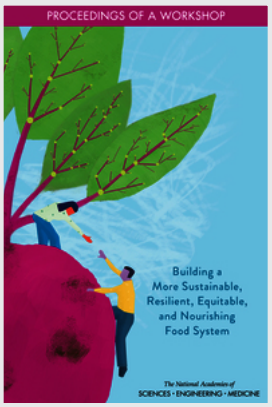

Building a More Sustainable, Resilient, Equitable, and Nourishing Food System: Proceedings of a Workshop (2021)

DETAILS

84 pages | 6 x 9 | PAPERBACK
ISBN 978-0-309-67885-8 | DOI 10.17226/25832

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SUGGESTED CITATION

National Academies of Sciences, Engineering, and Medicine 2021. *Building a More Sustainable, Resilient, Equitable, and Nourishing Food System: Proceedings of a Workshop*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25832.

Building a More Sustainable, Resilient, Equitable, and Nourishing Food System

PROCEEDINGS OF A WORKSHOP

Melissa Maitin-Shepard, *Rapporteur*

Food Forum

Food and Nutrition Board

Health and Medicine Division

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

THE NATIONAL ACADEMIES PRESS
Washington, DC
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, NW Washington, DC 20001

This activity was supported by contracts between the National Academy of Sciences and the National Institutes of Health (HHSN263201800029I/HHSN26300023); the U.S. Department of Agriculture (59-8040-8-003 and 123A9419P0026); and the U.S. Food and Drug Administration (HHSP233201400020B/75P00119F37096), with additional support from the Academy of Nutrition and Dietetics; American Heart Association; Cargill, Inc.; The Coca-Cola Company; Conagra Brands; General Mills, Inc.; Keurig Dr Pepper; Mars, Inc.; Nestlé Corporate Affairs; Ocean Spray Cranberries, Inc.; PepsiCo; and Unilever. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project.

International Standard Book Number-13: 978-0-309-67885-8
International Standard Book Number-10: 0-309-67885-4
Digital Object Identifier: https://doi.org/10.17226/25832

Additional copies of this publication are available from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

Suggested citation: National Academies of Sciences, Engineering, and Medicine. 2021. *Building a more sustainable, resilient, equitable, and nourishing food system: Proceedings of a workshop*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25832.

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This Proceedings of a Workshop was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published proceedings as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the charge. The review comments and draft manuscript remain confidential to protect the integrity of the process. We thank the following individuals for their review of this proceedings:

DENISE R. EBLEN, U.S. Department of Agriculture
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Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the content of the proceedings, nor did they see the final draft before its release. The review of this proceedings was overseen by **JOHN W. ERDMAN,** University of Illinois at Urbana-Champaign. He was responsible for making certain that an independent examination of this proceedings was carried out in accordance with standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the rapporteur and the National Academies.

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1

Introduction

On July 22–23, 2020, the Food Forum of the National Academies of Sciences, Engineering, and Medicine hosted a virtual workshop that explored integration of the health, societal, economic, and environmental effects and future needs of the food system. Planning committee chair Naomi Fukagawa, U.S. Department of Agriculture, provided opening remarks on the goals of the workshop and the Food Forum. She described the main objective of the 1.5-day workshop as understanding how to achieve a more sustainable, resilient, equitable, and nourishing food system.

The workshop opened with introductory remarks on new expectations for the food system (Chapter 2). The sessions that followed examined three main dimensions of the food system: vulnerabilities (Chapter 3), resiliency (Chapter 4), and transformation (Chapter 5). The workshop included discussions on global change, access to health care and food, resiliency in complex dynamic systems and resiliency for the future, and consumption- and production-oriented strategies for transforming the food system. The Statement of Task for the workshop is provided in Box 1-1.[1]

[1] The workshop planning committee's role was limited to planning the workshop, and this Proceedings of a Workshop was prepared by an independent rapporteur as a factual summary of what occurred at the workshop. Statements, recommendations, and opinions expressed are those of independent presenters and participants, and are not necessarily endorsed or verified by the National Academies of Sciences, Engineering, and Medicine, nor should they be construed as reflecting any group consensus.

BOX 1-1
Workshop Statement of Task

An ad hoc planning committee will plan and convene a 1.5-day public workshop that will build on the Institute of Medicine and National Research Council 2015 report *A Framework for Assessing Effects of the Food System.* The workshop will explore the integration of the health, societal, economic, and environmental effects and future needs of the food system.

Workshop presenters will explore how the different effects of the food system can be estimated, compared, and accounted for when considering a new intervention, such as policy or emergent technology. In doing so, workshop presenters may discuss topics such as public health, dietary guidelines, and the ability of the food supply to meet demands for nutrient-rich crops; food safety, security, and accessibility; resilience and regenerative agriculture; and environmental and economic sustainability, including the impact of climate-related issues.

The planning committee will define the specific topics to be addressed, develop the workshop agenda, and select and invite speakers and discussants. After the workshop, Proceedings of a Workshop—in Brief and full proceedings of the presentations and discussions at the workshop will be prepared by a designated rapporteur.

As Fukagawa noted, workshop presentations and discussions were intended to provoke and foster the exchange of thoughts and ideas and to offer insight into multisector solutions involving collaboration. Given that the workshop was held virtually, participants submitted questions for speakers online, and selected questions were read aloud by the session moderator.

2

New Expectations for the Food System

Patrick Stover, Texas A&M University, provided introductory remarks on new expectations for the food system and highlighted several recent publications relevant to the topic of the workshop.

FOOD SYSTEM EXPECTATIONS

As described by Stover, the two main goals of the U.S. Department of Agriculture's (USDA's) Agriculture Innovation Agenda[1] are to increase food production by 40 percent and reduce the environmental footprint of agriculture by 50 percent by 2050. He pointed out that food systems, people, the environment, and the economy are interconnected and interdependent, and they all require a systems thinking approach.

Stover explained that the number of people globally who are food insecure is expected to increase, as are costly diet-related chronic diseases. While the food system was historically designed to produce sufficient food to fuel a growing economy, he observed, it must now also nourish and sustain health, the environment, and agriculture. Looking to the future, the world's population is estimated to rise to 10 billion by 2050, requiring the production of more food on less land in the face of growing weather constraints.

In addition to producing more food, Stover continued, the world's food system should produce better food. He stated that advances in science and

[1] See USDA's Agriculture Innovation Agenda, available at https://www.usda.gov/aia (accessed September 16, 2020).

technology have introduced an emerging potential for the food system to address such issues as nutrient deficiencies, prevention and management of chronic disease, reduction of environmental impact, the economic sustainability of agriculture, the diversity of the food supply, the affordability and accessibility of food, and reduction of health care costs. He added that the U.S. federal fiscal year 2020 agriculture appropriations bill included an examination of how advances in science, policy, and practice related to healthier food enhance overall health, reduce obesity and related comorbidities, and lower health care costs.

RECENT PUBLICATIONS ON THE SUSTAINABILITY AND RESILIENCE OF THE FOOD SYSTEM

Stover described a series of past workshops and reports of the Food and Nutrition Board that provided background and context for the present workshop. He cited the 2012 workshop summary *Exploring Health and Environmental Costs of Food*, noting that speakers at that workshop highlighted how the current emphasis of the food system on reducing hunger and providing access to affordable calories has shifted the focus from the cost of food production to costs associated with other domains, such as health care, the environment, and national security (IOM and NRC, 2012). A systems approach is needed, Stover asserted, to address the costs in these domains that are tied to the food and agriculture system.

Stover then turned to the 2015 consensus study report *A Framework for Assessing Effects of the Food System*, which he said was intended to facilitate making holistic, science-informed decisions about food system policy and practice (IOM and NRC, 2015). As he described and as depicted in Figure 2-1, the report states that the food system is a complex, dynamic, adaptive system with goods and services flowing from farm inputs to the consumer, and reverse flows of money and demand information from the consumer back to the farm inputs. He added that many actors, players, domains such as social organizations, science and technology, the biophysical environment, and markets and policies influence these flows.

According to Stover, the report asserts, as shown in Figure 2-2, that food systems should promote the four goals of human health, environmental health, social health, and economic health. As he explained, it also suggests that the assessment of any change to the food system requires a systems approach, including an examination of the impact of the change on the entire value chain, from farm to consumer, and any unintended consequences. He noted further that, according to the report, such disruptions as social movements, weather, market forces, and even pandemics can have impacts on the entire food scystem. A key theme of the report, he explained, is the trade-offs among health, environmental, social, and

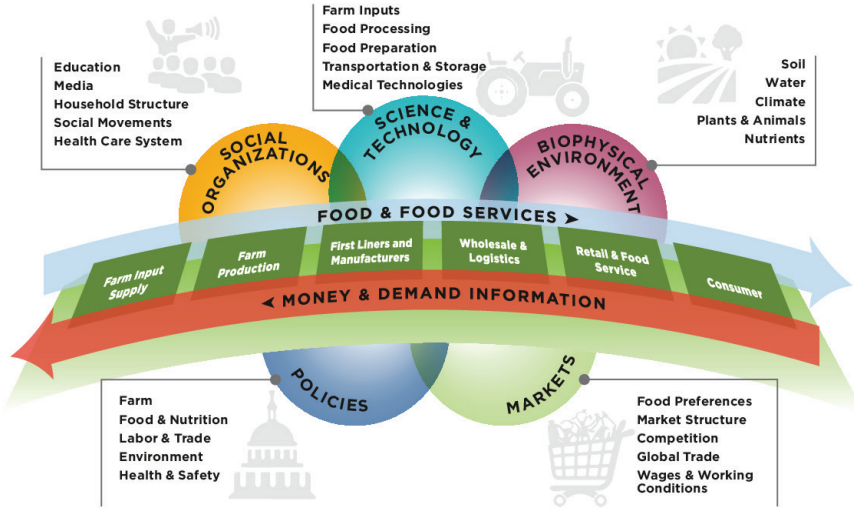

FIGURE 2-1 Conceptual illustration of the links between the food supply chain and the larger biophysical and social/institutional context, including flows in food systems.
SOURCES: Presented by Patrick Stover on July 22, 2020; IOM and NRC, 2015.

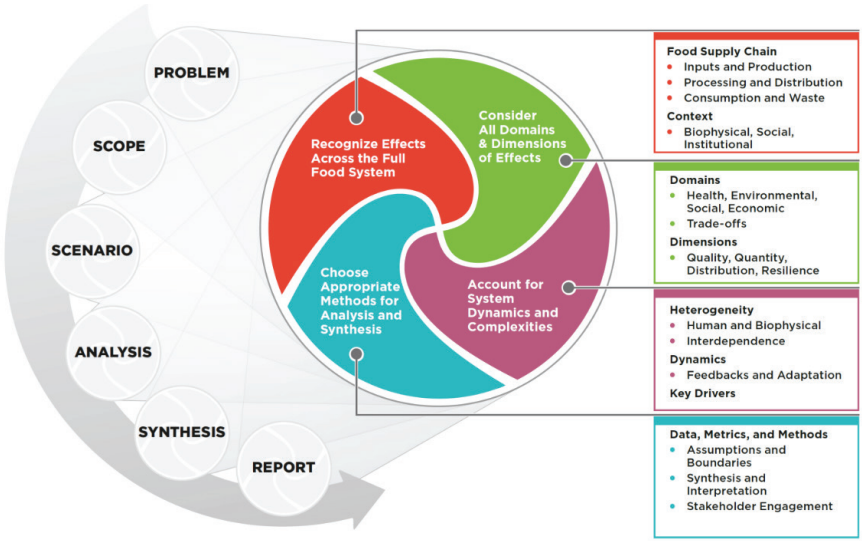

FIGURE 2-2 Conceptual illustration of an analytic framework for addressing the complexity of food systems.
SOURCES: Presented by Patrick Stover on July 22, 2020; IOM and NRC, 2015.

economic outcomes. He noted the report's emphasis on the importance of developing and using the best metrics, methods, and standards of evidence to inform food system policy and practice.

Stover also provided context regarding technological advances that could transform the food system, including a reduction in its greenhouse gas (GHG) emissions. He explained that agriculture accounts for about 10 percent of all GHG emissions in the United States and an even greater percentage globally[2] and referenced Dr. Rattan Lal, recipient of the 2020 World Food Prize, who stated that a 2 percent increase in the carbon content of the soil could offset 100 percent of the GHG emissions in the atmosphere.

As another example, Stover pointed to innovations in food and probiotics and in precision agriculture being used to reduce methane production. As an example, he cited the conversion of animal waste to fertilizer to enrich soil and promote plant growth, lowering the environmental impact of raising animals for food. Other innovations Stover suggested could reduce the environmental impact of agriculture include the use of silicates to capture atmospheric carbon in farmland, improved productivity of livestock through feed and genetics so that fewer animals are needed, and recycling of manure. He noted that climate change can impact agriculture through temperature increases and fluctuations in weather that reduce plant yields and cause flooding that disrupts animal agriculture.

Stover described some additional food system innovations, including increased local production of food through urban and controlled-environment agriculture.[3] These innovations, he explained, can reduce chemical inputs by 90–95 percent and provide a yield similar to that produced with traditional methods while using one-tenth of the land. However, he noted that these innovations are not cost competitive with traditional agriculture.

Next, Stover highlighted the Food and Nutrition Board's 2017 consensus study report on Dietary Reference Intakes based on chronic disease endpoints (NASEM, 2017). He explained that this report reflects a shift from using nutrient status and deficiencies to using prevention or management of chronic disease as the basis for determining nutrient needs for the American population. Given the complexity of chronic diseases, he argued, a systems approach is needed to understand the role of nutrients, physiology, and metabolism in those diseases. Both the National Institutes of Health and USDA (NIH, 2020; USDA, 2020) released strategic plans in 2020 that address nutrition research and include an emphasis on precision

[2] See EPA's "Sources of Greenhouse Emissions," available at https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (accessed September 16, 2020).

[3] According to the Cornell University College of Agriculture and Life Sciences, controlled-environment agriculture is "an advanced and intensive form of hydroponically-based agriculture where plants grow within a controlled environment to optimize horticultural practices" (Cornell University College of Agriculture and Life Sciences, 2020).

nutrition, which involves understanding the heterogeneity in how food interacts with people in the development of chronic disease. This analysis of the connection between food and individual health outcomes requires a systems approach, Stover asserted.

Stover also pointed to the need for improved understanding of the economics of the food system, as it accounts for 10 percent of U.S. employment and 5.4 percent of the nation's gross domestic product. Thus, he asserted, changes to the food system to achieve health and environmental goals will need to align with economics. He argued that new economic markets for farmers and ranchers must be created that will allow agriculture to become carbon neutral or positive, aligning economic with environmental and health outcomes of the food system.

In light of the impact of COVID-19 on the entire agriculture and food system value chain, in June 2020 the National Academies' Board on Agriculture and Natural Resources held a webinar[4] on COVID-19 and the food system that featured former U.S. and California secretaries of agriculture. Stover shared his key takeaways from the webinar, including that the food system had not been as resilient as it could have been in response to the pandemic. Participants in the webinar stressed that faster responses were needed to address changes in markets and consumer behavior, and that scenario planning examining system dynamics could be used to develop those responses. Participants also emphasized that climate change is a threat to agriculture and that preparations are needed to address this threat. In addition, the webinar highlighted that people with diet-related chronic diseases are the most vulnerable to experiencing adverse health effects from COVID-19, and that people from underserved minority communities, many of whom work in the food system, have been disproportionately affected.

In conclusion, Stover stated that the new expectations for the food system are clear, but the paths to achieving them are not, and he highlighted the importance of using high-quality science to determine the path forward. He suggested that the remainder of the workshop would address how the new expectations for the food system could be realized through science-based solutions that ensure the sustainability of agriculture and food systems for future generations.

[4] Available at https://www.nationalacademies.org/event/06-19-2020/covid-19-and-the-food-and-agricultural-system (accessed September 16, 2020).

3

Vulnerabilities of the Food System

Session 1 of the workshop, moderated by Matt Liebman, Iowa State University, focused on the vulnerabilities of the food system, including biophysical challenges and social and economic shortcomings and vulnerabilities, and how an agroecological framework can be used for improvement.

PLANETARY BOUNDARIES AND GLOBAL CHANGE

The first speaker in Session 1, Cynthia Rosenzweig, National Aeronautics and Space Administration Goddard Institute for Space Studies and Columbia University Earth Institute, spoke about the food system's planetary boundaries and global change, with emphasis on the effect of climate change.

Interactions Between the Food System and Other Systems

Rosenzweig opened by stating that much of the work to address climate change globally has focused on crop agriculture, with less attention paid to livestock and fisheries. However, she observed, other components of the food system, such as food processing, supply chains, shipping, demand and consumption, and food loss and waste, also impact climate change. She presented a diagram (see Figure 3-1) illustrating the interactions between the food system and the climate system, global ecosystems, the socioeconomic system, and food insecurity. Rosenzweig defined the socioeconomic system as comprising such human dynamics as demographics, economics, behavior,

culture, policy, and institutions. She pointed out that COVID-19 has highlighted the cascading impact of global systemic risks on the food system. The pandemic has led to disruptions in production, supply, and demand in the food system, she stated, a system that is already stressed by weather and climate events.

Further describing Figure 3-1, Rosenzweig noted that the four pillars of food security—availability, access, utilization, and stability—link to both human health and planetary health. She explained some of the successes and failures of the food system in addressing food security. She gave as an example that the food system successfully feeds the majority of the world's population and supports the livelihoods of more than 1 billion people. However, she observed, it falls short in that 690 million people globally are undernourished, and 2 billion have overweight or obesity. She added that the food system also contributes significant greenhouse gas (GHG) emissions.

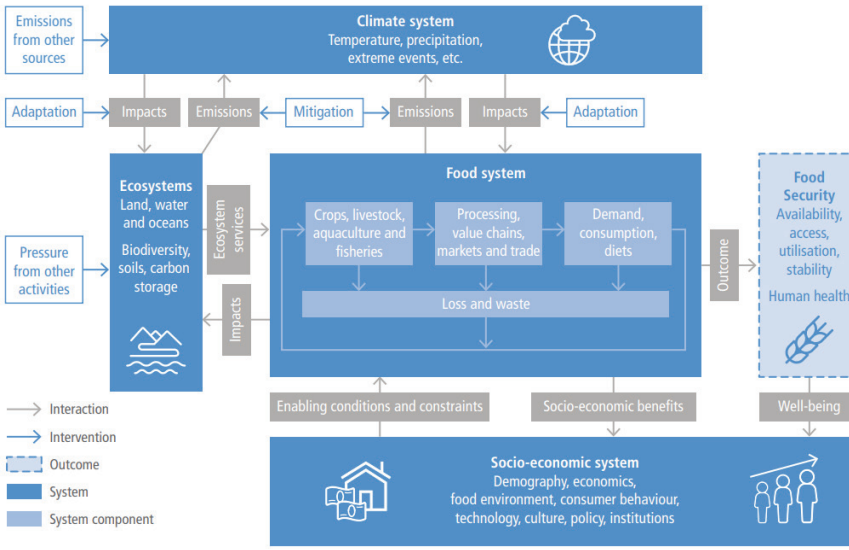

FIGURE 3-1 Conceptual illustration of the interactions between the food system and the climate system, global ecosystems, the socioeconomic system, and food security.
SOURCES: Presented by Cynthia Rosenzweig on July 22, 2020; IPCC, 2019. Reprinted with permission from the Intergovernmental Panel on Climate Change.

The Food System and Planetary Boundaries

Rosenzweig stated that similar challenges exist in achieving planetary health, noting that the food system is already crossing the four planetary boundaries of biosphere integrity, land use change, freshwater use, and nitrogen flow. She defined planetary boundaries as thresholds in the planetary system that when crossed negatively impact other global systems and compromise the resilience of earth systems. Turning to biosphere integrity, she defined it as the preservation of biodiversity and reduction of threatened species. Land use change, she continued, involves preservation of tropical and temperate forests. She also explained that freshwater use entails reducing agricultural withdrawals so that they do not impact environmental flow requirements, pointing out that nitrogen flow requires reducing fertilizer use where excess nitrogen leaching occurs.

Rosenzweig next described a simulation modeling the impact of the food system not crossing the planetary boundaries. It found that production would be significantly reduced, she reported, allowing the world's food system to feed only 3.4 billion of its projected future 10 billion inhabitants. Simulating instead a technological and cultural "U-turn" toward increasing global food supply within the four planetary boundaries, the researchers found that expanding irrigation, fertilizer, and cropland; managing water, nutrients, and land within those planetary boundaries; reducing food loss; and making dietary changes that involved evening out calorie intake across the world could allow the global food system to feed more than 10 billion people (Gerten et al., 2020). In response to a question following her presentation, Rosenzweig clarified that change on a global scale will require simultaneous local-level changes in many locations around the world.

Rosenzweig then turned to some of the challenges involved in achieving this goal. With respect to water, for example, she pointed to competition between the ecosystem and food production. She noted that half of irrigated cropland around the world faces a production loss of more than 10 percent if ecosystem water requirements are respected. She added that 20 percent of global food production depends on the ecological flow requirements in "hot spot" regions (Jägermeyr et al., 2017), which include parts of the central and southern United States. Rosenzweig noted that challenges in transforming the food system are exacerbated by climate change, including temperature increases across the globe and changes in precipitation that cause droughts, floods, and heat waves. She pointed out that the lower latitudes, which disproportionately include developing countries, are the most vulnerable to the impact of climate change. As she described, multiple global models show that such circumstances increase the risk for hunger.

Rosenzweig cited findings that high carbon dioxide levels also adversely impact nutrient quality. Using rice as an example, she explained that when

carbon dioxide increases, the protein, iron, and zinc in the crop decline. Livestock diseases are also affected by global temperature increases, she noted.

Proposed Solutions to the Impact of Climate Change on Food Production

Rosenzweig outlined multiple proposed solutions for addressing the impact of climate change on food production. One option, she stated, is mitigation, or the reduction of GHG emissions, through dietary change. She pointed to research indicating that a reduction in meat consumption, for example, reduces GHG emissions through reductions in livestock and the ability to sequester carbon on land not used to grow livestock feed. At the same time, she observed, solutions are needed to adapt the food system to changing climate conditions. She offered examples of adaptation strategies, such as providing farmers with packages of heat- and drought-tolerant plant species, which have been shown through research in West Africa to raise smallholder farmers' incomes. She acknowledged, however, that such strategies may not fully compensate for crop yield losses (Adiku et al., 2015).

Rosenzweig closed by considering the parallel global systemic threats of COVID-19 and climate change, noting that while the former came on quickly and the latter slowly, they both affect poor and minority populations disproportionately and impact the food system and food security around the world. She explained that COVID-19 has impacted food production through challenges with farm labor, supply chain shortages, and food access, directly affecting food security for millions of people around the world. Looking to the future, Rosenzweig stressed the importance of integrating the responses to COVID-19 and climate change.

ACCESS TO HEALTH AND FOOD

The second presentation of the session was made by Ricardo Salvador, Union of Concerned Scientists, who spoke about access to health and food.

Food System Dimensions and Domains

Salvador began by referencing the framework from the 2015 Institute of Medicine and National Research Council report shown in Figure 2-2 in Chapter 2 and highlighting a table in that report illustrating how the four dimensions of quantity, quality, distribution, and resilience within the food system manifest in the health, environmental, and socioeconomic domains (IOM and NRC, 2015) (see Figure 3-2).

With respect to quantity, within the health domain, Salvador noted the importance of ensuring that the food system produces sufficient calories.

Dimensions \ Domains	Health	Environment	Social and Economic
Quantity	Sufficient calories consumed for good health, but not obesity	Plentiful food production from agricultural land and water	Rising disposable income for consumers and/or food system workers
Quality	Safe working conditions and/or availability of food that is safe and meets recommended dietary allowances and dietary guidelines	Biodiversity and quality of natural environment in agricultural setting	Variety of affordable foods across income levels
Distribution	Access to a variety of foods for all groups in population	Distribution of agrochemical run-off risks across diverse landscapes	Cost of meeting dietary needs as share of household income at different income levels
Resilience	Recovery of trusted food safety level after contamination event	Recovery time for agricultural production after drought or flood	Community retains viability after loss of a major employer

FIGURE 3-2 Examples of how the four dimensions of quantity, quality, distribution, and resilience within the food system manifest in the health, environmental, and socioeconomic domains.
SOURCES: Presented by Ricardo Salvador on July 22, 2020; IOM and NRC, 2015.

Turning to the environmental domain, he cited trade-offs between productivity and conservation of land and water. Regarding the socioeconomic domain, he mentioned the goal of increasing disposable income to cover the costs of food.

In the dimension of quality, Salvador highlighted occupational, health, food safety, and nutrition guidelines as examples in the health domain. In the environmental domain, he noted the importance of maintaining biological and ecosystem integrity. In the socioeconomic domain, he pointed to the need for diverse foods to be available to people across income levels, emphasizing the importance of equitable access.

Moving on to the distribution dimension, Salvador explained that the health domain includes access to a variety of foods for all. In the environmental domain, he highlighted the importance of agricultural chemical run-offs not being redistributed outside the farm. In the socioeconomic domain,

he called out economic access to a variety of foods for all. Salvador also pointed out the consistency across dimensions within the socioeconomic domain, noting that affordability of food is as important as physical access.

Salvador focused particular attention on the dimension of resilience. He gave as an example of resilience within the health domain trust in recovery of the supply chain after a contamination, such as from *E. coli* O157. An example in the environmental domain is the time to return to active production after a drought or flood, events that he noted are increasing in frequency as a result of climate change. Using a Jenga™ tower as a metaphor, Salvador described economic resilience as a system in which the loss of one piece (a major employer) does not threaten the viability of the entire tower (the community).

Salvador emphasized the dynamic nature of the food system. He gave as an example a hog production facility, where inputs are combined with farming knowledge and management to generate outputs, which then generate consumption. Natural resource and human systems affect each other, he observed, and he stressed that a measure of resilience is how the system responds when challenged. In response to a disaster such as a flood, Salvador pointed out, the impact on such outcomes as air and water quality and erosion stem from human decisions about the production model in addition to the natural event. He noted that socioeconomic outputs can be assessed in the areas of health, market efficiency, public resources and policies, and public well-being.

Meatpacking Plant Workers

Salvador used the example of the meatpacking plant workers during the COVID-19 pandemic to further illustrate the points he had made. He began by commenting that these workers, the majority of whom are racial minorities, suffered from high COVID-19 infection and mortality rates. Referencing remarks made by former Secretary of Agriculture Tom Vilsack during a recent webinar[1] hosted by the National Academies of Sciences, Engineering, and Medicine's Board on Agriculture and Natural Resources, Salvador suggested that the industry needs to make changes to reduce the scale and concentration of its plants and adapt to the need for social distancing caused by the COVID-19 pandemic. He asserted that the meatpacking workers were exploited when they were compelled to continue to work, even in hazardous conditions, because they were designated "essential workers" and were financially dependent on their wages. He stressed that workers "do not have the political power to compel the government to

[1] Available at https://www.nationalacademies.org/event/06-19-2020/covid-19-and-the-food-and-agricultural-system (accessed September 16, 2020).

look after their safety and occupational well-being." By contrast, he stated, the largest meatpacking plants have significant political clout, as evidenced by their success in placing full-page advertisements in major newspapers requesting that their workers be designated as essential, thus compelling them to work and without the companies having to assume liability for the consequences.

According to Salvador, he presented this example as evidence that the business model in the food system leads to the exploitation and even death of vulnerable workers, and he pointed to racism as a potential contributing factor to these outcomes. He concluded his presentation with a call to action for science-based organizations to recognize the data, apply the food system framework, and advocate for policies that can improve socioeconomic outcomes and resilience.

AN AGROECOLOGICAL FRAMEWORK FOR THE FOOD SYSTEM

The final speaker of the session, Paula Daniels, Center for Good Food Purchasing, spoke about the need for an agroecological framework for the food system.

About the Center for Good Food Purchasing

Daniels began by briefly describing her background and the work of the Center for Good Food Purchasing. She explained that the center uses "the power of procurement to create a transparent and equitable food system that prioritizes the health and well-being of people, animals, and the environment," adding that it works to achieve this goal through adoption and implementation of the Good Food Purchasing Program by major institutions. Daniels provided a brief history of the good food purchasing movement, stating that it began in the 1970s with "solo voices" that have since become "a chorus." She noted that in prior positions as a food policy advisor and public works commissioner for the City of Los Angeles, she learned about the connection between agriculture and food consumption patterns and the opportunity to leverage the power of the city government to make change. In response, the City of Los Angeles created a Food Policy Council and several food programs, including the Good Food Purchasing Program.

Daniels noted that the Center for Good Food Purchasing has a certification program designed to disrupt the food system's economic model of relying heavily on global exports and advance the move toward a more regional food economy. She pointed out that most regions in the United States—even such agricultural states as California, Hawaii, and Iowa—consume only about 5–15 percent local food. She explained that the center's certification program uses the purchasing power of large institutions

that send significant market signals to the regional food economy to start making shifts, describing it as a lever for creating change in five aspects of the food system: (1) health and nutrition, (2) environmental sustainability, (3) valued workforce, (4) local economies, and (5) animal welfare. Purchasers commit to transparency in their purchasing, she reported, and the center uses a rubric to evaluate and provide feedback on those decisions based on established benchmarks. Daniels stated that this process has led to transformative shifts.

For example, Daniels developed the certification initiative through a 2-year process involving multiple stakeholders, including farmers; supply chain businesses; food processors; food distributors; government entities; and community-based organizations focused on issues of environmental sustainability, labor, health, and food access. The Los Angeles School District, the second largest school food service district in the country, with a $150 million annual food budget, adopted the program in 2012. Daniels reported that the school district went from purchasing 10 percent local to 60 percent local within 1 year, injecting $12 million into the local food economy and creating 150 new jobs.

Highlighting the potential impact of the certification program, Daniels noted that overall, the U.S. institutional food service market is worth $120 billion, including at least $13 billion attributable to the National School Lunch Program. The Good Food Purchasing Program accounts for about $1 billion of the market, serving a total of nearly 3 million students in at least 50 institutions in 20 cities, including Boston, Chicago, Los Angeles, New York, and Washington, DC. Daniels stated that the program has received international recognition from the World Food Council as one of eight top food policies to support agroecology.

Externalities of the Food System

Daniels next described the externalities of the food system, which she noted are not included in the cost of cheap food items such as hamburgers or candy bars. As she explained, the food system was designed in the mid-20th century, and she asserted that it needs to be redesigned. In the mid-1940s, she elaborated, many people worked in fields or factories, but by the 1980s, there were significantly fewer small farms in the United States as a result of corporate consolidation and industrialization in agriculture. Greater output was produced by fewer farms, she added. In the second half of the 20th century, she continued, packaged, processed foods were developed and mass marketed, and diabesity[2] rates skyrocketed in tandem.

[2] "Diabesity" is defined as "diabetes occurring in the context of obesity" (Farag and Gaballa, 2011).

Daniels shared a diagram of the eight "key lock-ins" of industrial agriculture, centered around concentration of power; they include an export orientation, an expectation of cheap food, and a feed-the-world narrative. She expressed disagreement with the need for industrial agriculture to feed the world, noting that current production levels are already above the caloric needs of the average person. However, she stressed, the food that is produced is not aligned with current dietary patterns, nor is it equitably produced or distributed. Daniels argued that the United States should move away from producing and exporting cheap, processed foods, noting that certain foods are cheap because the government subsidizes them.

Daniels recommended reframing conversations about the food system from a narrow focus on production to a broader consideration of social and cultural factors, healthfulness, and availability. Sharing an agroecological framework from the International Panel of Experts on Sustainable Food Systems and experts with Tasting the Future and the Global Alliance for the Future of Food,[3] she compared the existing and new ways of thinking about the food system: while the existing thinking is that "we," meaning primarily the Global North, feed the world, the new thinking is that the world feeds itself, and people are empowered to grow their own food. Daniels suggested further that food be valued as a public good instead of a commodity, with value rather than profits being maximized. She explained that the new thinking about the food system she had described is aligned with an agroecological framework, a multidisciplinary perspective that takes a holistic view of the system encompassing sociology, economics, history, and other disciplines. She recommended in particular the TEEBAgriFood (The Economics of Ecosystems and Biodiversity for Agriculture and Food programme) Evaluation Framework, which allows for inclusive accounting of these values (TEEB, 2018).

Daniels pointed out that the United States ranks in the bottom half of 67 countries on a food sustainability index (The Economist Intelligence Unit and Barilla Center for Food & Nutrition, 2018). She suggested that the nation needs to do more to catch up to other countries and embrace the 10 elements of agroecology described by the Food and Agriculture Organization of the United Nations (FAO, 2018).

Final Remarks

Daniels closed her presentation by again emphasizing the importance of purchasing power through public procurement as a key lever for government

[3] See the Global Alliance for the Future of Food's *Reframing How We Think About Food and Health*, available at https://medium.com/global-alliance-for-the-future-of-food/reframing-how-we-think-about-food-and-health-6fab171ad4b1 (accessed September 16, 2020).

in changing the food system. She proposed a new narrative of a food system that is resilient and supportive of local food economies, the workforce, humane treatment of animals, sustainability, and nutrition. She suggested that this vision could be achieved with a shift from primary dependence on an export model to investment in a diverse renewable and regionally sustainable system, following the model of the shift toward renewable energy.

PANEL DISCUSSION

Following the three presentations summarized above, Liebman led a panel discussion with Rosenzweig, Salvador, and Daniels.

Food System Vulnerabilities

In response to a question asking that they identify the major vulnerability in the food and agriculture system, Rosenzweig pointed to increasing climate events, while Salvador posited that socioeconomic disparities are even more important because those with greater socioeconomic standing can better withstand such challenges as climate change. Daniels highlighted corporate consolidation and vertical integration, as evidenced by the meatpacking plant example provided by Salvador, and suggested increasing emphasis on regional food systems, including regional food processing, ownership, distribution, and resilience, as a potential solution.

To increase attention to food safety, Daniels and Salvador suggested using technology to improve transparency and traceability from farm to fork, which could allow contamination to be quickly identified and mitigated. Salvador added that preventing contamination from occurring in the first place should also be a goal for the food system, while Rosenzweig noted that climate change could act to increase microbial contamination.

Thoughts on Research Priorities

In response to an audience member's question about priorities for research, Daniels highlighted opportunities in aquaculture as a form of environmentally sustainable animal food production and innovations in converting food waste to aquaculture feed. She noted that as of 2012, more seafood than beef was being farmed in the United States. Rosenzweig pointed to the need for more research on strategies for responding to such complex global cascading risks as COVID-19 and climate change, on strategies for climate change mitigation and adaptation, and on the effect of the food system on health and equity issues.

Salvador pointed to the need for more research on agroecology, which in his view is superior to the current system of replacing beneficial insects

and natural equilibrium with purchased fertilizers, insecticides, or bio-engineered crops, even though that system is convenient and provides broad access to crops outside their native locations. He suggested that ecological knowledge can replace these expensive purchased inputs and return more money to farmers, noting that most of the money in the food system goes to food processors and marketers rather than farmers. Salvador observed that agroecology is more than the replacement of one technical approach with another, as it requires supportive environments, policies, markets, and educational systems. He suggested that greater public investment in agro-ecological systems would benefit farmers and help revitalize rural economies through improved farm production, increased environmental quality, and greater social well-being.

Leveraging the Knowledge of Indigenous Populations and People of Color

Another audience member asked how best to leverage the knowledge of Indigenous and Black farmers and other people of color in the food and agriculture system to ensure food sovereignty[4] and agroecological health. Salvador responded that an important goal is to provide more equitably the resources needed to participate in the global cash-based economy, because people who lack these resources cannot afford to buy enough food and will go hungry if they do not produce it themselves. He pointed out that in the United States, people of color are more likely than White people to experience food insecurity as the result of a cycle of racial inequality and poverty that repeats itself over generations. He stressed that the nation's history of appropriating land and displacing and enslaving people has made it difficult for these groups to own land; build wealth; and access the best schools, hospitals, and other institutions, even hundreds of years later. This system, he asserted, perpetuates the cycle of poverty over generations, and he suggested that building food sovereignty requires investment in the appropriate knowledge and acknowledgment of the need for structural change.

Daniels pointed to the need for more research on aquaculture, which could provide opportunities for Indigenous farmers to produce food in a sustainable way. Rosenzweig added that intergovernmental science bodies, such as the Intergovernmental Panel on Climate Change, are intentionally incorporating broader knowledge systems, including Indigenous and local knowledge, in their assessment processes.

[4] According to La Via Campesina, whose members first coined the term, food sovereignty is "the peoples', Countries', or State Unions' right to define their agricultural and food policy, without any dumping vis-à-vis third countries" (La Via Campesina, 2003).

Role of Livestock in Climate Change

Responding to a question about the role of livestock in climate change, Rosenzweig suggested that any programs or policies to address climate change should consider the impact on the billion smallholder farmers around the world who depend on livestock for their food and livelihood. She stressed the need to create just transitions to sustainable agroecological systems that include livestock in ways that are more resilient and responsive to climate change challenges. As strategies for achieving this goal, she highlighted better grazing, land management, improved manure management, better-quality feed, genetic engineering, and cellular agriculture. Daniels recommended that the government set regional targets for transformation toward a more resilient food system as it has for the energy system, creating markets for more regenerative production.

Water Quality and Quantity

Liebman concluded the session by asking the panelists to address the vulnerabilities in water quality and quantity in the medium and long term. Daniels suggested the possibility of using re-treated, recycled water in agriculture. Rosenzweig and Salvador pointed out the need for greater awareness, such as through a media campaign, that water systems are shared between agriculture and other ecosystems around the world. Rosenzweig also highlighted the importance of conservation techniques through irrigation. Salvador noted the importance of utilizing production systems that are consistent with the current hydric and climate patterns, and suggested that data on future climate impacts can be used to make decisions that save lives and livelihoods.

4

Resilience of the Food System

Session 2 of the workshop, moderated by Kristie Ebi, University of Washington, focused on the resiliency of the food system. Presentations during this session addressed resiliency within complex dynamic systems, resilient properties of the current food system, and resiliency for the future.

RECAP OF THE INTRODUCTORY REMARKS: NEW EXPECTATIONS FOR THE FOOD SYSTEM

Patrick Stover, Texas A&M University, began the session with a brief recap of his remarks from Session 1 (see Chapter 2). He emphasized that the food system, people, the environment, and the economy are interconnected and interdependent and must be considered with a systems thinking approach. He reiterated that the workshop was building on the Institute of Medicine (IOM) and the National Research Council (NRC) report *A Framework for Assessing Effects of the Food System* (IOM and NRC, 2015).

Stover restated that expectations for the U.S. food system have changed over the years. Beginning after World War II, he elaborated, the system was designed to produce sufficient food to feed society and fuel economic growth; today, the system is also expected to address such goals as environmental sustainability.

Stover again referred to the framework from the 2015 IOM and NRC report, shown in Figure 2-2 in Chapter 2, which he said can serve as a decision-making tool for policy and practice related to food and agriculture. The framework highlights four primary outcomes of any effects on

the food system: human health, environmental health, social health, and economic health. Stover emphasized as well how the framework points to the importance of considering the entire food chain, understanding that it is a complex, adaptive system and that such disruptions as climate change, weather effects, and pandemics will have impacts throughout the system. The report further stresses the need for measures and standards of evidence that allow for science-informed decisions and understanding of the trade-offs across the above four outcome areas.

In closing, Stover shared key issues highlighted in each of the presentations in the prior session: issues related to climate change and agriculture (Rozenzweig), social inequities across the agricultural chain from production to consumption (Salvador), and food as a public good and the role regional food systems could play in increasing diversity and resiliency within the food system (Daniels).

RESILIENCY WITHIN COMPLEX DYNAMIC SYSTEMS

John R. Porter, Fondation Agropolis Montpellier, France; University of Copenhagen, Denmark; and University of Greenwich, United Kingdom, spoke about resiliency within complex dynamic systems. He began by stating that robustness,[1] resilience, and efficiency are important elements of a 21st-century food system. He asserted that climate change is the challenge that will define the future, noting that reducing greenhouse gas (GHG) emissions requires changes in both production and consumption. He suggested that, in addition to improving the efficiency of fossil fuel production, a goal for consumption should be to shift from wanting "more from less" to wanting "enough from less." Increasing efficiency in production increases both overall production and emissions, he observed, while improving efficiency and limiting consumption provides "enough from less" and limits emissions. He argued that economies should be designed for supportive robustness and resilience, rather than simple increases in efficiency.

System Redundancies and Efficiencies

Porter shared four hypotheses related to system redundancy and resilience: (1) more from less does not lead to increased robustness; (2) system redundancy is a good thing; (3) increased complexity can lead to increased robustness and resilience, but it can also hinder resilience; and (4) decreased robustness leads to decreased efficiencies, while increased robustness leads

[1] "Robustness" refers to the ability of food systems to minimize the variability of specific agricultural outputs, such as crop yield, despite the occurrence of perturbations (Urruty et al., 2016).

to increased efficiencies. To illustrate these hypotheses, he used different countries' responses to the COVID-19 pandemic. With respect to the third hypothesis, Porter clarified that increased complexity sometimes leads to increased robustness and resilience and sometimes does not. When systems become more complex and duplicative, he elaborated, they become more robust and resilient, but when they become too complex, some of the robustness and resilience is lost.

Porter showed a graph defining production efficiencies for the economic and energy sectors based on GHG emissions per unit of energy, energy per gross domestic product (GDP), and GDP per population (the so-called Kaya identity). He noted that in many Western economies, GHG emissions from oil have increased relative to those from other sources of fuel with higher heat content values, and energy per GDP has decreased. However, he said, since World War II, GDP per population has approximately doubled as other production efficiencies have decreased.

Applying the above principles to the agricultural sector, Porter then presented a diagram (see Figure 4-1) showing how emissions from the food system can be calculated on a per area and per product basis using the Kaya-Porter identity. He pointed to the equation shown in Figure 4-1, according to which GHG equals yield over area times energy over yield times GHG emissions over that energy times the area of production. He noted that land use change, soil emissions, carbon intensity, efficiency of energy use, productivity, and the cultivated area can all affect the amount of GHG emissions from a crop. Since 1970, GHG emissions from soil and

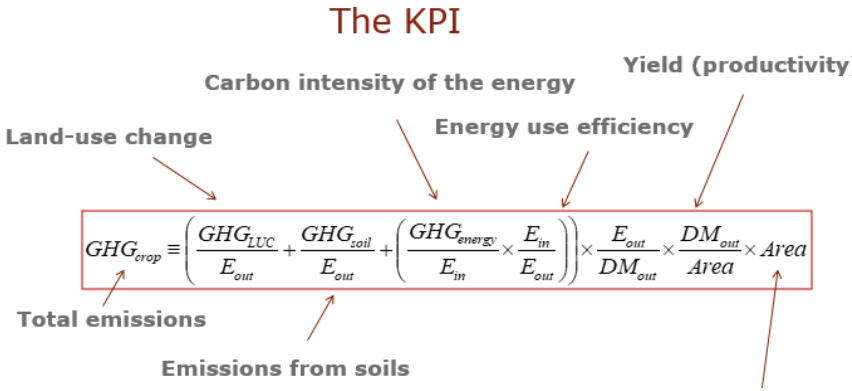

FIGURE 4-1 Presentation and explanation of the Kaya-Porter identity, used to calculate emissions from the food system on a per area and per product basis.
SOURCES: Presented by John R. Porter on July 22, 2020; modified from Bennetzen et al., 2016.

total GHG emissions per produced crop have declined. However, Porter asserted, this is because production has been increasing and not because GHG emissions have declined, as total GHG emissions from crops have increased over this same period.

Porter next described three resource use efficiencies: (1) radiation efficiency, or how much dry matter is produced for a given amount of radiation; (2) water use efficiency, or production per water used; and (3) nutrient use efficiency. He noted that these efficiencies are often considered separately but stressed that they interact, and he shared a framework that can be used to explore the trade-offs among the three resource use efficiencies. The evidence for this framework derives from research in New Zealand showing how efficiency of nutrient use interacts with efficiency of water use, and the interaction is different for irrigated versus nonirrigated crops. Porter explained further that there are trade-offs among wealth, health, consumption, and GHG emissions, and that the Kaya and Kaya-Porter identities can be joined to provide a multidimensional picture of food production and consumption and health.

In response to a question from Ebi following his presentation about where increased redundancy is needed in the food system to increase resilience, Porter highlighted the importance of increasing the diversity of food production, distribution, and consumption.

Linear and Circular Food Systems

Porter next described the difference between linear and circular food systems. He explained that with a linear food system, about 50 percent of the expected production is lost to waste at various points in the system, whereas with a circular food system, losses are minimized and recycled back into the system. Porter shared several principles of circular food systems:

- Plant biomass is the basic building block of food and should be used by humans first.
- Food and resource losses should be minimized, and by-products of food production, processing, and consumption should be recycled back into the system.
- Animals should be used for providing protein and nutrition.

Porter added that research on circular food systems lags far behind that of linear food systems.

Final Remarks

Porter ended his presentation by returning to the four hypotheses he had proposed at the beginning of his talk. He emphasized that the food system cannot be changed unless the economic system on which it is based also changes. He argued that consumers should consider whether they have enough and how they can use less. He concluded by asserting that change begins when people begin to feel uncomfortable.

RESILIENT PROPERTIES OF THE CURRENT FOOD SYSTEM

Cynthia Daley, California State University, Chico, spoke about resilient properties of the current food system from the perspective of the farmer.

Impact of COVID-19

Daley began by stating that farmers are in a time of crisis as a result of climate change, trade wars, and declines in commodity prices. She noted the dichotomy that COVID-19 has had a positive effect on some components of the food system and a negative effect on others. To illustrate this point, she observed that the grocery and packaged food industries are doing well, while meatpackers and institutional food suppliers are not. Daley pointed out that producers of perishable commodities lacking diversity in their production and distribution channels have been the most adversely affected by COVID-19 because they have been unable to switch to alternative markets. These producers are not resilient, she added, because they are price takers, unable to control input costs, and locked into inflexible contracts. She noted that as a result, farm debt and bankruptcies due to COVID-19 have increased, as have suicide rates among farmers, which are above the national average.

On a positive note, Daley observed that local food systems are particularly resilient, and as a result of COVID-19, demand for local food is higher than ever. She shared the example of the Sloot Farm in Minnesota, which prior to COVID-19 sold hogs as a commodity to Tyson Foods. In response to the pandemic, she continued, the farm adapted quickly and began processing the meat locally and selling it online, finding that demand through the regional food system outpaced supply. As another successful example, Daley cited White Oak Pastures in Georgia, which is vertically integrated, does direct marketing, has diverse products and practices, operates at scale, and is well managed by a farmer who utilizes systems thinking.

Resilient Food Systems

Daley suggested that a resilient food production system should reward farmers for exercising good stewardship and staying out of debt, value soil health and ecological systems, promote diverse markets and competitive pricing, and support local and rural economies. She lamented that the current system is resulting in a loss of soil, nutrients, institutional knowledge, farmers, and species diversity, while GHG emissions are increasing.

Referencing the report *On True Cost Accounting and the Future of Food* (Global Alliance for the Future of Food, 2019), Daley noted the need for better accounting of the true cost of the nation's cheap food policy, which is efficient but not resilient. She suggested that regenerative agriculture[2] could help increase resiliency by increasing soil conservation and reducing emissions, pesticide use, runoff, and nutrient loss.

Daley highlighted several programs that she said can help farmers increase resiliency, move toward regenerative agriculture, and reduce GHG emissions. She noted that several of these programs are facing potential budget cuts due to the budget deficit resulting from the pandemic, citing the example of the Natural Resources Conservation Service's Conservation Programs, which are designed to help consumers and producers move toward a system based on regenerative agriculture. She suggested that these programs need to be more accessible. As another example, she pointed to the Healthy Soils Program within the California Department of Food and Agriculture, which invested $22 million last year in regenerative farming practices impacting 30,000 acres, reducing GHG emissions by an estimated 37,000 tons.

According to Daley, research has shown that regenerative agriculture can have a significant effect on reducing emissions and removing carbon dioxide from the atmosphere. She shared photos illustrating regenerative farming practices, such as crop rotation, use of compost and animal manure, no-till and low-disturbance till, and managed grazing, and stressed the importance of systems thinking in implementing these practices.

Daley closed with a quote from The Ohio State University soil scientist Rattan Lal about the potential for addressing climate change by increasing the carbon content of the soil. She argued further that the food system should become more farmer-centric and better support farmers and ranchers in a paradigm shift toward increased resiliency and regenerative farming practices.

[2] According to the Center for Regenerative Agriculture and Resilient Systems at California State University, Chico, regenerative agriculture practices are "those that have the potential to move landscapes in the direction of increased functionality by adhering to one or more of the principles of soil health, along with enhancing the synergies of ecosystem processes" (CRARS, 2020).

Responding to a question about farm workforce issues after her presentation, Daley responded that many large farms depend heavily on seasonal labor, and the downward pressure on commodity prices has created downward pressure on worker pay. She also addressed a question about the effect of grazing on regenerative agriculture and carbon sequestration, noting that animals are effective at converting crop residue into high-quality protein for humans, and can provide ecological benefits when managed appropriately.

RESILIENCY IN THE FUTURE

The final speaker of the session, Rosamond Naylor, Stanford University, spoke about resiliency for the future and blue foods, which she defined as foods produced in freshwater and ocean aquatic systems.

Resilient Food Systems

Naylor defined a resilient food or agriculture system as one that can quickly rebound in response to a stress or shock. She cited climate change effects, such as droughts, floods, and temperature fluctuations, and market shocks, such as the 2008 Great Recession and the COVID-19 pandemic, as common stressors. She suggested that with respect to resiliency, it is important to ask the questions resilient to what, in what, and for whom.

With respect to COVID-19, Naylor suggested that hunger may kill more people than the virus itself, both globally and within the United States, adding that more than 1 million people in the United States visited a food bank for the first time as a result of the pandemic. She also noted that COVID-19 has adversely affected meatpacking workers, who are primarily people of color (see the summary of Salvador's presentation in Chapter 3), and people with diet-related diseases, such as heart disease, diabetes, and obesity, who are more likely to die from the virus.

Naylor posited that a resilient food system produces more variety and not just more calories. She noted that China was able to achieve a significant reduction in global hunger through its green revolution and production of such staple crops as rice. However, the high-starch, low-protein diet did not provide people with the proper nutrition to learn and be productive.

Aquatic Food Systems

Naylor suggested that aquatic foods can provide nutrients and protein affordably, stating that "fish are rich food for poor people" and for all people. She pointed out that one in five people depend on aquatic foods as their main source of protein. Although experts in global food security,

terrestrial agriculture, and ocean conservation are often siloed, she continued, these systems are connected through climate change, technology, natural resources, and policy.

Considering resilience within the context of an interconnected global food system, Naylor observed that growth in population and in incomes drives demand for food, animal protein, and animal feed, along with biofuel for transportation, and that these demands are then met with terrestrial livestock and aquaculture. She asserted that more substitution options in the production and consumption of protein foods, such as fish, chicken, and legumes, could help reduce price variations. Citing a 2014 paper finding less volatility in prices for aquaculture and fisheries than for cereals and oils, she suggested that greater diversity of aquatic foods relative to terrestrial crops and livestock makes aquaculture more resilient (Troell et al., 2014).

Naylor explained that she is engaged in an assessment aimed at incorporating blue foods into international discussions about the global food system and evaluating the role of these foods in nutritious, sustainable, and equitable diets. Ebi asked a question about how climate change will be incorporated into the blue foods assessment, given the impact of rising ocean temperatures and acidification. In response, Naylor stated that the assessment will address climate vulnerability given that climate change can impact fish physiology, pests, and pathogens, and that storms and floods are risky for aquaculture as for all food production systems.

Naylor reported that global capture fish production has remained relatively constant in recent decades, and that there has been more than a threefold increase in aquaculture production in the past 20 years. More than half of capture fish production comes from small-scale fisheries, she observed, and more than two-thirds of farmed aquatic foods come from small-scale systems. She shared a graph showing that growth in aquaculture since 1900 has exceeded that for other terrestrial crop and livestock commodities.

Naylor next discussed aquaculture feeds as a major sustainability issue in aquaculture. The ratio of fish feed to fish produced through aquaculture has dropped substantially in the past 20 years, she elaborated, from about 2:1 to 0.28:1. To address this issue, a substantial portion of the feed now comes from fish processing waste, livestock waste, grains, and even algae and insects in some places, she added, replacing fish oil and fish meal that were used historically and perpetuating a circular system.

Naylor closed her presentation by highlighting three key takeaways: (1) blue foods have the potential to provide protein and micronutrients for people around the world; (2) interest in the environmental and social sustainability of blue food systems has increased; and (3) connections between land and sea are growing. She stated that dietary intake of fish continues to rise in the United States (National Marine Fisheries Service, 2020), and fish feeds are increasingly including plant-based materials.

In response to a question about ensuring food safety in aquaculture when waste is used as feed, Naylor explained that waste from one species is not used as feed for the same (or a similar) species, and feed companies test the feed to ensure its safety. She noted that food safety is a more significant issue in low-income countries, where human and other wastes are often dumped into aquaculture ponds. She also acknowledged concerns about the possibility that plants used for feed potentially have pesticide residues.

PANEL DISCUSSION

After the presentations, Ebi facilitated a discussion among Porter, Daley, and Naylor.

Thoughts on Research Needs

Ebi began by asking about the key research needs to increase understanding of the resiliency of complex adaptive systems. Porter responded that much work has been done on the consumption side of food security, but more research is needed on the production side and the integration of production and consumption. Naylor described the need for more research on improving nutrition; on food safety; and on the environmental effect of aquaculture involving lower-value fish around the world, as most research investment to date has focused on such high-value commodities as salmon, shrimp, tuna, and other marine fish that are commonly eaten in the United States. She also pointed to the need for more research on the contribution of antibiotic use in aquaculture to antibiotic resistance.

Daley added that there is a need for more socioeconomic research on how to implement the changes that are needed, including adoption of more sustainable practices by farmers and a systems-based approach. She mentioned a farmer peer network in Iowa that leverages social connections to make change. In addition, she pointed to a need for more research on what public policy changes are needed to drive global shifts in the food production system.

Consumer Incentives

Ebi asked about incentives for consumption that could help transition the food system more quickly. Daley responded that increasing consumer interest in the impact of production practices on animal welfare, nutrient density, GHG emissions, and human health could help change consumption behavior. She noted that several brands are leveraging this messaging, as consumers are willing to pay more for food that they perceive to be more nutritious, organic, or otherwise produced in a superior way. However,

Daley pointed out that producers are incentivized by the quantity of what they produce, not its nutrient density, emphasizing the need for public policy change in this area. Porter suggested that nutrition labels can also inform consumption decisions.

With respect to aquaculture, Naylor added that a segment of consumers concerned about antibiotic use and sustainability is driving some change in global markets. While some large retailers, such as Costco and Walmart, have begun to market and sell sustainable seafood, he observed, this still amounts to less than 2 percent of total aquatic food products, primarily high-value commodities. Ebi stated that consumers do not fully understand the difference between sustainability and resilience.

Porter and Daley suggested that successes in changing social norms around tobacco use could serve as a model for changing norms in the food system. Daley noted that media and film, in particular, played a key role in the antitobacco campaign. Ebi added that a key message in tobacco control is that secondhand smoke kills nonusers, and suggested that a similar point could be made about the harms of the agricultural system.

Ebi and Naylor highlighted the need for greater understanding of motivations for consumer behavior and increased reliance on social science research, including the field of behavioral economics. They also suggested that having leadership model positive behaviors, such as healthy eating, could be influential, particularly for children. This leadership could come from a range of sources at various levels, including former First Lady Michelle Obama, celebrities, or a school chef. Ebi observed that education and resources also influence behavior, highlighting the adverse impact of food deserts. She highlighted a comment from an audience member who suggested that referring to consumers as citizens could help them assume greater responsibility around sustainability.

Production Incentives

Porter recommended addressing climate change through macroeconomic changes, such as the development of a carbon standard that values the economy on the basis of carbon stocks. He expressed the view that soil preservation should be a societal goal.

Daley recommended incentivizing the shift to a perennial farming system, noting that in the current system, farmers with fixed costs want to produce as much of a single crop as possible. However, she said, switching to a perennial crop system would require investments in new equipment and infrastructure. She also suggested modeling the impact of this shift on economic outcomes for farmers. In addition, she pointed to nutrient labeling regulations that prohibit identifying the superior nutrient density of foods produced in certain ways as a disincentive for changing production

methods. As an example, she cited labeling regulations that prohibit specifying that grass-fed beef is higher than traditional beef in certain nutrients.

Naylor added that aquaculture has adopted many technologies and practices from agriculture and livestock farming, and the farming of only a small number of high-value aquatic species is having an adverse ecological impact. She argued for increased redundancy and incentives to adopt more sustainable approaches. She also pointed out that farmers often use the easiest and most profitable production methods and often lack access to complete information about all potential options.

Naylor, an economist by training, went on to suggest that economics is often the "invisible hand" that spurs change for both producers and consumers. The current economic system is top-down, she elaborated, giving the example discussed previously by Salvador (see Chapter 3) of the large meatpacking companies that mandated that their employees work during the COVID-19 pandemic when an alternative would have been for people to eat less meat. As an example of a process that could change the current economic system, she cited the recent protests over racial equity and social justice as a bottom-up approach. Finally, she pointed to the question of who can afford to eat clean, safe food as a global social justice issue, with some populations being forced to put having access to safe food second to having access to food at all.

Sustainable Solutions in Low-Income Countries and Communities

Ebi asked the panelists about how increased sustainability and resiliency can be facilitated in low- and middle-income countries and communities that lack education, knowledge, technology, and resources. Daley responded that several U.S. Department of Agriculture initiatives, including improvements to the Supplemental Nutrition Assistance Program and increased access to farmers' markets in food deserts, are working toward these goals.

Naylor observed that food is cultural and that solutions vary in different parts of the world depending on such factors as economic, political, and transportation systems. She cited the example of South Asia, where small and medium-sized businesses have been established by entrepreneurs looking to meet demand for protein and local or regional foods. However, she continued, a different solution may be needed in parts of Africa, for example, where transportation networks are not as good. She asserted that solutions should both provide incentives for making food system changes and eliminate policies that perpetuate the status quo, noting that supply chain disruptions caused by COVID-19 have led the Indian government, for example, to rethink its agricultural subsidies.

In response to another audience member's question, Daley suggested that local gardens at schools and in low-income housing areas could help

provide access to fresh fruits and vegetables and improve health and wellness among people in those settings. Porter pointed out that both government and philanthropic funders are interested in addressing food security, and in particular the link between food security and the COVID-19 pandemic.

Food Safety

Ebi asked the panelists a set of questions from audience members about how to ensure food safety and reduce contamination, including microplastics in the ocean and lead in the soil. Daley suggested the use of remediation measures to remove heavy metals from foods from contaminated soils, noting that some work has been done on bioengineering of biological tools to make them useful for this purpose. However, some soil is still too contaminated to be used. Porter added that certain trees can be used to extract heavy metals from the soil, which can then be harvested and used to create energy. He mentioned some of his prior research focused on establishing an agricultural production system that is fossil fuel energy neutral. In this research, he reported, while about 10 percent of the land was used to produce energy crops, the yield per hectare was more than 10 percent greater, more than offsetting the extra land used for biomass. He suggested that the use of fast-growing trees is an innovative way to provide an energy source, help remediate some of the heavy metals in the soil, and improve the land use ratio. Naylor lamented that toxins are also a concern with aquaculture, particularly in lower-income countries.

Thoughts on Next Steps

In closing, Ebi asked for recommendations about where researchers can obtain funding and how practitioners can get started on implementing the priorities identified. Ebi and Daley both noted the importance of interdisciplinary collaboration. Naylor pointed to the importance of regional funders and thinking creatively about how to solve problems locally, such as connecting food banks with farmers during COVID-19.

5

Transformation of the Food System

The final session of the workshop, moderated by Christian Peters, Tufts University, focused on transformation of the food system. Speakers addressed both production- and consumption-oriented strategies for effecting this transformation and the necessary supporting policies.

INTRODUCTION

Peters began by providing a recap of the first two sessions (see Chapters 2, 3, and 4) and then introduced the third. He noted that the workshop was designed so that all sessions would be interdisciplinary and would address both short-term issues, such as COVID-19, and long-term issues, such as climate change.

Recap of Day 1

Peters summarized key points from Stover's introductory remarks at the beginning of the workshop and the presentations during the first two sessions on day 1. He added that while the food system historically was expected to provide "food, feed, and fiber," it now is also expected to improve human health, reduce the ecological footprint of the food produced, and move from being a carbon source to a carbon sink. Sharing a diagram of an agricultural paradigm from a 1999 report (Welch and Graham, 1999), Peters pointed to expanding expectations that include production and sustainability paradigms as part of a broader food system. The production paradigm is focused on productivity and efficiency, he elaborated, while

the sustainability paradigm is focused on ecological impact. In addition to production and sustainability, Peters observed, new expectations for the food system consider human health and human needs.

Introduction to Day 2

Setting the stage for Session 3, Peters posed the question of what the goals are for transformation of the food system. Referencing the Brundtland report, he defined sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). He highlighted two key concepts from that report: that the essential needs of the world's poor should be a priority, and that technology and social organization limit the environment's ability to meet present and future needs. Peters shared the 17 United Nations (UN) Sustainable Development Goals (SDGs), established in 2015, noting that they are a holistic international agenda for achieving sustainable development. The SDGs, he explained, address the following topics: (1) poverty; (2) hunger; (3) health and well-being; (4) education; (5) gender equality; (6) clean water and sanitation; (7) clean energy; (8) work and economic growth; (9) industry innovation; (10) inequalities; (11) sustainable cities and communities; (12) responsible consumption and production; (13) climate action; (14) life below water; (15) life on land; (16) peace, justice, and strong institutions; and (17) partnership. Overall, he elaborated, the SDGs contain 169 targets.

Peters then described several of the 2030 targets included in SDG 2, to end hunger. For example, Target 2.1 is to end hunger and ensure access to adequate nutrition by all people; Target 2.2 is to end all forms of malnutrition; Target 2.3 is to double agricultural productivity and the incomes of small-scale food producers; Target 2.4 is to ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production; and Target 2.5 is focused on maintaining the genetic diversity of seeds, cultivated plants, and animals. Unlike the other targets with a deadline of 2030, Peters noted, Target 2.5 had a deadline of 2020. He added that while the SDGs and their many targets could be perceived as a laundry list of activities, he reiterated that the SDG framework provides a holistic way of viewing the needs for sustainable development.

Peters next presented a diagram of agriculture and food systems from The Economics of Ecosystems and Biodiversity (see Figure 5-1), which depicts how the 17 SDGs fit into the categories of (1) planet; (2) people, dignity, and justice; and (3) prosperity. He pointed out that relevant outcomes include food security and nutritional diversity, cultural diversity, long-term ecological stability, and sustainable agriculture systems. He also

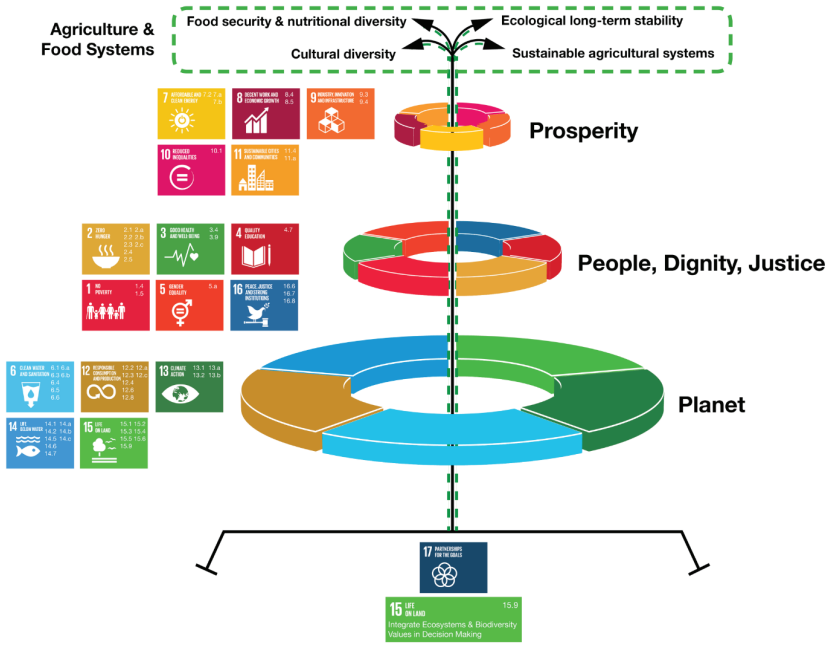

FIGURE 5-1 Conceptual illustration of the intersection between the Sustainable Development Goals and goals for the food and agriculture system.
SOURCES: Presented by Christian Peters on July 23, 2020; TEEB, 2018. Reprinted with permission from the United Nations Environment Programme (UN Environment).

noted that the relevance of the SDGs highlights that the issues discussed in the workshop are timely and of international importance.

Peters spent the rest of his presentation focused on the question of how to create a transformed food system. He outlined possible strategies for feeding the world's population and achieving food security included in a 2010 paper titled "Food Security: The Challenge of Feeding 9 Billion People," which at the time was the projected global population in 2050 (Godfray et al., 2010). These strategies, he continued, include the production-oriented strategies of increasing the yield potential, closing yield gaps by applying available technologies and increasing productivity, and expanding aquaculture; the supply chain strategy of reducing food losses; and the consumption strategy of changing the mix of plant- and animal-based foods in people's diets.

Peters also discussed Figure 2-1 in Chapter 2 as a roadmap for implementing the above strategies, highlighting the supply chain elements

and emphasizing the importance of working at multiple levels and within multiple dimensions of the food system. He pointed out that this figure shows food and food services flowing toward the consumer and money and demand information flowing toward the farmer. Additional domains that interact with the food system, he observed, include organizations, the health care system, science and technologies, the biophysical environment, policies, and markets.

Referencing a figure from a recent paper on the coexisting and interrelated health crises of obesity, undernutrition, and climate change (see Figure 5-2), Peters stressed the importance of working at multiple scales, including natural systems; cultural norms and policies; governance systems; macrosystems, such as transportation and human design; mesosystems, such as schools, hospitals, and workplaces; and microsystems, such as families and communities.

Finally, Peters informed the audience that the four speakers to follow would address different aspects of food system transformation, including incentives, consumption-oriented strategies across the value chain, design strategies for preferred food futures, and policy approaches to enable pathways for change.

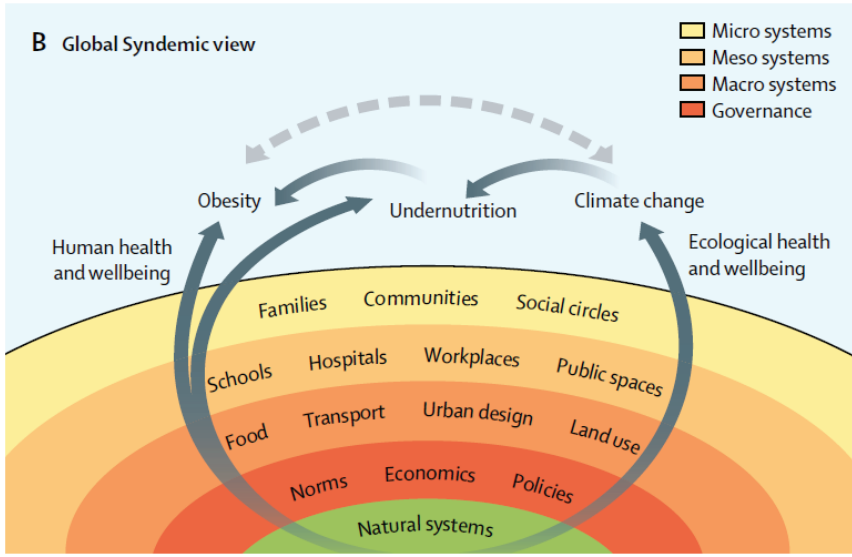

FIGURE 5-2 Conceptual illustration of the multiple levels of action needed to address the global syndemic of obesity, undernutrition, and climate change.
SOURCES: Presented by Christian Peters on July 23, 2020; Swinburn et al., 2019. Reprinted with permission from Elsevier.

Addressing a question from Naomi Fukagawa about whether to start with food system transformation at the local, national, or global level, Peters responded that he sees impact at each level as the sum of impacts at the level below. He suggested that the level at which to start depends on where there is readiness for change.

INCENTIVIZING FOOD SYSTEMS TRANSFORMATION

Pradeep Prabhala, McKinsey & Company, spoke about incentivizing food systems transformation. Framing the context for his presentation, he noted that progress toward the SDGs has been uneven as food systems have been focused primarily on increasing production and addressing hunger and malnutrition, but have made little progress toward protecting the environment or advancing integrated health outcomes. Prabhala observed that the food system accounts for about $10 trillion in economic value and about $12 trillion in external costs, meaning that the sector overall generates more costs than benefits. Many of these costs, he added, are borne by the health and environmental sectors.

As Prabhala explained, an ideal food system should be inclusive, sustainable, efficient, and nutritious. Successes to date, he reported, have included productivity gains in food production following the 2008 food crisis and progress toward addressing hunger and malnutrition. Global challenges, he continued, include degradation of 95 percent of the world's land by 2050, one in five children experiencing stunting due to undernutrition, two in five adults having overweight or obesity, and food loss costing $940 billion annually. He noted that strategies for increasing production do not necessarily address these other challenges.

Transformation requires fundamentally changing the way food is both produced and consumed, Prabhala asserted, including getting 500 million farmers globally to change their farming practices and 7.7 billion consumers to change their consumption patterns. Responding to an audience member's question, he stated that in countries with consolidated agricultural systems, the large players have significant influence over small shareholder farmers, but this is not the case in all countries. Challenges to achieving the necessary changes, he explained, are economic, educational, and attitudinal. For example, he pointed out that many smallholder farmers will not make changes unless they are financially beneficial, while others lack knowledge about the changes that are needed or do not want to make changes to long-standing habits.

Prabhala suggested that incentives are needed for both producers and consumers to make the needed changes. He argued that effective incentives should fund the costs of behavior change, mitigate transition or switching costs, and cover ongoing economic costs of the change. He also stressed

the need to remove or restructure disincentives, including $100 billion in government subsidies for the agriculture sector.

Food System Incentive Pathways

Prabhala proposed four pathways for incentivizing key actors to create a food system that is sustainable, nutritious, inclusive, and efficient. The first he termed "repurposing public investment and policies," which involves changing how and why governments spend money and constructing effective policies. He noted that governments often spend money in an attempt to balance social, economic, and other outcomes, and stated that alternative solutions must replace those investments. He cited as an example of an effective policy a tax on carbon to offset the carbon being produced through agriculture. The second pathway is what Prabhala termed "business model innovation," which involves changing the way companies do business through technology, product innovation, or innovation in business models in a way that creates the appropriate incentives. Prabhala identified the third pathway as the "institutional investment pathway," which involves investors setting standards for how their money is spent. Prabhala noted that some investors set such standards in response to data on the economic risk posed by climate change. Finally, he described the "consumer behavior change pathway," based on recognition that consumer demand can lead to changes in other parts of the ecosystem.

According to Prabhala, these four pathways are interconnected, and they all involve either policy or business model changes. He pointed out, however, that different pathways are appropriate for different countries and contexts, and that trade-offs in their implementation must be managed. He added that many of the necessary changes will happen at the national rather than the international level.

Activating the Pathways

Prabhala then provided a few examples of how the pathways he had described have been activated and challenges overcome, noting that various constraints often prevent the pathways from being activated effectively.

With respect to repurposing public investment and policies, Prabhala posited that governments may make suboptimal decisions about the food system because of the siloed nature of government operations and a lack of communication across ministries. In addition, he said the evidence for interventions may be limited, and governments want to scale programs only if they are known to be effective. Lack of political will, stakeholder resistance, lack of capacity for systemic change, and transition costs can

also present barriers, he observed. He noted that in emerging markets in particular, food security is a significant determinant of election outcomes.

Prabhala described some examples of governments that have overcome some of the challenges he outlined. One example he cited was the Great Lakes Protection Fund, through which governors invested collaboratively in projects that could affect the water basin. As another example, he highlighted the Punjab, India, government's Save Water, Earn Money program, which reduced electricity and water use in agriculture.

With respect to business model innovation, Prabhala identified as a key risk innovating while still making the economic model work, particularly if the innovation is more costly. To illustrate this point, he used the example of consumer food companies that want to innovate to improve the healthfulness of their ingredients but face challenges if consumers are not willing to pay the higher cost of the healthier ingredients. Prabhala stressed the importance of changing business models in the context of the business environment. He also pointed to the need for strong leadership and often a culture change in the way a company does business. In addition, he observed, government could incentivize business model innovation.

With respect to the institutional investment pathway, Prabhala stated that because institutional investors make significant investments in food systems, they have significant influence over the way companies spend their capital. Institutional investors could set clauses that dictate how the capital must be deployed. However, he said, challenges include a lack of intermediation mechanisms to deploy the capital in the intended ways, a lack of understanding of the risk and return of certain investments, and a difficult environment for change. Prabhala suggested that this challenge could be met by channeling institutional capital into natural capital by creating new intermediation mechanisms. As an example of a successful intervention, he pointed to the Global Agriculture and Food Security Program of the World Bank, which works to shift some of the risk away from institutional investors and support their investing in interventions with more inclusive outcomes.

With respect to consumer behavior change, Prabhala emphasized the need for consumers to make sustainable changes in their food choices. He added that some of these changes will require consumer education, and some will require increased support from businesses.

In conclusion, Prabhala stressed the importance of bringing the four pathways together at the country level and aligning actors toward a more inclusive, sustainable, efficient, and nutritious food system.

In response to a question from Peters about a tax on carbon emissions, Prabhala emphasized that the impact of an intervention depends largely on how it is operationalized and implemented. He suggested that in the United States, for example, the carbon footprint of agriculture could be reduced

if farmers adopted regenerative practices that led them to sequester more carbon and reduce the net footprint of their operations. He suggested further that a carbon market could be developed that would verify the farmers' carbon impact and provide supplemental income to those that adopted the preferable practices. However, he added that in a more fragmented environment, a carbon market would not be possible because the cost of verification would outweigh the benefits. In these environments, he argued, there would need to be alternative policy levers for achieving the intended goal.

CONSUMPTION-ORIENTED STRATEGIES: CONSIDERING THE WHOLE VALUE CHAIN

Philippe Caradec, Danone North America, spoke about consumption-oriented strategies. He asserted that consumers are interested in the value proposition for products, and to be credible and authentic, companies should consider the entire value chain, including the agricultural inputs, food production and processing, brand commitments, and packaging.

Sharing findings from the nationwide Food and Health Survey conducted by the International Food Information Council, of which he is co-chair, Caradec reported that about 60 percent of consumers want food that is produced in an environmentally sustainable way (IFIC, 2020). He identified the top factors that consumers use to determine whether food is produced in a sustainable way: labeling and packaging, such as using recyclable packaging; labeling the food as sustainably sourced, non-GMO (i.e., without genetically modified organisms), locally grown, or organic; and using minimal packaging. Caradec noted that familiarity with regenerative agriculture increased significantly between 2019 and 2020.

Strategies for Addressing Environmental Impact

Caradec provided background on Danone, including the company's 2030 goals. He described the company as the largest certified public-benefit B corporation in the world, using business as a force for good. A certified B corporation must provide both a return to its investors and a public benefit, he explained, which Danone accomplishes by bringing healthier food to as many people as possible with the lowest environmental impact. In response to a question from Peters, Caradec stated that the company uses its certified B corporation logo and storytelling to educate consumers about Danone's commitment to addressing climate change. He observed that consumers make a difference when they "vote with their dollars" and purchase products that reflect their values.

Caradec highlighted one of Danone's 2030 goals in particular: "to serve the food revolution with partners." He described the company's emphasis

on partnerships, including the One Planet Business for Biodiversity initiative, which was launched in September 2019 at the UN Climate Action Summit and is part of the French President's One Planet Lab framework. The coalition is hosted by the World Business Council for Sustainable Development, Caradec elaborated, and includes 21 companies and organizations collectively worth more than $500 billion. He explained that the Council is focused on agricultural biodiversity, including scaling up of regenerative agriculture, product diversification, and support for high-value ecosystems. Caradec asserted that partnerships with farmers, producers, government, consumers, academia, and civil society are key to achieving these goals.

Business Model Innovation

As an example of how Danone is changing its business model around agricultural inputs, Caradec explained that for a portion of its supply of milk in the United States, the company has reduced the price volatility of milk by using a model that pays for the farmer partner inputs and guarantees farmer partners a specific profit margin. As a result, he added, the farmer partner can try changes in agricultural practices to increase sustainability at scale without bearing the associated risk. Caradec reported that Danone is focusing on soil health, including biodiversity; increased carbon sequestration; and assurance of fair returns per acre. He added that the company also intends to work with farmers to support their implementation of such sustainability practices as low- and no-till farming, use of crop cover, and expansion of biodiversity. Caradec noted that while Danone may suggest changes to farming practices, the farmers themselves make the ultimate decisions about what will work best on their land, and that the program has expanded from 25,000 acres to nearly 60,000 acres in the United States. He also mentioned the Next Frontier Project of Danone's Horizon Organic brand, which is focused on regenerative soil health, farmer care and safety, and reduced environmental footprint, with the goal of Horizon Organic's becoming the first carbon-positive brand by 2025.

Packaging Innovation

With respect to packaging, Caradec explained how Danone takes a circular approach and is aiming for 100 percent of its packaging to be reusable, recyclable, or compostable by 2025. He added that Danone has invested in the Closed Loop Fund, focused on packaging collection, sorting, and recycling in secondary markets, as well as consumer education. He stated that the company is also committed to preserving natural resources, including a goal of having 25 percent recycled material in plastic packaging

and 100 percent recycled material in one brand of its plastic water bottles by 2025.

BEYOND RESILIENCE: DESIGN STRATEGIES FOR OUR PREFERRED FOOD FUTURES

Hildreth England, MIT Media Lab, spoke about design strategies for the future food system. Her work is broadly focused on recasting the technology design process to distribute positive impact more equitably and intentionally, in collaboration with and for the most marginalized societies. Her presentation addressed the benefits of thinking like an artist and a designer, why inclusive co-design strategies optimize the food system for all people in the system and promote resilience, examples of using design to make an impact, and co-design principles that are based on her lab's research.

Introduction

England began by sharing an anecdote from her involvement in user experience testing for a shopping app for mothers participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). A co-worker asked, "Why do they [the WIC mothers] need good design?" This experience and further research on cooperative design principles made England realize that good design is a collective good. All people, she argued, including WIC mothers, farmers, grocery store workers, and other food system stakeholders, respond to, need, and deserve good design.

The MIT Media Lab, for which England works, is a research institute that grants a media arts and sciences degree, which combines science and engineering with art and design. An artist, nutritionist, designer, and diplomat, England has dedicated her career to making design choices with the people for whom she is designing. She described how at the MIT Media Lab, bioengineers often collaborate with artists and designers to conduct research in such disciplines as space exploration, social justice, artificial intelligence, robotics, and education. England shared a diagram (see Figure 5-3) illustrating the perpetuation of creative energy, which she described as a compass to guide the infusion of art and design into the food system. England highlighted the fluid movement from one realm to another, making the point that behavior change is both a science and an art.

Benefits of Co-Design Strategies

In considering how to achieve transformation of the food system, England quoted a former director of the MIT Media Lab as saying, "You

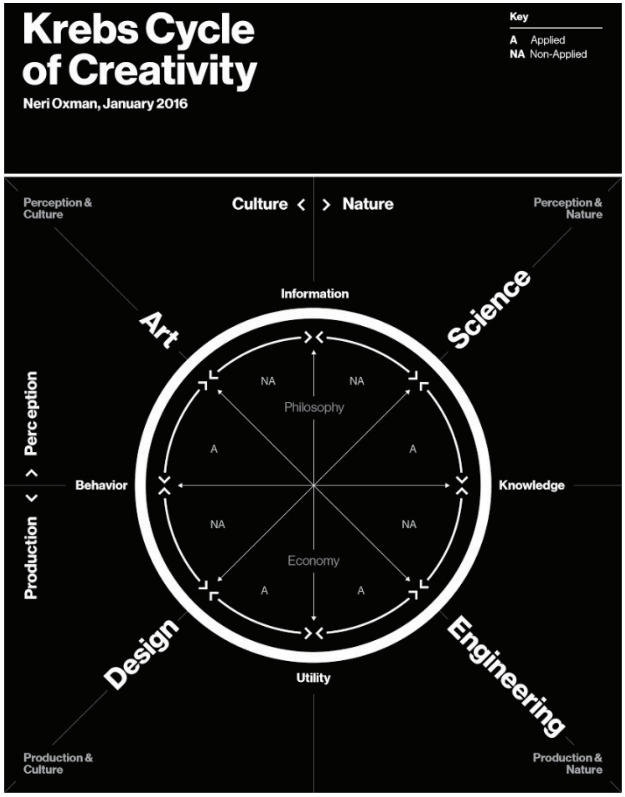

FIGURE 5-3 A map describing the perpetuation of creative energy (creative ATP or "CreATP"), analogous to the Krebs cycle for biochemical energy production.
SOURCES: Presented by Hildreth England on July 23, 2020; Oxman, 2016. Reprinted with permission from the *Journal of Design and Science*.

can't change culture by winning an argument. You change culture by changing hearts and minds." Art and design are the heart of food system transformation, she asserted, and added that the science of behavior change is about emotions, such as desires, that prompt people to act. She explained that designers use an artist's perception and stories to produce tools and environments that shift culture and inform science, engineering, and knowledge. She defined culture as "a collection of behaviors at scale shifted by creative perception and production;" in other words, culture is derived from the creation of new habits at scale.

England described how one might approach the food system as an artist and designer, proposing the need for design strategies that integrate emotions into the supply chain. She explained that while tools and technologies

increase efficiency, standardize processes, and improve access, principles optimize for both products and people. Designing for people requires strategy encompassing tools and context, she continued, noting that when people are engaged at scale, there is an opportunity to create a more equitable and sustainable food system that provides agency to its actors. England pointed out that even small design changes can make a major difference in feelings of confidence, self-efficacy, and curiosity.

England emphasized the benefits of design co-creation, particularly with marginalized communities, to balance academic expertise with lived experience and provide for more equal scaled distribution of the design benefits. The food system, she argued, is built on existing inequities and injustice, and co-design allows for the use of design to create more equitable tools in an equitable way and to measure impact. It can also help build social resilience, she asserted, which she defined as the ability to return to a functional state instead of breaking when stressed. She described co-design as a culture shift that leverages untapped resources and works toward the collective aim of reshaping a more equitable and sustainable food culture. She also stressed the importance of evaluating the impact of design strategies after their implementation to assess their impact and, in particular, to identify any adverse consequences for marginalized communities. England pointed out that equal opportunities do not necessarily lead to equal impact, and stated that co-design can help reshape the food culture to make it more equitably beneficial and environmentally sustainable.

Examples of Use of Co-Design Principles

England shared a few examples of resources that use the design principles she had outlined. She described the Better Buying Lab at the World Resources Institute, which released a playbook to guide diners toward plant-rich dishes in food service, providing recommendations for behavior change strategies for chefs and food service workers. She also highlighted Innit, a food environment choice architecture platform that brings consumer packaged goods companies, retailers, and home appliance manufacturers together in a digital platform that shifts behavior toward transparency, collaboration, sharing, and integration across food environments and pathways. As another example she cited IDEO, a design firm working with The Rockefeller Foundation, which designed place-based, people-centered interventions in the food system, such as the redesign of hotels' all-you-can eat culture to reduce food waste. The company is also responsible for the Food System Vision Prize, as well as OpenIDEO, a social impact platform powered by design thinking that lets anyone help design solutions to challenges across the food system. Finally, England mentioned Ikea's in-house research and innovation design lab Space 10, which is using the company's

global supply chain to explore more sustainable food and food environment solutions.

Questions to Guide Food Systems Co-Design

England concluded by recommending several questions to guide co-designs for food system transformation: (1) whether there is flexibility in the designs for co-designers to make changes to remain resilient; (2) who is not at the table; (3) whether new design is needed, or only slight tweaks to the old design are sufficient; and (4) who should develop the solution.

Following England's presentation, Peters asked her for guidance on how best to bring in other people as co-designers without implying that the designer has all the answers. She responded that the design process establishes a power dynamic from the beginning regarding roles and expectations for who has the solutions. She stressed the importance of bringing the people who would benefit from the design into the process early, and stated that the role of the designer should be to facilitate and capture the conversation and increase feelings of confidence and self-efficacy among those creating the solutions.

POLICY APPROACHES TO ENABLE MULTIPLE PATHWAYS TO CHANGE

The final speaker of the workshop, Catherine Kling, Cornell University, spoke about policy approaches to enable multiple pathways to change, noting that those approaches complement the producer, supply chain, consumer, and design approaches described by prior speakers. Her presentation included three key themes: (1) economic and social incentives drive the food system; (2) economically efficient systems will often be more sustainable and resilient because they use scarce resources without waste to provide the most value; and (3) market failures, such as asymmetry or lack of information and powerful controls on prices or decisions, require policies to correct them. Kling shared her goals for food system transformation, which included affordable and nutritious diets; good farm profitability and working conditions; environmental sustainability, including reduced greenhouse gas (GHG) emissions and improved water quality, reduced air pollution and odors, and protection of wildlife habitat and biodiversity; animal welfare; and food safety.

Market Inefficiencies in the Food System

Kling described several market inefficiencies in the food system. Defining externalities as unintended side effects of market production or

consumption that impose costs on others, she stated that externalities, particularly those of public goods, provide benefits or costs for people regardless of whether they are involved in the market. As an example she cited GHG emissions, which are released unintentionally through the production of fossil fuels and cause damage around the world.

Another market inefficiency Kling described is market power, which denotes a situation in which a small number of buyers or sellers control the market and prices. She identified as still another market inefficiency lack of information about risks and benefits, such as whether a food is healthy or what risks are associated with farm labor.

Kling pointed out that each of these market inefficiencies may require a different policy solution. For example, she said, a cap and trade program can address externalities involving GHG emissions and air and water pollution; antitrust regulations can address market power inefficiencies; and education and public service tools can address education failures. Kling explained that policy can level the playing field for players across the supply chain and the entire food system. In response to a question from Peters, she reiterated that markets will not solve the problem of global warming because it is a market failure, and policy interventions, such as a worldwide cap and trade program, are needed.

Kling pointed out that markets are agnostic about fairness and equity. However, she said that while these issues are not market failures, they should be addressed through policy in the form of social safety net and poverty reduction programs and education and training. She suggested that for every problem, it is important to understand the incentive causes and identify the appropriate policy solutions.

Mississippi River Watershed Case Study

Kling spent the rest of her presentation using the example of agriculture in the Mississippi River watershed to illustrate the need for tailored policy approaches. She described the Mississippi River watershed as an area covering 40 percent of the continental United States and 57 percent of U.S. farmland, including nearly 100 million acres of corn, 84 million acres of soybeans, and 45 million acres of wheat, making it the second most productive agricultural system in the world. She added that it has more than 300 animal species and is crossed by 60 percent of migratory birds. The majority of the corn and soybeans grown in the region is used for fuel (ethanol) and animal feed, she elaborated, with only a small amount going to food, being processed into oils and sweeteners. Kling noted that this area also has high and increasing levels of harmful nitrogen and phosphorous.

Kling stated that the policy interventions needed to address the issues in this low-cost commodity market differ from those used in a local or organic

market. The environmental impact of agriculture on the region is harmful and significant, she stressed. She pointed out that overall, 10 percent of all GHG emissions are caused by agriculture, suggesting that a carbon tax or cap and trade system that compensates farmers who sequester carbon should be encouraged. Water quality in many of the rivers, streams, and lakes in the Mississippi River watershed is poor, she added, and there has been a significant reduction in wildlife habitat and biodiversity, due largely to agriculture. Kling noted that about 90 percent of the original wetlands in the United States have been lost. In addition, she pointed to a dead zone in the Gulf of Mexico that is commonly referred to as "the size of the state of Connecticut," which would have to be addressed by reducing and optimizing fertilizer use and changing farming practices. Kling referenced one study according to which a solution would require these changes to be implemented on 90 percent of the land.

According to Kling, policies to address the adverse environmental impact of the agricultural practices she had outlined include regulations to reduce and optimize fertilizer use; taxes; and requirements regarding such farming practices as use of cover crops, erosion control, protection of wetlands, and use of bioreactors. Tax revenue could be used to subsidize the desired activities, she suggested. She asserted that these policy changes would increase prices and improve the alignment of incentives in the system.

The Role of Policy

Regarding the role of policy, Kling argued that policy should address the core problem as directly as possible. Multiple problems require multiple responses, she observed, and one size does not fit all. She stated that policies level the playing field, enable supply chain management, and facilitate implementation of consumer preferences.

Peters relayed a question from an audience member about how to address the contribution of multiple sectors to adverse environmental impacts in such places as the Chesapeake Bay Basin and incentivize action. Kling replied that while each sector currently has targets for reduction, those targets are voluntary; thus, the market failure persists because the actors are not appropriately incentivized to make the necessary changes. She suggested that policies would be needed to implement incentives for change.

PANEL DISCUSSION

Following the presentations summarized above, Peters facilitated a discussion with Prabhala, Caradec, England, and Kling.

Coordinated Versus Individual Actions

Peters began by asking the panelists which food system transformations are most important for coordinated action, rather than isolated actions by individual companies or governments. Caradec replied that actions by both coalitions and individual companies are needed, referencing Danone's work at both levels.

Both Prabhala and Kling suggested that when it is difficult for an individual company or farmer to internalize the external costs of action, a coalition or multisector collaboration may be needed. In contrast, when the entities that implement a strategy will realize returns on that action, external actors are not necessary. Prabhala gave as an example that replenishing water basins is expensive, so most companies would be unable to afford to take that action without harming their economic model. In this situation, he suggested, an intervention forcing all companies to internalize these costs equally might be needed. In contrast, Prabhala observed, more than half of 25 possible interventions to reduce the carbon footprint of agriculture pay for themselves over a period of time, meaning that companies or farmers that implement them will experience a financial benefit. In these situations, he stated, the companies can effectively internalize the costs of action without having to rely on external actors. Kling added that individual farmers and growers can afford to make costly changes only when they are all required to do so and everyone's costs therefore increase simultaneously, leading to higher prices being passed through the chain.

Kling also highlighted how states have established regional coalitions to address GHG emissions given the lack of action at the national level, noting that government entities, nongovernmental organizations, and private businesses can all form coalitions. Prabhala pointed out that when collective action is required, an entity is needed to facilitate and organize the stakeholders.

The Role of and Impact on Small-Scale Farmers

Peters asked for input on the role of small-scale farmers in advocating for agroecology and in supporting and leveraging the use of local and Indigenous knowledge in efforts to transform the food system. Caradec responded that in the United States, Danone works with both small-scale farmers and larger farms, while outside the United States, many of the company's suppliers are smallholder farmers organized into cooperatives. Prabhala pointed out that solutions can be scaled in different ways, including an individual firm integrating components, replicating what has worked in a different place, and "formalizing the informal" by compiling effective subscales. He suggested that different models will work in different settings,

and that the roles of policy and financing mechanisms differ. Prabhala observed that each model has its own pros and cons and unique set of challenges.

England added that allowing smallholder farmers to keep doing business without forcing them to scale makes them more resilient to a crisis. She suggested asking the question of why small farmers need to scale and whether they might be better off remaining small and nimble. Peters pointed out, however, that in many industrialized countries, farm size and scale are increasing, and farms may have to scale to stay viable. Prabhala agreed, pointing out that even in such places as Africa where there are many smallholder farmers, scaling is necessary for entities too small to implement interventions. He argued that technology and broader economic development can help support transformations in emerging markets that drive productive improvements among small farmers.

Kling observed that in the United States, the majority of the farmland in the Mississippi River watershed is farmed by large-scale producers that have crop insurance and are heavily subsidized by the federal government. She explained that while the number of U.S. farmers declined substantially in the past century, the same amount of land is still being farmed, meaning that farms have grown in scale. She added that many of these farmers also have off-farm income and are successful business owners.

Equity and Inclusion

Relaying a question from an audience member, Peters asked England how to continue the momentum regarding equity and inclusion within agriculture and environmental preservation. She responded that while "equity" and "inclusion" are frequently used as buzzwords, their actual practice is difficult, and food system transformation will require many years. She reiterated the importance of considering who is not at the table and why not, even if the impact of a proposed change appears to be small. She also suggested examining current practices and the reasons behind them before making a change.

Consumer Behavior Change and the Role of Public Policy

Peters asked about the role of behavior change in supporting the kind of dietary change that leads to food system transformation, noting that he sees benefit in better engaging behavior change specialists, such as registered dietitians, in transformation efforts. Prabhala asserted that the context or environment in which people eat greatly influences their food choices. He pointed to the increased focus on precision nutrition, which would allow for the provision of personalized advice based on individual genetics.

Caradec explained that Danone North America is using public policy to push for the adoption of a flexitarian diet, which would include increased plant-based nutrition and less sugar. He also pointed out that there are many different types of consumers, and companies need to offer products that meet their varied expectations. According to England, because food is one of the most intimate choices that people make on a daily basis, influencing behavior change requires understanding the roles of environments, emotions, and psychology in individual food choices.

The panelists had a robust conversation about the role of public policy in supporting behavior change. Kling argued that the role of policy in supporting behavior change is to provide people with accurate information and education that will enable them to make their own choices, but it is not the government's job to change people's behavior through taxes or other interventions. Caradec expressed the view that public policies, such as nutrition standards for school meals, the WIC program, and others aligned with Danone's reduction of sugar in its yogurts for children, can also influence changes in the marketplace. He stated that Danone made changes to achieve that reduction but did not announce the changes until after they had been implemented so as not to adversely impact people's perceptions of the yogurt's taste. He urged that other food manufacturers take such action to improve their product portfolios.

Prabhala argued that people often make poor choices because of a lack of information or exposure to misinformation. He suggested that policy makers use regulation to support smarter choices, such as through labeling. Caradec stated that the United States already has an excellent Nutrition Facts label. England noted, however, that consumption decisions are shaped by the food environment and food policies, such as whether a food is available in schools or where it is placed on a grocery store shelf. She pointed out that just because the Nutrition Facts label exists does not mean that people use it to make decisions; when busy, stressed, or distracted, she asserted, people often fall back on whatever meets their emotional needs.

England suggested further that punitive policies, such as soda taxes, may be appropriate when balanced with positive incentives. Prabhala agreed on the need for mechanisms that penalize people for behaving in ways that impose costs on society, such as health care costs borne by government programs. Kling expressed opposition to soda taxes because, she argued, people should be educated and allowed to make their own decisions. She added that in a fully functioning market, health insurance companies would offer lower premiums for people who eat well or have a healthy body weight. Prabhala illustrated this idea by describing the pilot program of an insurance company in South Africa that provides incentives for healthy behaviors, such as purchasing produce or being physically active.

Given the connection between good nutrition and health outcomes, Peters asked whether efforts to transform the health and agriculture systems should be undertaken in parallel. Prabhala pointed to the need for better communication between policy makers in health and in agriculture, noting that cross-functional policy working groups have been established in some countries. He suggested further that changes in consumer choices will influence decisions on agricultural production in the long term. Prabhala referenced the fact that 80 percent of U.S. agricultural production is for soybeans, wheat, rice, and corn, and argued that increased production diversity is necessary to support achievement of the dietary diversity needed for improved health.

Enough from Less

Peters concluded by referencing a comment made by Porter in an earlier session (see Chapter 4) about the need to shift from "getting more from less to getting enough from less," and asked how to define what is "enough." England stated that there is already more than enough food to feed everyone in the world; the problem is with equitable distribution, as a great deal of food is wasted. Caradec pointed out, however, that while there are enough calories for everyone, the foods that are consumed, even in the United States, are not the most nutrient dense. Finally, Prabhala pointed to the frequent trade-offs that must be made between farm productivity and other outcomes, such as environmental impact, but suggested that technology and innovation can help address these challenges.

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A

Workshop Agenda

Healthy People, Healthy Planet: Building a More Sustainable, Resilient, Equitable, and Nourishing Food System

Food Forum Virtual Workshop
July 22–23, 2020

DAY 1, JULY 22

10:00 AM **Welcome and Opening Remarks**
Naomi Fukagawa, *Director, Beltsville Human Nutrition Research Center, U.S. Department of Agriculture (USDA)*
Planning Committee Chair

10:05 AM **Introductory Remarks: What Should We Expect of the Food System?**
Patrick Stover, *Vice Chancellor, Texas A&M AgriLife, and Dean, Texas A&M University College of Agriculture and Life Sciences*
Planning Committee Member

SESSION 1: Vulnerabilities of the Food System
Moderator: **Matt Liebman,** *Henry A. Wallace Endowed Chair for Sustainable Agriculture, Iowa State University*
Planning Committee Member

10:20 AM **Planetary Boundaries and Global Change**
Cynthia Rosenzweig, *Senior Research Scientist, National Aeronautics and Space Administration Goddard Institute for Space Studies, and Adjunct Senior Research Scientist, Columbia University Earth Institute*

10:40 AM **Q&A**

10:45 AM **Access to Health and Food**
Ricardo Salvador, *Director of Food & Environment Program, Union of Concerned Scientists*
Planning Committee Member

11:05 AM **Q&A**

11:10 AM **The Need for an Agroecological Frame for the Food System**
Paula Daniels, *Co-Founder and Chair, Center for Good Food Purchasing*

11:30 AM **Q&A**

11:35 AM **Panel Discussion**

12:30 PM **ADJOURN SESSION 1**

SESSION 2: Resilience of the Food System
Moderator: **Kristie Ebi,** *Professor, University of Washington*
Planning Committee Member

1:30 PM **Recap of Introductory Remarks: What Should We Expect of the Food System?**
Patrick Stover, *Vice Chancellor, Texas A&M AgriLife, and Dean, Texas A&M University College of Agriculture and Life Sciences*
Planning Committee Member

1:40 PM **Resiliency Within Complex Dynamic Systems**
John R. Porter, *Scientific Consultant, One Planet Fellowship Programme, Fondation Agropolis Montpellier; University of Copenhagen; University of Greenwich*

2:00 PM **Q&A**

2:05 PM **Resilient Properties in the Current Food System**
Cynthia Daley, *Director and Co-Founder, Center for Regenerative Agriculture & Resilient Systems, California State University, Chico*

2:25 PM **Q&A**

2:30 PM **Resiliency in the Future**
Rosamond Naylor, *William Wrigley Professor of Earth System Science, and Founding Director, Center on Food Security and the Environment, Stanford University*

2:50 PM **Q&A**

2:55 PM **Panel Discussion**

4:00 PM **ADJOURN SESSION 2**

DAY 2, JULY 23

SESSION 3: Transformation of the Food System
Moderator: **Christian Peters,** *Associate Professor, Tufts University*
Planning Committee Member

10:00 AM **Introduction**
Christian Peters, *Associate Professor, Tufts University*
Planning Committee Member

10:20 AM **Q&A**

10:25 AM **Incentivizing Food Systems Transformation**
Pradeep Prabhala, *Partner, McKinsey & Company*

10:45 AM **Q&A**

10:50 AM **Consumption-Oriented Strategies: Considering the Whole Value Chain**
Philippe Caradec, *Vice President Public and Government Affairs, Danone North America*

11:10 AM **Q&A**

11:15 AM **Beyond Resilience: Design Strategies for Our Preferred Food Futures**
Hildreth England, *Strategist, MIT Media Lab*

11:35 AM **Q&A**

11:40 AM **Policy Approaches to Enable Multiple Pathways to Change**
Catherine Kling, *Tisch University Professor, Dyson School of Applied Economics and Management, Cornell University*

12:00 PM **Q&A**

12:05 PM **Panel Discussion**

1:00 PM **ADJOURN SESSION 3 AND WORKSHOP**

B

Acronyms and Abbreviations

GDP	gross domestic product
GHG	greenhouse gas
GMO	genetically modified organism
SDG	Sustainable Development Goal
TEEBAgriFood	The Economics of Ecosystems and Biodiversity for Agriculture and Food programme
UN	United Nations
USDA	U.S. Department of Agriculture
WIC	Special Supplemental Nutrition Program for Women, Infants, and Children

C

Biographical Sketches of Workshop Speakers and Moderators

Philippe Caradec, M.S., is the vice president of public and government affairs of Danone North America, the North American business unit of Paris-based Danone. Danone North America was formed in April 2017 by combining the North American businesses of Danone Dairy (including The Dannon Company) and WhiteWave Foods to further the company's mission to bring health through food to as many people as possible. Mr. Caradec is responsible for federal, state, and local public and government affairs in the United States, as well as the oversight of these subjects for Danone Canada, Danone Waters of America, Happy Family, and Nutricia North America. Prior to joining Danone, he worked as a consultant in Washington, DC, specializing in technical and regulatory matters affecting the imported food and beverage industry. Previously, Mr. Caradec was the assistant agricultural attaché for technical and regulatory affairs at the embassy of France in Washington, DC. He completed graduate studies at the National Superior School of Agronomy in Rennes, France, and an M.S. in food science from Purdue University.

Cynthia Daley, Ph.D., is a professor at the College of Agriculture at California State University, Chico. She currently serves as the Rawlins Endowed Professor for Environmental Literacy Director of the Center for Regenerative Agriculture and Resilient Systems (CRARS) and as the founder of the Organic Dairy Education & Research Program. CRARS is a consortium of interdisciplinary faculty and farmers who recognize the ecological benefits of regenerative farming practices, including water conservation, soil fertility, and carbon sequestration. The center's guiding principle

is that agriculture, when done regeneratively, can be the solution to soil degradation and climate change. Dr. Daley completed an undergraduate degree at the University of Illinois and a doctorate at the University of California, Davis.

Paula Daniels, J.D., is the co-founder and the chair of the Board of the Center for Good Food Purchasing, which uses the power of procurement to create a transparent and equitable food system that prioritizes the health and well-being of people, animals, and the environment. This is accomplished through a national network of large institutions who have adopted and implemented the Good Food Purchasing Program. Thirty-two institutions in 15 cities across the United States are now enrolled in this program, which received a 2018 Future Policy Award from the World Future Council. The center partners with many organizations, including the Food and Agriculture Organization of the United Nations and the International Federation of Organic Agriculture Movements. As a lawyer, Ms. Daniels has held a number of senior positions in government in California, including the senior advisor on food policy to Mayor Villaraigosa of Los Angeles. She has also taught food policy at the University of California, Berkeley; the University of California, Los Angeles; the University of Southern California; and the Vermont Law School. Ms. Daniels earned a J.D. from the Southwestern University School of Law.

Kristie L. Ebi, Ph.D., M.P.H., is a professor in the Department of Global Health at the University of Washington. She conducts research and practice on the health risks of climate variability and change, focusing on understanding sources of vulnerability, estimating current and future health risks of climate change, designing adaptation policies and measures to reduce risks in multistressor environments, and estimating the health co-benefits of mitigation policies. Dr. Ebi has assisted multiple countries in Africa, Asia, Central America, Europe, and the Pacific in assessing their vulnerabilities and implementing adaptation policies and programs. She has been an author on multiple national and international climate change assessments, including the *Fourth National Climate Assessment* and the *Special Report on Global Warming of 1.5* by the Intergovernmental Panel on Climate Change. Dr. Ebi holds an M.S. in toxicology and an M.P.H. and a Ph.D. in epidemiology from the London School of Hygiene & Tropical Medicine, where she also completed 2 years of postgraduate research.

Hildreth England, M.S., R.D.N., is a strategist and a designer at the Massachusetts Institute of Technology (MIT) Media Lab, where she focuses primarily on the strategy and integration of inclusive co-design methodologies. She is also the director of PlusMinus, a smart home system,

and co-chair of the MIT Food and Sustainability Working Group. She is exploring how to recast the technology design process to more equitably and intentionally distribute positive impact, especially with and for society's most marginalized people. As a registered dietitian nutritionist, Ms. England leads participatory design projects that center on diverse and underserved voices in the fields of sustainability, public health, and food and agriculture. Before joining the MIT Media Lab, she spearheaded innovation strategy for Texas WIC (the Special Supplemental Nutrition Program for Women, Infants, and Children), chaired the city of Austin's Sustainable Food Policy Board, and served as the assistant director of the Open Agriculture Initiative at MIT. Her design work has been included in the Triennale di Milano, the Cooper Hewitt Design Triennial, the Barbican Centre, and the Victoria and Albert Museum. Ms. England holds degrees in foreign service from Georgetown University and in nutrition from Texas State University. She was a 2015 fellow of the Masters in Food Innovation Program at the Università degli studi di Modena e Reggio Emilia, Italy.

Kelsey Freeman Saelens, M.S., is the director of federal government relations at Cargill, Inc., a Minnesota-based agribusiness company. She leads Cargill's food and nutrition policy agenda and serves as the lead government relations advisor and a federal lobbyist for Cargill's food ingredient businesses. Prior to coming to Cargill, Ms. Freeman Saelens was Nestlé's manager of corporate and government affairs, leading the company's policy agenda on human rights, global food security, ingredient sourcing, international trade, and health care. She has also worked in government affairs at the National Confectioners Association and was a policy fellow for the Energy and Commerce Committee of the U.S. House of Representatives. Ms. Freeman Saelens holds two degrees from the University of Maryland, College Park, and an M.P.P. from The George Washington University.

Naomi K. Fukagawa, M.D., Ph.D., is the director of the Beltsville Human Nutrition Research Center of the U.S. Department of Agriculture. Previously, she served as a professor of medicine and the acting director of the gerontology unit at the University of Vermont. Dr. Fukagawa is a board-certified pediatrician and an expert in nutritional biochemistry and metabolism, including protein and energy metabolism, oxidants and antioxidants, and the role of diet in aging and chronic diseases such as diabetes mellitus. She has served on numerous review panels for the National Institutes of Health (NIH), served as the chair of the NIH study section for general clinical research centers, and served on the NIH study section on the integrated physiology of obesity and diabetes. Dr. Fukagawa maintains an active research laboratory where she focuses on the impact of environmental stressors (metabolic or physical) on human health. Specifically, she studies the health effects of exposure to

petrodiesel and biodiesel exhaust; the potential of diet to mitigate the adverse effects of environmental stressors; and, while addressing these issues, maintaining adequate food production in an environmentally friendly and sustainable manner. Dr. Fukagawa holds an M.D. from Northwestern University and a Ph.D. from the Massachusetts Institute of Technology.

Catherine L. Kling, Ph.D., is the Tisch University Professor in the Dyson School of Applied Economics and Management and the faculty director at the Atkinson Center for Sustainability at Cornell University. She is the past director of the Center for Agricultural and Rural Development at Iowa State University, where she also held the president's chair in environmental economics. Dr. Kling has published nearly 100 refereed journal articles and book chapters, which have received more than 8,000 citations, and she is the editor of the *Review of Environmental Economics and Policy*. She specializes in the economic valuation of ecosystem services and integrated assessment models for water quality modeling, and she receives support for her research from a wide range of agencies. Dr. Kling chairs the Water Science and Technology Board of the National Academies of Sciences, Engineering, and Medicine and has served on six of its studies. She has also served as the president of the Association of Environmental and Resource Economists, held editorial positions at 10 economics journals, and received 7 awards from professional associations for her research. Dr. Kling is an elected fellow of the Association of Environmental and Resources Economists and the Agricultural & Applied Economics Association, and she is a university fellow at Resources for the Future. She served for 10 years on the Science Advisory Board of the U.S. Environmental Protection Agency. Dr. Kling holds a Ph.D. from the University of Maryland.

Matt Liebman, Ph.D., is a professor of agronomy and the Henry A. Wallace Endowed Chair for Sustainable Agriculture at Iowa State University. Prior to this position, he was on the faculty at the University of Maine. Dr. Liebman is a fellow of the American Society of Agronomy, and he served on the committee of the Institute of Medicine and National Research Council that produced the 2015 report *A Framework for Assessing Effects of the Food System*. He is also a member of the board of directors for Wheatsfield Cooperative Grocery in Ames, Iowa. Dr. Liebman's research, teaching, and outreach activities focus on ways to improve environmental quality and agricultural productivity while reducing dependence on agrichemicals and fossil fuels. His specific interests include diversified cropping systems; weed ecology and management; and the use of native prairie species for biofuel production and soil, water, and wildlife conservation. Dr. Liebman holds an A.B. in biological sciences from Harvard University and a Ph.D. in botany from the University of California, Berkeley.

D. Julian McClements, Ph.D., is a Distinguished Professor in the Department of Food Science at the University of Massachusetts Amherst. He specializes in the areas of food biopolymers and colloids, particularly the development of food-based structured delivery systems for bioactive components. Dr. McClements is the author of numerous books, including *Future Foods: How Modern Science Is Transforming the Way We Eat*; three editions of *Food Emulsions: Principles, Practices, and Techniques*; and *Nanoparticle- and Microparticle-Based Delivery Systems: Encapsulation, Protection and Release of Active Compounds*. In addition, he has published more than 1,000 scientific articles in peer-reviewed journals, as well as numerous book chapters and conference proceedings, and he holds 12 patents. Dr. McClements has received awards in recognition of his scientific achievements from the American Chemical Society, the American Oil Chemists' Society, the Society of Chemical Industry, the Institute of Food Technologists, and the University of Massachusetts. He is a fellow of the Royal Society of Chemistry, the American Chemical Society (Agricultural and Food Division), and the Institute of Food Technologists. Dr. McClements's research has been funded by the U.S. Department of Agriculture, the National Science Foundation, the U.S. Department of Commerce, the National Aeronautics and Space Administration, and the food industry. He completed a Ph.D. in food science at the University of Leeds, United Kingdom, and postdoctoral research at the University of Leeds; the University of California, Davis; and the University College Cork, Ireland.

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Christian Peters, Ph.D., M.S., is an associate professor at the Friedman School of Nutrition Science and Policy at Tufts University. He teaches in the agriculture, food, and environment program, offering courses in agricultural science and policy and in food systems modeling. Dr. Peters studies the sustainability of food systems using computational modeling and interdisciplinary research. He is interested in understanding how dietary patterns influence sustainability, how much food can be supplied through locally and regionally scaled systems, and how transdisciplinary approaches can help design and study such systems. Dr. Peters is engaged in multiple collaborative research projects on regional food systems and sustainable diets. Some of his best known work includes the development of a framework for estimating the land requirements of diets and human carrying capacity and a spatial modeling approach for mapping potential foodsheds. Dr. Peters holds a B.S. in environmental sciences from Rutgers University and an M.S. and a Ph.D. in soil and crop sciences from Cornell University.

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Ricardo Salvador, Ph.D., M.S., is the director and the senior scientist for the Food and Environment Program of the Union of Concerned Scientists. He began his career with the Texas A&M University Extension Service and later joined the agronomy faculty at Iowa State University (ISU). At ISU, Dr. Salvador helped establish the first graduate program in sustainable agriculture in the United States, which he chaired. Subsequently, he was the program officer for food, health, and well-being at the W.K. Kellogg Foundation. Dr. Salvador earned an undergraduate degree in agricultural science from New Mexico State University and an M.S. and a Ph.D. in crop production and physiology from Iowa State University.

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