Box 4.3 in Flanagan et al. (2019a).

7. This observation is illustrated by Figure 1.8 of Flanagan et al. (2019a). The total share of food produced that is lost or wasted is roughly the same per region, hovering between 31 and 36 percent (except for South and Southeast Asia). Yet the share of food loss and waste occurring at the consumption stage is much higher in high-income regions than in low-income ones.

8. Video available at https://www.youtube.com/watch?v=4wH878t78bw&t=427s.

9. The FLW Standard was developed by the Food Loss and Waste Protocol, a multistakeholder effort convened by WRI and involving the CGF, FAO's Save Food Initiative, the EU FUSIONS initiative, UNEP, the World Business Council for Sustainable Development (WBCSD), and WRAP.

10. Prepared by WRAP and WRI, with financial support from the Walmart Foundation and WRAP; www.thefoodwasteatlas.org.

11. Prepared by the WBCSD with technical input from Quantis and WRI; www.flwprotocol.org/why-measure/food-loss-and-waste-value-calculator/.

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WORLD
RESOURCES
INSTITUTE

10 G STREET NE
SUITE 800
WASHINGTON, DC 20002, USA
+1 (202) 729-7600
WWW.WRI.ORG

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