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A National Strategy to **REDUCE FOOD WASTE** at the Consumer Level

Barbara O. Schneeman and Maria Oria, *Editors*

Committee on a Systems Approach to Reducing Consumer Food Waste

Board on Environmental Change and Society
Division of Behavioral and Social Sciences and Education

Food and Nutrition Board
Health and Medicine Division

A Consensus Study Report of

The National Academies of
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Reviewers

This Consensus Study Report 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 report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report:

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Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by **MAXINE L. SAVITZ**, retired, Honeywell, Inc., and **CATHERINE E. WOTEKI,** Iowa State University. They were responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

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Preface

Food waste occurs in multiple segments of the food supply chain; the focus of this report is on the segment comprising food wasted at the consumer level—food that was intended for human consumption but was discarded by consumers. A widely used statistic indicates that this wasted food accounts for one-third of all food purchased by consumers, yet, most consumers are not able to estimate their amount of wasted food or are likely to underestimate their amount. This waste is obviously associated with an economic cost to households, but also has environmental and social costs that may be less visible to many consumers.

Although the behavior of individuals is seen as the source of wasted food, that behavior is a consequence of various factors within the food system that, through their interactions, result in waste. Understanding what leads to this loss of usable food requires understanding the factors in the food system that impact an individual's personal behavior and facilitate this waste. In particular, wasting food is accepted within the current food system. This report, then, poses the question of how the food system could be modified to change attitudes and habits and motivate consumers to reduce the amount of food they waste. To address this question, it was necessary to look beyond what happens at the household level to the drivers that result in the overacquisition of food and the choice of highly perishable foods rather than nutritionally equivalent shelf-stable options. These behaviors have consequences for decisions about storage of food, handling leftovers, and timing for utilization of perishable items among many other household decisions that can result in waste. Understanding these drivers depends

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in turn on probing the factors underlying these behaviors, which include perceptions of wasted food at the household level; economic factors; and food literacy, such as knowledge about food safety, the prevalence of food myths, and information on appropriate food preparation and storage. At the consumer level, food is likely to be wasted if excess food purchases spoil or perish before they can be used, do not match food preferences, or consist of items consumers do not have the skills to prepare. In contrast, there are ways to reduce what might be wasted, such as using more shelf-stable food items (e.g., frozen or canned fruits and vegetables), improved technology for storage of food items, or food service operators creating alternative mechanisms for distributing food inventory that cannot be used as originally planned.

The COVID-19 pandemic emerged as the committee was finalizing this report. We realized that the evolving situation associated with this crisis illustrates many of the strengths and vulnerabilities of the current food system that impact the issue of food waste. Food has been lost before reaching the consumer as a result of disruptions in the transportation system, the food service sector, and the labor force responsible for food production and processing, as well as the loss of income for many households. These disruptions have resulted in the destruction of crops and other commodities because they cannot be harvested and utilized as well as food distribution systems that were not prepared for the rapid changes in utilization by various sectors. It is the committee's hope that lessons learned about the management of food availability during the pandemic can be used by those to whom the recommendations in this report are addressed and that this time also constitutes a teachable moment that provides opportunities to change behavior. For example, media articles on understanding date labels have been published to help consumers avoid wasting safe, usable food based on those labels alone, and the crisis has given many households the opportunity to be more in touch with food and develop a better understanding of its use and household preferences. Such awareness can be a step toward reducing food waste. Although some might argue that the issue of wasted food has reduced importance during this crisis, the economic cost of such waste to consumers should not be ignored. Although the recommendations in this report were not developed to respond specifically to this crisis, they can be helpful in reducing this cost to consumers.

In developing this report, the committee was challenged by the limited availability of evidence-based strategies for reducing food waste. These existing strategies are focused primarily on building awareness and motivation so as to increase intent to reduce food waste rather than providing consumers with the opportunity and ability to change their behavior with respect to wasted food. However, initiatives to change consumer behavior in diverse areas ranging from energy and water conservation to weight

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management provided the committee with insight into the elements of effective strategies. By leveraging this total knowledge base, it is possible to design and evaluate promising strategies; however, monitoring and long-term evaluation will be necessary to learn what is effective and why.

The committee's conclusions and recommendations are not targeted simply at consumers but encompass the importance of action by multiple stakeholders, including government at all levels, nongovernmental organizations, commercial entities, nonprofit organizations, volunteer organizations, educational institutions at all levels, and foundations. Actions taken by these various stakeholders can give consumers the motivation, opportunity, and ability to reduce food waste. The report highlights the federal initiative Winning on Reducing Food Waste because certain coordinating activities are essential to catalyze efforts at other levels within the system. At the same time, however, it is abundantly clear that to be effective, programs must be tailored to local or regional conditions; accordingly, each of the pathways discussed in the report identifies roles for actors at all levels. By recognizing the importance of all of these stakeholders, the report illustrates addressing food waste at the consumer level, requires considering all the factors within the food system that result in such waste to identify solutions that can give consumers the motivation, ability, and opportunity to reduce this waste at the household level.

In developing this report, the committee received valuable input and outstanding support from several sources. We benefited from the information and insights presented at our public meetings and appreciate the participation of numerous presenters in these sessions (more detailed information on the presenters can be found in Appendix A). We were assisted by the very able work of Maria Oria (senior program officer, Food and Nutrition Board, National Academies of Sciences, Engineering, and Medicine), who was instrumental in the management and development of the report; Alice Vorosmarti (associate program officer, Food and Nutrition Board), who carefully amassed the articles, reports, and related resources that the committee accessed for its work; Tina Latimer (senior program assistant, Board on Environmental Change and Society [BECS], National Academies), who helped with all logistical needs, Jose Mendoza-Torres (senior librarian, National Academies), who conducted in-depth literature searches; Alexandra Beatty (senior program officer, Division of Behavioral and Social Sciences and Education [DBASSE], National Academies), who improved the organization and formatting of the report; Toby Warden (board director, BECS, National Academies) and Monica Feit (deputy executive director, DBASSE), who provided valuable input on managing and completing the committee's statement of task; and Ann Yaktine (director, Food and Nutrition Board) for her support for and encouragement of this project. We also wish to express our appreciation to the study sponsors, the Walmart

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Foundation and the Foundation for Food and Agriculture Research, for their foresight in understanding the importance of this topic in the context of the food system.

Finally, as chair of the committee, I am personally grateful to my fellow committee members for their commitment to the committee's work, including analysis of a large volume of material, and for their insight as to how this information could be used to develop a strategy that would respond to the committee's statement of task within a demanding time line. By exhibiting respect for the opinions of their fellow committee members, working to find common ground, and providing constructive input on drafts, they have developed a strategy, documented in this report, that reflects the analysis and insights of the committee as a whole. It has been a pleasure to work with and learn from the entire group.

Barbara O. Schneeman, *Chair*
Committee on a Systems Approach to Reducing Consumer Food Waste

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Summary

Approximately 30 percent of the edible food produced in the United States is wasted and a significant portion of this waste occurs at the consumer level. Despite food's essential role as a source of nutrients and energy and its emotional and cultural importance, U.S. consumers waste an estimated average of 1 pound of food per person per day at home and in places where they buy and consume food away from home. Many factors contribute to this waste—consumers behaviors are shaped not only by individual and interpersonal factors but also by influences within the food system, such as policies, food marketing, and the media. Some food waste is unavoidable, and there is substantial variation in how food waste and its impacts are defined and measured. But there is no doubt that the consequences of food waste are severe: the wasting of food is costly to consumers, depletes natural resources, and degrades the environment. In addition, at a time when the COVID-19 pandemic has severely strained the U.S. economy and sharply increased food insecurity, it is predicted that food waste will worsen in the short term because of both supply chain disruptions and the closures of food businesses, which affect the way people eat and the types of food they can afford.

Many factors influence food waste in the United States. Researchers, nongovernmental organizations, federal agencies, and others have focused on reducing food waste, yet relatively little attention and coordination have focused on supporting the consumer in reducing food waste. To build on what has been learned, the Walmart Foundation and the Foundation for

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Food and Agriculture Research (FFAR)[1] provided funding to the National Academies of Sciences, Engineering, and Medicine to conduct a consensus study of ways to reduce U.S. food waste at the consumer level.

To carry out this study, the National Academies convened the Committee on a Systems Approach to Reducing Consumer Food Waste, whose members brought expertise in food waste, psychology and marketing, sociology, public health, nutrition, behavioral economics, food systems, urban planning, intervention design, and implementation science. The committee was charged with reviewing pertinent research from the social and behavioral sciences; identifying strategies for changing consumer behavior, taking into account interactions and feedbacks within the food system; and developing a strategy for addressing the challenge of reducing food waste at the consumer level from a holistic, systems perspective.

The committee explored the reasons food is wasted in the United States, including the characteristics of the complex systems through which food is produced, marketed, and sold, as well as the many other interconnected influences on consumers' conscious and unconscious choices about purchasing, preparing, consuming, storing, and discarding food. Based on its review of evidence about what drives consumer behaviors and the efficacy of interventions designed to alter those behaviors, the committee identified a strategy for reducing food waste at the consumer level, as well as the research needed to support this strategy and future progress. The dramatic effects of COVID-19 on food supply chain operations and consumers' behaviors may exacerbate many problems associated with food waste, and also present new opportunities; the strategy presented here is broad and adaptable to changing circumstances.

FOUNDATION FOR THE STRATEGY

The body of research that specifically addresses consumer food waste is limited and emerging, so the committee also considered evidence from the study of consumer behavior and ways to shape it in six related domains (energy saving, recycling, water use conservation, waste prevention, diet change, and weight management). This work draws on diverse disciplines (e.g. food science and nutrition, public health, behavioral economics, marketing, sociology, social psychology), and researchers have proposed models and frameworks to explain consumer behavior, some of which have been applied to the study of food waste. The committee identified one of these, the *motivation-opportunity-ability (MOA)* framework, as especially useful

[1] The Walmart Foundation and FFAR made a presentation to the committee at its first meeting about the study charge and their perspectives on the need for the study. They had no other discussions with the committee throughout the study process.

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for identifying and analyzing individual behavioral drivers while also taking into account the importance of context[2] and habit in driving behavior.

The MOA framework posits that consumers are most likely to act in a particular way when they not only are motivated to do so but also have the ability and opportunity to act on that motivation. This framework proved useful to the committee in understanding how interactions among multiple drivers—including not only individual-level factors but also the actions of others, such as retailers, other food providers, and policy makers—affect how consumers acquire, consume, store, and dispose of food. The framework was also useful for integrating current knowledge about drivers with insights from the research on interventions.

Drivers of Consumer Behavior

Research on specific drivers of food waste at the consumer level is still emerging, but, particularly when considered in light of lessons from research in other domains, it offers some promising insights. Consumer behaviors regarding food acquisition, consumption, storage, and disposal are complex; depend on context; and are driven by multiple individual, sociocultural, and material factors within and outside the food system that interact to produce food waste. Thus, reducing wasted food at the consumer level will require strategies that consider the interactions between consumers' motivation to change behaviors and their ability and opportunity to change them through both reflective and automatic processes. Although the available evidence base does not yet support prioritization of particular targets for reducing food waste at the consumer level, it does indicate that the 11 categories of drivers listed in Box S-1 show promise as the basis for interventions.

Interventions to Alter Consumer Behavior

Interventions that address the wasting of food at the consumer level have been studied, but the research on these efforts is still relatively new and focuses primarily on increasing motivation rather than increasing ability or opportunity. Research to date does not yet provide the highest level of support for widespread adoption of specific interventions in multiple contexts. Nevertheless, the committee found evidence suggesting that that the approaches listed in Table S-1 are promising and merit further investigation. The committee urges caution in extrapolating to generalized statements about these interventions, both because the efficacy and effectiveness of any intervention will depend on it being well designed, tailored to the context, and well implemented, and because of the importance of considering the elements of the MOA framework.

[2] Context refers to the circumstances, conditions, or objects by which one is surrounded.

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BOX S-1
Categories of Drivers of Consumer Food Waste

Food waste is driven by

A. consumers' knowledge, skills, and tools;
B. consumers' capacity to assess risks associated with food waste;
C. consumers' goals with respect to food and nutrition;
D. consumers' recognition and monitoring of their food waste;
E. consumers' psychological distance from food production and disposal;
F. heterogeneity of consumers' food preferences and diets;
G. the convenience or inconvenience of reducing food waste as part of daily activities;
H. marketing practices and tactics that shape consumers' food behaviors;
I. psychosocial and identity-related norms related to food consumption and waste;
J. factors in the built environment (including in household and retail environments) and the food supply chain; and
K. policies and regulations at all levels of government.

TABLE S-1 Types of Interventions and Examples with Evidence (Tier 1 Studies) and Suggestive Evidence (Tier 2 Studies) of Efficacy in Reducing Food Waste[a,b]

Intervention	Examples
Appeals	With evidence: • Delivering materials with appeal combined with other messaging intervention types (such as information, feedback) direct to residents • Providing food systems education to students and having them contribute to the design of a poster with an appeal message • Sharing information about harms of food waste • Requesting diners to reduce portions, take less food, or take more trips to the buffet With suggestive evidence: • Using a self-affirmation intervention to increase receptivity to food waste prevention messages • Displaying posters encouraging university diners not to take food they would not eat • Displaying posters triggering negative social emotions associated with wasting • Linking altruistic or virtue messages with waste prevention

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TABLE S-1 Continued

Intervention	Examples
Engagement	With evidence: • Engaging schoolteachers and students through curriculum and related projects to deepen understanding of and personal commitment to reducing food waste • Engaging food service workers, managers, and patrons to deepen understanding of the magnitude and consequences of food waste and to jointly develop solutions customized to their food service setting
Social Comparisons	With suggestive evidence: • Using social interactions and shared values to promote waste reduction among multiple partners in community • Reducing the social stigma of requesting a box for restaurant leftovers by having the server offer it • Using public commitments as a way to be accountable • Using public demonstrations of results through such interventions as bin cameras
Feedback	With suggestive evidence: • Providing personalized feedback about the success of waste reduction efforts as part of a broader set of intervention strategies
Financial	With evidence: • Paying more as more waste is discarded from the home With suggestive evidence: • Offering price discounts on suboptimal food • Removing discounts for bulk or multiunit purchases
Nudges	With evidence: • Reducing food quantities in buffet settings through the use of smaller plates, smaller portions, or tray removal • Switching serveware from paper to plastic plates • Increasing consumers' psychological ownership of food With suggestive evidence: • Increasing food's appeal through changes in meal quality and timing • Removing date labels • Setting appropriate refrigerator temperatures

continued

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A National Strategy to Reduce Food Waste at the Consumer Level

TABLE S-1 Continued

Intervention	Examples
Information	With evidence: • Conducting campaigns that provide booklets, refrigerator magnets, informational emails sent directly to participants in home or school settings, generally used as part of a multifaceted intervention combined with appeal or feedback interventions • The above plus providing food storage containers With suggestive evidence: • Tailoring information to respondent needs • Conducting small, intensive workshops • Asking participants to read a single article about food waste • Publicly sharing information through such means as posters, recipes, in-store cooking demonstrations, and social media as part of a multifaceted campaign • Conducting national campaigns providing information and skills to reduce food waste

[a]Tier 1 studies met criteria: an intervention was implemented, wasted food was measured, causal effect can be attributed, and statistical analysis was adequate. Tier 2 studies failed to meet at least one of those criteria.

[b]The committee urges caution in extrapolating the information in this table to generalized statements about the efficacy and effectiveness of these interventions, which will depend on many other factors.

Although the research does not point directly to interventions that can be implemented with confidence across contexts and populations, it does offer important lessons that can be used in the tailoring of interventions to particular needs. For example, consideration of how a particular driver (e.g., psychological distancing) is likely to influence food waste (e.g., by affecting motivation) and the cognitive processes it activates (e.g., reflective or automatic processing) offers clues about other drivers that may also be at work in a given context and, therefore, where to focus intervention efforts. It is also essential to integrate plans for implementation and evaluation into the process of designing an intervention.

Research from the six related domains offers additional insights that have not yet been assessed in the context of reducing consumer food waste but are likely to be useful to designers of food waste reduction interventions:

- Multifaceted interventions that take advantage of more than one mechanism may be more effective than a single intervention alone.
- Characteristics of the context in which a behavior is occurring influence, and may override, other drivers.

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- It is critical to understand the cognitive processes, which fall on a continuum ranging from reflective to semireflective to automatic, involved in the behaviors an intervention is intended to modify. Identifying and understanding habitual behaviors is also critical to designing any intervention.

A STRATEGY FOR REDUCING FOOD WASTE AT THE CONSUMER LEVEL

The strategy the committee proposes builds on the efforts of the many stakeholders that are already engaged in efforts to reduce consumer food waste. The strategy identifies three primary pathways to changing consumer behavior and includes recommendations about the responsibilities of the various partners whose participation will be necessary to this coordinated effort to reduce food waste at the consumer level. The three pathways are

1. changing the U.S. food environment to discourage waste by consumers;
2. strengthening consumers' motivation, opportunity, and ability to reduce food waste; and
3. leveraging and applying research findings and technology to support consumers in food waste reduction.

Pathway 1: Change the U.S. Food Environment to Discourage Waste by Consumers

Implement change and innovation in the food industry.

RECOMMENDATION 1: Food trade associations and their joint alliances (e.g., the Food Waste Reduction Alliance, the National Restaurant Association, FMI-The Food Industry Association, the Consumers Brand Association, and smaller food trade associations) and nonprofit organizations should expand their efforts to reduce food waste by convening an ongoing public–private–academic forum with the goal of coordinating industry efforts. Specifically, this forum should

- assist association members in pursuing evidence-based best practices and interventions to reduce food waste at the consumer level, providing regularly updated written guidance and consultation services;
- encourage association members to evaluate their food waste reduction efforts and publish their findings, and provide tools and assistance for these purposes;

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- develop materials to inform members about the impacts of food waste and to characterize the business case, in terms of costs and benefits, of food waste reduction practices;
- support and participate in relevant research;
- create communities of practice in which members can share innovations and lessons learned; and
- work with third-party certifying organizations to include practices that reduce food waste at the consumer level as criteria in their environmental standards, and to encourage members to meet those standards.

RECOMMENDATION 2: With guidance from their food trade associations, manufacturers, retailers, and food service venues should

- develop promotions and other in-store cues that prioritize acquisition of the optimal amount and variety (including frozen, shelf-stable, and perishable) of products rather than prompting overacquisition; and
- implement and evaluate evidence-based strategies that help reduce consumer food waste by combining elements—including presentation of food (amount and variety) to reduce overacquisition and communications targeting consumers—that increase consumers' motivation, opportunity, and ability to alter wasteful behaviors.

Include food waste reduction in industry certification.

RECOMMENDATION 3: The International Organization for Standardization, the Green Restaurant Association, the U.S. Green Building Council, and other organizations in charge of developing environmental standards for businesses should include practices that reduce food waste at the consumer level as criteria in those standards, and encourage food businesses to modify their practices to meet those criteria.

Develop and harmonize sensible date labeling.

RECOMMENDATION 4: Food industry trade associations, consumer organizations, and other nonprofit organizations should coordinate and advocate for the passage of federal legislation to harmonize the language and standards for use of date labels for packaged food sold in the United States. They should also coordinate efforts to educate the public about the information provided on date labels and how they can use that information to ensure that they neither consume unsafe food nor waste safe food.

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Implement state and local policies encouraging behaviors that prevent food waste.

RECOMMENDATION 5: State and local governments should institute policies that reduce the discarding of wasted food. Such policies include (but are not limited to) fees for the removal of municipal solid waste per unit of waste and mandatory organic recycling practices, such as composting. These policies should be integrated with related policies (e.g., on recycling, food recovery), such as those to reduce environmental impact or promote equity-related outcomes.

RECOMMENDATION 6: The Environmental Protection Agency and nongovernmental entities, such as foundations, should support local jurisdictions and states in developing and instituting policies that discourage the discarding of edible food. Actions to this end include providing research, tools, and information and investing in partnerships and forums (e.g., social innovation labs) that bring key stakeholders together to develop feasible interventions that are acceptable to the affected communities.

Pathway 2: Strengthen Consumers' Motivation, Opportunity, and Ability to Reduce Food Waste

Conduct a national behavior change campaign.

RECOMMENDATION 7: As part of the federal Winning on Reducing Food Waste Initiative, the U.S. Department of Agriculture, the Environmental Protection Agency, and the Food and Drug Administration should lead the development of a centralized platform for a behavior change campaign. This campaign should be designed both to inform the public about the environmental, economic, and social benefits of reducing food waste and tools and strategies for reducing their own waste, and to address nonconscious drivers of food waste, as well as consumers' ability and opportunity to change wasteful behavior. This platform should be designed to stimulate, guide, and support current efforts at the state and local levels and those led by nongovernmental entities. The platform should incorporate the following elements

- provide resources and easy, everyday tips for reducing food waste;
- make use of a variety of traditional (e.g., books, website, apps) and new (e.g., short media content bursts, short sound bites, multimedia, gamification, refrigerator magnets) tools and tactics;
- use positive messaging;

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- provide multiple cues at the food acquisition, consumption, and disposal stages;
- focus on reaching consumers during "teachable moments";
- use social science research, particularly as related to norms and consumers' psychological distance from food and food production;
- deliver short, intense, and frequent action ideas and nudges;
- include components and mechanisms that are culturally relevant to various settings and populations, such as food service employees, retail food establishments, students, workplaces, grocery shoppers, and general consumers;
- include provisions for rigorous evaluation of effectiveness and reward for behavior change;
- urge stakeholders to alter social and economic contexts to provide opportunities for behavior change; and
- spur influencers to help alter norms and amplify messages.

Spread and amplify messages about food waste through influencers.

RECOMMENDATION 8: Professional (e.g., the Culinary Institute of America, the Institute of Food Technologists, the Academy of Nutrition and Dietetics) and community organizations should work with their memberships and with influencers, such as dietitians, state extension specialists, recipe providers, cooking show hosts, chefs, and social media personalities, to promote the use of their platforms to advance consistent food literacy information, provide evidence-based guidance about optimizing the consumption of food and minimizing waste, and help shift social norms by providing information about the positive effects of supporting consumers in reducing waste.

Include instruction and experiential learning about food literacy in education curricula.

RECOMMENDATION 9: Nongovernment organizations (e.g., the World Wildlife Fund) should engage with other appropriate entities (e.g., state departments of education, U.S. Department of Agriculture's Food and Nutrition Service, foundations) in concerted, coordinated efforts to provide K–12, postsecondary, and secondary institutions with appropriate tools and resources and promote their use in instruction and hands-on learning about the social, environmental, and economic impacts of food waste and ways to reduce it.

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Pathway 3: Leverage and Apply Research Findings and Technology to Support Consumers in Food Waste Reduction

Support research and technology.

RECOMMENDATION 10:[3] Government agencies at all levels and relevant foundations concerned with the problem of food waste should support the proposed food waste reduction strategy by investing in

- research to develop methods for measuring food waste at the consumer level, including the collection of data on food waste, both aggregated and by type of food, and reasons for wasting food in the United States, as part of an overall effort to measure food waste at the national level;
- research and pilot studies that are adequately designed to evaluate interventions for reducing consumer-level food waste and both the intended and unintended outcomes of those interventions, and are integrated with implementation plans;
- training in intervention evaluation and implementation planning for appropriate staff of community-based organizations and graduate students through, for example, an evaluation institute; and
- dissemination of information about the efficacy and effectiveness of interventions, including detailed descriptions of the intervention design and implementation.

Coordination and Partnership in Pursuit of the Three Pathways

The overarching goal of the committee's proposed strategy is to create and sustain a broad societal commitment to reducing food waste. Leadership and financial support from the federal level will be necessary to stimulate and coordinate the efforts of the multiple stakeholders involved and to support the transition from a society in which attitudes and habits facilitate the wasting of food to one in which the consumption and management of food consistently reflect its value and importance. The improved coordination and cross-sectoral discussions fostered by the new initiative could have multiplier effects and advance solutions and innovations rapidly.

[3] This text was revised for clarification since the prepublication release: "food waste reduction initiative" has been changed to "proposed food waste reduction strategy" to refer to the broad, national food waste reduction strategy recommended by the committee, so as not to be confused with the Winning on Reducing Food Waste Initiative. The Winning on Reducing Food Waste Initiative is an existing collaboration of the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, and the U.S. Food and Drug Administration and is referenced directly in Recommendation 11.

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RECOMMENDATION 11: The U.S. Department of Agriculture, the Environmental Protection Agency, and the Food and Drug Administration should expand the Winning on Reducing Food Waste Initiative by coordinating with key stakeholders at multiple levels and across societal sectors, including state and local governments, nonprofit organizations, foundations, industry leaders, food producers, and others, in efforts to reduce food waste at the consumer level. The federally sponsored initiative should

- be the locus of practical information for the consumer and guidance on the evaluation and implementation of interventions to be disseminated by initiative partners;
- support the development and management of a public clearinghouse for sharing information on current research and evaluation data and on funding opportunities relevant to researchers, funders, policy makers, social marketers, and other stakeholders;
- support research-based interventions that take into account consumers' motivation, opportunity, and ability to reduce food waste and apply lessons from behavioral change disciplines; and
- work with others in resolving technical challenges, including by developing and publishing standard terminology for research and practice related to food waste.

Table S-2 provides an overview of the potential contributions that stakeholders would make to the committee's proposed coordinated food waste reduction strategy.

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TABLE S-2 Potential Contributions of Partners in the Committee's Strategy

Partner	Example Contributions
Federal agencies	• Coordinate efforts encompassed by the Winning on Reducing Food Waste Initiative • Provide resources for collaboration and coordination with a broad group of stakeholders (e.g., state and local governments, corporations, academic institutions, foundations) • Develop evaluation and implementation guidelines • Coordinate and fund a national behavioral change campaign, and provide relevant stakeholders and the public with tools and strategies for reducing food waste • Provide research, adaptable tools, and information to state and local entities • Coordinate and provide support for research and for a clearinghouse for sharing information and resources • Where federal agencies have jurisdiction over institutional procurement, support initiatives aimed at reducing consumer food waste
State and local government	• Coordinate efforts with respect to food waste among agencies • Provide funding to support food waste reduction efforts • Adapt and disseminate the national behavioral change campaign • Provide the public, businesses, and institutions with resources and easy everyday tips for reducing food waste • Encourage and support changes to the built environment and to food marketing that help reduce food waste • Establish and evaluate policies that encourage reduction of food waste behaviors, such as pay-as-you-throw disposal fees, and integrate them with other relevant policies • Coordinate efforts to provide schools, universities, and other educational institutions with appropriate tools and to promote the inclusion of food literacy and associated practical opportunities in curricula • Where state governments have jurisdiction over schools or institutional procurement, support initiatives aimed at reducing consumer food waste

continued

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TABLE S-2 Continued

Partner	Example Contributions
Manufacturers, retailers, and marketers	• Provide evidence-based food safety and other information to help consumers reduce food waste • Use evidence-based guidance to develop and offer promotions that may reduce food waste, including prioritizing acquisition of the optimal amount and variety (including frozen, shelf-stable, and perishable) of foods rather than stimulating overacquisition, with the goal of helping consumers improve their decision making in ways that are likely to reduce food waste • Develop and offer in-store cues that activate unconscious behaviors that prioritize acquisition of the right amount and variety (frozen, shelf-stable, and perishable) of foods rather than large quantities • Work with researchers to evaluate impacts and potential unintended consequences of interventions to reduce consumer food waste
Food producers and the agriculture sector	• Inform consumers about the impacts of food waste, and provide tips to help them reduce such waste • Reach out to consumers with the goal of reducing their physical and psychological distance from food and food production
Restaurants and other food service providers (e.g., cafeterias at workplaces)	• Use evidence-based guidance to design, implement, and tailor interventions to reduce consumer food waste—for example, optimize portions and number of options offered; redesign menus and food presentation, such as buffets; stop using trays; encourage taking a sample helping and returning for more if desired; provide containers for leftovers; and provide tips for consumers on how to reduce food waste • Work with researchers to evaluate impacts and potential unintended consequences of interventions to reduce consumer food waste
Food industry organizations (e.g., National Restaurant Association, FMI-The Food Industry Association, Food Waste Reduction Alliance, Consumers Brand Association)	• Engage with the Winning on Reducing Food Waste Initiative to coordinate efforts and use consistent methods, approaches, and terminology, and support evidence-based best practices for reducing food waste at the consumer level by providing regularly updated written guidance, consultation services, and tools to the relevant industries • Encourage businesses to evaluate their efforts and provide tools, funds, and connections to researchers for this purpose • Develop materials for campaigns aimed at specific sectors to educate the business community about costs and benefits of these activities • Create communities of practice to support sharing of innovations and lessons learned

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TABLE S-2 Continued

Partner	Example Contributions
International Organization for Standardization and other standards organizations	• Include practices that reduce food waste at the consumer level as criteria in environmental management systems or other standards for food businesses
Nongovernmental organizations	• Develop/support the development of guidelines, tools, and best practices to reduce food waste at the consumer level • Support and conduct relevant research • Continue to support with guidelines and information innovators, industries, and institutions that provide food through such channels as cafeterias in schools, universities, and workplaces • Engage with the Winning on Food Waste Initiative and others to develop consistent measures, methods, interventions, and terminology
Professional associations (e.g., the Culinary Institute of America, the Institute of Food Technologists, the Academy of Nutrition and Dietetics)	• Work with their memberships to promote the use of their platforms to advance consistent food literacy information, including evidence-based guidance to help people optimize the consumption of food and minimize its discarding, and help shift social norms by providing information about the effects of wasting food
Influencers (e.g., recipe providers, cooking show hosts, chefs, social media personalities), extension specialists, consumer organizations, community leaders, and other educators	• Assist in disseminating guidance about food waste prevention from the Winning on Reducing Food Waste Initiative, advancing consistent food literacy information, including evidence-based guidance to help people optimize the consumption of food and minimize its discarding • Help shift social norms by providing information about the effects of wasting food
Schools, colleges, and universities	• Implement interventions that can help students and staff reduce food waste
Innovators (e.g., developers of software and apps)	• Improve existing technologies and create new ones (e.g., features of the built environment, appliances, apps) to help consumers with reducing food waste

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Partner	Example Contributions
Foundations	• Invest in research to advance measurement of food waste at the consumer level and study of the drivers of food waste behavior and mechanisms for changing that behavior • Support food waste reduction programs/resources • Require and provide resources for evaluations in funded projects, and ensure that funded interventions are building on best practices and evidence rather than reinventing approaches
Researchers and academic institutions	• Produce research to support future innovations and build the knowledge base on drivers of consumer behavior and on best practices for interventions to change that behavior

Effective implementation of research-based interventions is an ongoing process that requires evaluation, adaptation to local conditions, and often design modification. The government partners and others who contribute funding for elements of the proposed food waste reduction strategy can ensure that systematic evaluation is built into the effort.

RECOMMENDATION 12: Government agencies and others who fund interventions pursued as part of the proposed strategy to reduce food waste at the consumer level, as well as developers of state and local policies and regulations, should require that the effects of an intervention, policy, or regulation on reducing food waste and increasing consumer capacity to reduce food waste, as well as on other elements of the food system and issues beyond food waste, be evaluated. The results of this evaluation should be peer-reviewed and made available to researchers and the public.

RESEARCH TO SUPPORT INTERVENTIONS AND THEIR IMPLEMENTATION

To sustain the strategy proposed by the committee, ongoing work will be needed to address significant gaps in the knowledge base related to two distinct but interconnected areas: (1) understanding drivers of consumer behavior and best practices for interventions to change that behavior, and (2) understanding how promising interventions can be implemented effectively.

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Understanding Drivers of Consumer Behavior and Interventions to Change that Behavior

With respect to the drivers of consumer behaviors related to food waste, the committee highlights the need to expand understanding of consumers and the context for the distribution of food in the United States. Research targets in this area include

- consumer segmentation regarding food waste behaviors and attitudes so that interventions can be targeted;
- assessment of the benefits of reducing food waste for the different sectors of the food industry so those benefits can be communicated to industry leaders and relevant staff;
- identification of gaps in food literacy by population groups and settings so communication and education approaches related to food waste can be tailored and designed to be more effective; and
- understanding of the rapidly changing food industry, particularly supply chain disruptions induced by the COVID-19 pandemic and how the pandemic is affecting food-related behaviors and other outcomes.

It will also be valuable to expand the focus of research beyond the individual consumer. The literature has not yet fully explored drivers of behavior that operate across contexts outside the household, for example, or how behaviors and attitudes related to food waste translate across contexts such as home, restaurants, and work. The committee also believes that more studies of causal, correlational, and intervening drivers and their interplay are needed.

With respect to interventions, the committee noted multiple examples of interventions with promising results that can be further tested across contexts and scales, with rigorous methods, to identify best practices. Future progress in this research area can be supported by

- more long-term follow-up studies;
- studies that include appropriate control groups and other design elements that support robust causal inferences and measurement of waste, rather than intentions to reduce waste;
- integration of the development of intervention and implementation strategies;
- further modeling research, other systems-oriented studies including methods for understanding multifaceted interventions, and qualitative studies; and

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- expansion of the research base to encompass diverse population groups, particularly low-income communities, and diverse contexts and different scales.

Understanding How Promising Interventions Can Be Implemented Effectively

Implementation of interventions identified as promising requires careful attention not only to unexpected outcomes but also to such factors as feasibility, capacity, fidelity to the intervention design, cost, and appropriateness to the settings in which the intervention will be implemented. Many of the food waste interventions that have been studied have demonstrated efficacy in experimental settings. However, few of these promising interventions have been evaluated systematically for effectiveness in real-world and large-scale applications. Interventions that demonstrate high levels of efficacy and effectiveness are needed to significantly reduce consumer food waste. Translational research is needed to apply frameworks, methods, and existing evidence from implementation research to food waste initiatives. Research that integrates intervention development with implementation research is needed to identify and refine the most promising approaches so they can be put into practice at broad enough scale to have meaningful effects.

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1

Introduction

Food is both essential to life, providing vital nutrients and energy, and a source of pleasure and emotional sustenance. It has symbolic associations with love, comfort, stress reduction, security, rewards, cultural expression, creativity, and power. Food choices are influenced by a lifetime of individual and social experiences. Food and eating behaviors are often set in childhood and can be closely tied to family and cultural traditions and norms.

Despite its importance, however, people waste a significant amount of food, and the problem is growing. Hall and colleagues (2009) estimated that the amount of food wasted per capita in the United States had increased approximately 50 percent since 1974. Globally, one-third (1.3 billion tons) of food produced for human consumption is lost or wasted each year (Gustavsson et al., 2011), at a cost of approximately $1 trillion (FAO, 2014). By one estimate, (based on measures of food waste in the municipal solid waste stream) across the U.S. food supply chain, from agriculture to consumption, approximately 40 to 60 million tons of food, both edible and inedible, is wasted (EPA, 2020; ReFED, 2016). An estimate based on measures of discarded food at all destinations is that once edible food leaves the farm, approximately 30 percent (66.5 million tons) is wasted each year (Buzby et al., 2014).

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PURPOSE OF THIS STUDY

Many factors influence food waste in the United States, but because a significant portion of this waste occurs at the consumer level, interventions to alter consumer behavior will be vital if meaningful reductions are to be achieved. Yet despite broad agreement about the importance of reducing food waste throughout the supply chain (see, e.g., NASEM, 2019) and increasing attention to the problem, the majority of food waste reduction initiatives to date have not been focused at the consumer level. Reasons for this may include both a lack of evidence regarding effective strategies and insufficient attention to the complexity of causes and responses within a complex food supply system.

In this context, the Walmart Foundation and Foundation for Food and Agriculture Research (FFAR)[1] provided funding to the National Academies of Sciences, Engineering, and Medicine for a study of strategies for reducing food waste at the consumer level. To carry out this study, the Division of Behavioral and Social Sciences and Education and the Health and Medicine Division of the National Academies appointed a committee of experts to identify and recommend actionable strategies, including a path forward for implementation, for reducing food waste at the consumer level by applying knowledge from the social and behavioral sciences, including lessons learned from the social sciences in other comparable arenas (e.g., water and energy conservation, recycling). The committee also considered issues of equity and the potential for interventions to have different effects on different population groups. (Box 1-1 presents the committee's statement of task.) The committee hopes that the strategies and recommendations detailed in this report will stimulate action and the coordination of effective strategies for reducing food waste at the consumer level, as well as further research to support future progress.

SCOPE OF THE FOOD WASTE PROBLEM

Characterizing the extent of the problem is challenging because there is substantial variation in how food waste is defined and measured, which makes comparisons and the tracking of progress difficult. Studies may differ in, for example, the portion of food waste considered "edible" versus "inedible;" the part of the food supply accounted for (e.g., postharvest only versus the full food supply); and methodologies used for measuring wasted food (e.g., direct versus indirect methods) (Spang et al., 2019).

[1] At the committee's first meeting, the Walmart Foundation and FFAR made a presentation about the study charge and their perspectives on the need for the study. They had no other discussions with the committee throughout the study process.

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Box 1-1
Statement of Task

An ad hoc committee will examine food waste in the United States at the individual consumer level at home and away from home. The committee will apply knowledge from the social and behavioral sciences to identify strategies for behavior change with consideration to interactions and feedbacks within the broader complex, dynamic food system. Drawing upon the food system overview described in A Framework for Assessing Effects of the Food System, the committee will:

- Review the existing data, information, and research on consumer food waste, including assessments of effectiveness for past and current reduction efforts;
- Make actionable recommendations for food waste reduction strategies; and
- Identify implementation strategies to reduce wasted food at the consumer level from a holistic, systems perspective.

Furthermore, many estimates rely on secondary or outdated data (Xue et al., 2017), which increases the uncertainty of the estimates. Although recent efforts to develop standards and guidance have begun to address some of the problems with the quantification of food waste, many challenges remain (Hanson et al., 2016). (Appendix C provides a full description of the different methods used and various definitions of food waste and loss.) Nonetheless, despite the complexities of the available information, it is possible to sketch out an overview of the problems and their consequences.

First, as food moves through the food system from production to consumption, loss and waste occur at all stages, but the largest proportion occurs at consumption (Lipinski et al., 2013). It is not possible to be precise about the percentages because of the lack of alignment among the measures used, but several estimates demonstrate this point:

- The portion of food waste occurring in U.S. households and places where consumers interact with food away from home has been estimated at close to 80 percent of the total (edible and inedible) amount of food waste produced (ReFED, 2016).
- An estimated 30 percent (or 67 million tons) of edible food in the United States is wasted at the retail and consumer levels of the food system (Buzby et al., 2014; Gunders, 2017).
- U.S. consumers waste approximately 1 pound of food per person daily, with fruits and vegetables most likely to be wasted, followed

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A National Strategy to Reduce Food Waste at the Consumer Level

by dairy, meat, and grains[2] (Conrad et al., 2018;[3] Hoover and Moreno, 2017; McDermott et al., 2018).

Looking at just the household level, some researchers have collected empirical data to estimate the portion of all wasted food that is edible by food type and discard destination (Hoover and Moreno, 2017; McDermott et al., 2019). Small studies have also quantified plate waste (the portion of food that is served but ultimately wasted) (e.g., Roe et al., 2018). Still, empirical food waste data come primarily from sources that have not been peer reviewed or were published outside of the United States, such as the Wasted Resources Action Programme (WRAP) in the United Kingdom (Gillick and Quested, 2018; Quested and Luzecka, 2014; Quested et al., 2013). Even less information is available about the proportion of consumer-level food waste that occurs in the home versus out-of-home settings, which would be useful for prioritizing resources.

Although it is clear that consumers waste a substantial proportion of the food they buy, food disposal is only one consideration when they make decisions about food. For example, a 2019 survey of U.S. consumers found that fewer than half think about food waste some of the time when they are at the grocery store, eating out, or at home (IFIC, 2019). The survey also revealed that such factors as price and preferences are more important than food waste considerations in making decisions about food.

The consequences of food waste are severe: the wasting of food depletes natural resources, degrades the environment, and constrains efforts to increase access to healthy diets for low-income populations. Life-cycle analyses have been used to quantify and disaggregate the environmental impacts of food production (Heller and Keoleian, 2015; Ivanova et al., 2016; Nemecek et al., 2016). One estimate is that the impacts of production and use of food from production to consumption are responsible for 48 percent and 70 percent of global household impacts on land and water resources, respectively (Ivanova et al., 2016).

When food goes uneaten, the environmental impacts stem from both waste of the resources used to grow the uneaten food and its disposal. By one recent estimate, food waste accounts for 15 percent of the total municipal solid waste generated in the United States (EPA, 2019), a figure that does not include all discarded food, such as that disposed of down the drain. The food waste in landfills is converted partly to methane, a

[2] The greatest economic cost is for uneaten meat, poultry, and fish, followed by vegetables and dairy products (Buzby et al., 2014).

[3] Estimate based on secondary data from the U.S. Department of Agriculture's (USDA's) Loss-Adjusted Food Availability data series.

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greenhouse gas[4] with 28 times the warming potential of carbon dioxide. Thus, it is estimated that the average American contributes 315 pounds of carbon dioxide equivalent annually (28 percent of all landfill greenhouse gas emissions) by discarding edible food and food packaging (Kling and Hough, 2010). Greenhouse gases are also emitted in the process of growing, processing, distributing, transporting, retailing, and cooking food that is eventually wasted. With all that in mind, a typical American's annual food waste could account for the emission of more than 12,000 pounds of carbon dioxide equivalent, which is approximately the level of emissions from driving a car for 13,500 miles (Kling and Hough, 2010). Globally, the emission of 4.4 gigatons of carbon dioxide equivalent—8 percent of annual global greenhouse gas emissions—results from food that is wasted (FAO, 2015).

In terms of global land use, a total of 1.4 billion hectares, an area nearly 1.5 times that of the United States, is used to grow food that is ultimately wasted (FAO, 2019). This is significant because land use ultimately has effects on biodiversity and people's livelihoods. Moreover, the application of nutrients used in growing food that is eventually discarded results in increased ammonia emissions, which further degrade air and soil quality, as well as wasted water and runoff-induced algal blooms in coastal waters. The amount of food produced but uneaten also implies substantial waste of water and energy, essential natural resources. For example, wasted food is responsible for more than 25 percent of total agricultural use of fresh water and about 4 percent of total U.S. oil consumption (Hall et al., 2009). Researchers have used modeling to estimate that halving food waste across all stages of the food supply chain could reduce the total environmental impact of the U.S. food system by 8 to 10 percent (Read et al., 2020).

Even as more than 30 percent of total food produced in the United States is wasted, 42 million Americans struggle with food insecurity (Coleman-Jensen et al., 2016). This disconnect is even more striking at the international level. According to the Food and Agriculture Organization (FAO), 1.3 billion tons of food is wasted globally, while nearly 900 million people are undernourished (FAO, 2019). As distressing as these figures are, it is important to note that much of the food that is wasted cannot realistically be recovered for human consumption, for reasons including food quality and decay, logistics, and the costs of recovery. Most food that gets wasted in the home is not likely to be appropriate for donation. Efforts to reduce consumer food waste have important benefits, but a broader suite

[4] Estimation of greenhouse gas emissions in terms of "carbon dioxide equivalent" facilitates comparison of estimates of different greenhouse gases, for example, carbon dioxide, methane, and nitrous oxide.

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of interventions is needed to make that food available and affordable to households experiencing food insecurity.

APPROACH TO THE STUDY

As this overview of the scope of the problem suggests, the study committee's charge required careful thinking about research and conceptual approaches from multiple fields. Accordingly, the committee included experts in food waste, psychology and marketing, sociology, public health, nutrition, behavioral economics, food systems, urban planning, intervention design, and implementation science (see Appendix F for biographical sketches of the committee members).

Study Process

The committee's conclusions and recommendations are based primarily on a review of the relevant technical literature and two public sessions held with researchers and leaders in the field of food waste and other relevant fields (see Appendix A for the agendas for these public sessions).

The committee reviewed the existing body of research on food waste at the consumer level, including assessments of the levels of waste and associated impacts, current and past interventions to reduce this waste, and drivers of consumer behavior around wasted food. To review this literature, the committee developed a search strategy that was applied to multiple databases (Agricola, Embase, Medline, ProQuest Research Library, PubMed, and Scopus). The search included peer-reviewed articles published in English after 2004 (see Appendix B for the search syntax and results). A total of 882 publications were scanned for relevance to the committee's task. In addition to the peer-reviewed literature, the committee reviewed grey literature on efforts of various groups to reduce food waste at the consumer level, including interventions, guidelines, and various other relevant topics.

The committee also sought insights in domains identified as similar to that of food waste for the purpose of studying consumer behavior and ways to influence it. Thus, the committee conducted additional literature searches targeting systematic reviews of research on strategies for promoting energy conservation, water conservation, waste prevention/management, recycling, diet change, and weight management.

Finally, the committee notes that the U.S. food supply chain and economy have experienced substantial disruptions during the COVID-19 global pandemic, which started in 2019 when the committee had completed most of its deliberations. There is not yet evidence regarding how consumer food waste patterns may have shifted during the pandemic, but the disruptions have undoubtedly affected consumers and their behaviors and had other

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impacts on the food supply around the world.[5] Increases in food insecurity and challenges for consumers in efficiently acquiring food are just two of the issues that have already become obvious. It is possible that the challenges of the pandemic could increase consumers' receptivity to efforts to assist them in reducing waste. This report could not address these fast-moving changes, but uncertainties about how the food supply and future consumers' behaviors will be shaped by the pandemic underscore the importance of attention to food waste.

A Systems Approach

The committee was asked to consider the full breadth of the complex, dynamic food system and in its analysis to draw on the food system overview presented in *A Framework for Assessing Effects of the Food System* (IOM and NRC, 2015) (see Box 1-1). A recommendation of that report is to move beyond a linear food supply chain model (from farm to table to landfill) to one that accounts for the interconnectivity and dynamic relationships among the various systems and structures within the food system (see Figure 1-1). Taking a systems approach makes it easier to understand and minimize the unintended negative consequences of interventions (tradeoffs), as well as to identify opportunities to maximize the benefits of changes, by illuminating the interactive relationships within the food system.

The 2015 report provides a framework intended to be applicable to many situations and to support the anlysis of proposed interventions aimed at influencing aspects of the food system. With this in mind, the committee attempted to apply the four principles laid out in the 2015 report to the food waste context while also recognizing the practical issues that must be addressed, such as uncertainties and gaps in data and information.

Principle 1: Recognize effects across the full food system. Consumer behavior, the focus of the current report, is shaped—or driven—by upstream influences. That is, the actions of farmers or food processors, for example, shape the context in which consumers make conscious and unconscious decisions and the options they have. Thus the committee investigated not only drivers of consumer behavior (see the discussion of terminology below) and interventions that directly affect individuals, but also other factors, such as policy, the actions of the food industry (i.e., food service venues and food retailers) and the media, and food marketing. We bounded our search by focusing on drivers that are proximal to the consumer and on interventions designed to prevent or reduce food surplus.

[5] See, e.g., http://www.ipes-food.org/_img/upload/files/COVID-19_CommuniqueEN.pdf; https://wrap.org.uk/sites/files/wrap/Citizen_responses_to_the_Covid-19_lockdown_0.pdf.

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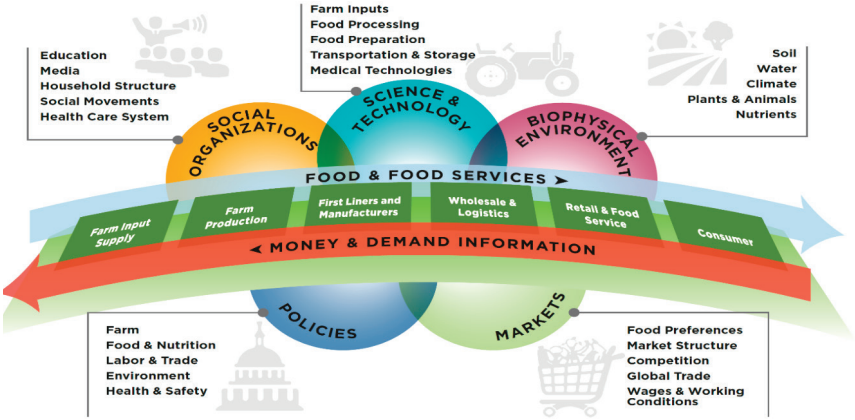

FIGURE 1-1 The U.S. food supply chain is a multilayered system that is interconnected with the larger biophysical environment and the social context.
SOURCE: IOM and NRC, 2015 (Figure S-2).

Principle 2. Consider all domains and dimensions of effects. The 2015 report notes that any intervention targeting the food domain may have consequences not only in that domain but also in other domains, such as health. The consequences in other domains may be positive or negative, intended or unintended, and they can be disproportionally larger than those intended for the intervention. The committee found limited research salient for exploring this issue with respect to food waste, but wherever possible, we considered potential consequences of interventions to reduce food waste in other areas, such as the possible effects of a technology used for this purpose on food safety.

Principle 3. Account for system dynamics and complexities. The food system is dynamic and heterogeneous, characterized by substantial variability in the goals and motivations of stakeholders and in the influences that drive consumer behavior. The committee acknowledged these variables and the tensions among them even when relevant empirical data or resources for obtaining such data were not available.

Principle 4. Choose appropriate methods of analysis and synthesis. Study of the topic of food waste is hampered by factors that include limited experience in this area among researchers, industry, and communities, as well as the lack of standard research methodology and terminology noted earlier. Accordingly, this report includes the committee's recommendations for improved methods, including analytical and modeling approaches, that would provide a more complete picture of the drivers of food waste behaviors and inform the selection of interventions.

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Although existing research did not support a true systems analysis of the problem of food waste, the committee applied the ideas behind such an analysis by taking into account

- the influence of other factors and actors in the food system beyond the consumer; and
- the synergy among various drivers of food waste.

We also explored the work of other authors in the field of systems thinking, such as Meadows (1999, 2008), who proposes a framework for systems change in which different types of interventions work in synergy to address a particular societal challenge. Others have categorized the types of prevention interventions to reduce food waste at the consumer level as "strong" or "weak" (Mourad, 2016): a strong intervention is one with long-term benefits that calls for changing the roots of the problem, whereas a weak intervention focuses on consumer behavior alone. The committee considered these concepts in its deliberations.

Integrating Work from the Social, Behavioral, and Economic Sciences

Researchers in fields including food science, nutrition, public health, behavioral economics, marketing, sociology, social psychology, land use planning, geography, and implementation science have in one way or another contributed to understanding of why consumers do what they do and how consumer behaviors can be shaped through interventions. While each of these fields has made important contributions, they identify and investigate questions in different ways that reflect the conceptual underpinnings of their disciplines.

For example, some psychologists and behavioral economists consider food waste primarily as a context within which fundamental psychological effects may be explored or knowledge extended. Specialists in food marketing tend to look to data from either laboratory or field experiments that systematically alter one aspect of the food decision environment, with the goal of isolating novel effects on, say, quantities purchased or willingness to pay, rather than focusing on reducing waste as a key outcome. Behavioral economists use field studies to test how well findings from psychology and economics work in real-world settings. Scholars in urban geography and planning explore the role of space and the built environment in shaping food practices and the influence of such factors as urbanization, class, culture, and infrastructure. Public health nutrition researchers analyze food- and nutrition-related behaviors, perform program and policy evaluations, and study individual, social, and structural factors that shape behaviors and

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opportunities. Agricultural and resource economists may draw on broad-scale survey data as well as laboratory and field experiments, often considering human-ecosystem feedback, the effects of informational interventions, and the interactions between business and individual behaviors as related in particular to the food system. And researchers in implementation science, a field that has blossomed in the last decade, focus on the specific elements needed to use the findings from small-scale studies successfully in designing population-scale interventions that can change behaviors. Researchers in several of these fields complement quantitative approaches with qualitative studies to better understand the underlying dynamics and processes that shape behaviors and their contexts.

Diverse Terminology

Coordinating findings from across such disparate areas of study poses a challenge. Researchers in these fields are seeking to understand similar phenomena from their own perspectives and have developed terminology that is idiosyncratic to their domains. Their distinct usages of often similar terms reflect conceptual differences in their approaches. The discrepancies in usage can confuse interpretation and meaning.

A key concept in the study of food waste illustrates the problem: the influences on behavior that are called "drivers" in many contexts are also referred to as "determinants," "determining factors," "motivators," or "predictors" in other fields, with definitions that overlap significantly but are not identical. These terms reflect varying stances on what is most important (e.g., the statistical meaning of prediction versus behavioral influences such as motivation), which can make it challenging to parse the meaning of similarities and differences in findings. At the same time, the diffusion of new categorizations and terminology can allow meaningful comparisons to emerge across fields.

The definition of food waste itself is another challenge. As noted earlier, researchers who study food waste define it in varying ways (e.g., sometimes including spoiled or otherwise inedible food and sometimes not), and also measure it in multiple ways, which complicates the comparison and integration of data and analysis. For the purposes of this report, "food waste" is defined as food that is either still edible or became spoiled before it could be consumed and is discarded by consumers in any discard location, including landfills or composting facilities. While recognizing that whether a food (or part of a food) is considered edible depends on cultural, religious, and even personal preferences, the committee focuses only on edible food in this report, given that it is the portion most conducive to waste prevention. Further, this report focuses on consumer-level waste; waste at other levels of

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the food supply chain (e.g., at the retail level) is relevant to this report only to the extent that it influences waste at the consumer level. For example, the food wasted by the consumer in food service venues (e.g., restaurants, school cafeterias) is within the scope of this report. Conversely, the waste that occurs in the operation of food service venues as food is purchased and prepared, although equally important, is beyond the scope here, as is the food waste resulting from retail store operations. Other terms relevant to this report are defined as they arise in the discussion. Appendix G provides definitions of all terms with the potential to cause confusion.

Theoretical Frameworks

The use of theories of change and conceptual frameworks helps identify bridges and address inconsistencies in the study of consumer behavior. Theories and frameworks can guide the design of behavioral interventions by identifying constructs and mechanisms that are important to the desired outcomes, which in turn supports the identification of variables and outcomes that will need to be measured in order to disaggregate effects (Thomson and Ravia, 2011). However, relatively few studies of interventions designed to influence behavior use theoretical frameworks to guide design (Sweet and Fortier, 2010; Thomson and Ravia, 2011; Varotto and Spagnolli, 2017). In some domains, such as diet- and physical activity-related behavior change, researchers have found only sparse and inconsistent evidence that theory-based interventions are effective or lead to better outcomes (Samdal et al., 2017). In addition, behavioral theories can be poor at explaining how the initiation and maintenance of behavior might differ (Samdal et al., 2017). Despite these challenges, researchers can beneficially apply theories and frameworks to standardize monitoring and evaluation practices and reporting of outcomes (Cox et al., 2010; Fjeldsoe et al., 2011). Some of this work has been the basis for the development of models designed to account more holistically for consumer behavior.

The committee's review of the six behavioral domains identified as similar to that of food waste demonstrated that multiple theories have been dominant in studies of behavioral change, ranging from the psychological (the theory of planned behavior and modified versions [Ajzen, 1991]) and value-norm-belief theory (Stern and colleagues, 1999, 2000) to others based in sociology (e.g., versions of social practice theories [Schanes et al., 2018]). While each has some strengths, they all have shortcomings that make them difficult to apply across a broad literature; Box 1-2 provides a look at the context in which these theories emerged. The committee considered the applicability of several theoretical frameworks to consumer-level food waste behavior.

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Box 1-2
The Science of Behavior Change

Many theories and frameworks have been used to understand and predict individual behavior. There is no consensus on which theories and frameworks are most useful, and the dominant theories have evolved over time. Early theories of behavior change, such as social cognitive theory, the theory of planned behavior, and the transtheoretical model, were influential efforts to explain why people adopt a behavior. This set of theories characterized human behavior as being predominantly conscious and reason driven, and this category of behavior is sometimes referred to as "System 2" processing (Koop et al., 2019; Marteau, 2017; Varotto and Spagnolli, 2017). Theories focused on System 2 behavior highlight the role of knowledge transfer and ways to improve self-efficacy in changing behavior (Koop et al., 2019). The shortcomings of System 2 theories for explaining behavioral outcomes was increasingly apparent by the end of the 20th century, as the importance of accounting for automatic and emotion-driven factors was recognized (Marteau, 2017). New models of behavior (sometimes called System 1 theories) emerged that characterized human behavior as being more automatic and emotion driven than the System 2 theories had allowed. Most recently, it has been recognized that individual behaviors are responsive to both System 1 and 2 processes, and researchers have begun to measure drivers and create study designs that take both into account.

The *theory of planned behavior* focuses on drivers related to the intention to behave in a certain way. Researchers that use the theory of planned behavior, therefore, often do not focus on measuring actual behavior (Graham-Rowe et al., 2014; Koop et al., 2019; Stancu et al., 2016; Stefan et al., 2013; Visschers et al., 2016; van der Werf et al., 2019). Though heavily used in the food waste literature, this theory has shortcomings for explaining food waste behavior (Schanes et al., 2018). First, the theory is best suited to capturing consumers' intentions to engage in single behaviors, divorced from other considerations that may create disconnects between their intentions and their actions. Indeed, the amount of food consumers waste is often determined not only by their intentions, but also by contextual factors they cannot control that impede their intended actions. Further, food waste is often driven by factors outside the scope of conscious choices, many of which occur in tandem with contextual and social factors that are not intended or planned by the consumer (Quested et al., 2013). Scholars have labeled this phenomenon the "value-action gap" (Barr, 2006). Because there may be a substantial gap between intentions and behavior related to waste, a theory that focuses so heavily on intentions may offer little explanation of actual behavior.

The *value-belief-norm theory*, offered by Stern and colleagues (1999, 2000), was developed primarily for application in the field of nonactivist environmental behaviors. This theory posits that biospheric,[a] altruistic, and egoistic values give rise to beliefs that shape behaviors. These values influence individuals' general ecological worldview, understanding of adverse consequences of behaviors that harm the environment, and sense of their own ability to reduce such harms.

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Together, these beliefs may then give rise to proenvironmental personal norms, which drive a host of behaviors. This framework has shown strong predictive power in the domain of environmental behaviors, which suggests potential value in the food waste context if food waste were seen by consumers primarily as an environmentally damaging action. However, even if environmental beliefs and norms are drivers for some consumers in some cases, this approach addresses only the individual decision maker, not the many other elements of the food waste system.

Widely used in qualitative research, *theories of practice* (also known as *social practice theory* or *practice theory*) are used to understand routinized behaviors. In contrast to the theory of planned behavior, theories of practice treat consumer action as being influenced by a rich combination of factors. According to Shove and colleagues (2012), the three key elements of practice theory are (1) **material** (e.g., technologies, infrastructure, tools, logistics, objects); (2) **meaning** (e.g., values, cultures, emotions, paradigms); and (3) **competence** (skills, capacity, and knowledge). Social practice theory recognizes that individuals' practices and behaviors are shaped by a combination of the three interrelated factors (Hargreaves, 2011; Reckwitz, 2002; Shove et al., 2012; Warde, 2005). In this model, practices and behaviors are not regarded simply as individual choices: the influences of institutions and systems are taken into account (Mattioni et al., 2020). Behavior is thus likened to practices, defined as repeated actions that are enacted together. According to these theories, discarding food should be considered a "bundle of practices," including behaviors related to the planning, provisioning, preparation, consumption, and discarding of food. Understanding each of these behaviors by itself and in relation to the others is critical to understanding how food is transformed into waste by households (Hargreaves, 2011; Southerton and Yates, 2015).

Because they take into account how consumer behavior is influenced by social and marketing cues, theories of practice provide a natural link to a systems perspective. However, the majority of work applying these theories does not allow for broad quantification of the effects of interventions or for comparisons across studies.[b] Further, while the concept of bundles of practices offers important insights, this combinatory approach makes it more difficult to identify separate drivers that may appear across contexts. Thus, results from studies applying these theories are difficult to generalize or integrate with those that identify single drivers of food waste (see Soma, 2019).

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[a]A biospheric value orientation is the perspective that concern for the health of the biosphere, earth's biological system, should guide moral and ethical decisions.

[b]For example, Soma (2019) quantitatively applied theories of practice to understand the influence of income and retail choice on food waste in households in Indonesia.

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A framework that allows the identification and analysis of individual behavioral drivers but also acknowledges the importance of context and habit in driving behavior—the *motivation-opportunity-ability (MOA) framework*—has been used in food waste research in both academic and practitioner settings (e.g., Scott et al., 2015; van Geffen et al., 2016) and related fields (e.g., Addo et al., 2018; Geiger et al., 2019; MacInnis and Jaworski, 1989). The committee found that this model offered the most useful approach for analyzing the drivers of food waste behaviors and interventions to modify those behaviors in the context of our statement of task (Box 1-1). The key elements of this framework as they apply to food waste have been defined as follows (van Geffen et al., 2016):

- **Motivation to prevent food waste**—a person's willingness to perform actions that reduce the likelihood or amount of food waste being generated. Relevant aspects of motivation are attitude, awareness, and social norms.
- **Opportunity to prevent food waste**—the availability and accessibility of materials and resources required to prevent food waste. Relevant aspects of opportunity are time and schedule, economic and other contextual factors, material and technologies, policy, and infrastructure.
- **Ability to prevent food waste**—a person's proficiency at solving the problems encountered when performing actions that help prevent food waste. Relevant aspects of ability are knowledge and skills.

Like theories of practice, the MOA framework supports analysis of behavior that may be driven by habit rather than explicit intention. Indeed, the MOA framework also makes clear that when motivation, opportunity, *or* ability is low, consumers are likely to be influenced by factors related to routine, choice context, nonconscious factors, or social norms, and that addressing individual, group, and societal cues will increase the chance of sustained behavioral change. This insight is important in a systems approach to reducing food waste.

A few examples illustrate the interactions among motivation, opportunity, and ability. Even for individuals who wish to reduce food waste (have high motivation), refrigerators that are set at the wrong temperature (low opportunity) may make it very difficult to translate that motivation into the desired outcome. On the other hand, ignoring motivation can also undermine efforts in two ways. First, communities may provide ample opportunity and ability to reduce food waste, but if individuals are faced with conflicting motivations (i.e., conflicting drivers), such as the desire to take advantage of bulk buying opportunities, those interventions are not likely to succeed. Second, if executing behaviors to reduce food waste requires

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high levels of motivation, the level of motivation in itself may be a driver of food waste. Where motivation is relatively low, opportunity and ability may need to be so strong that wasting food would require more effort than not doing so. One way to address this would be to build habit systems that make nonwasting automatic. For example, a community might develop a program whereby opting in to food waste reduction processes is automatic, but opting out would require more effort. In this case, consumers would need little motivation—they would simply need to lack a countervailing motivation.

The MOA framework allows for consideration of the roles of habits, norms, and other automatic behaviors. The committee used the MOA approach to anchor its analysis of the possible drivers of consumer behaviors and interventions designed to change those behaviors.

STRUCTURE OF THE REPORT

The remainder of this report is organized into five chapters. Chapter 2 describes the context for food waste at the consumer level. Chapter 3 discusses the drivers of consumer-level food waste, including both lessons learned from other disciplines and the research specific to food waste. It identifies implications for the design of interventions targeting food waste behaviors. Chapter 4 reviews the research on interventions to reduce food waste, again taking into account lessons from other disciplines. Chapter 5 presents the committee's strategy for reducing food waste and its recommendations for implementing this strategy. Finally, Chapter 6 describes research needed to support the design of interventions and highlights the importance of implementation planning.

REFERENCES

Addo, I.B., M.C. Thoms, and M. Parsons. 2018. Household water use and conservation behavior: A meta-analysis. *Water Resources Research* 54(10):8381-8400.

Ajzen, I. 1991. The theory of planned behavior. *Organizational Behavior and Human Decision Processes* 50(2):179-211.

Barr, S. 2006. Environmental action in the home: Investigating the 'value-action' gap. *Geography* 91(1):43-54.

Buzby, J.C., H.F. Wells, and J. Hyman. 2014. The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the United States. *Economic Research Information Bulletin* 121.

Coleman-Jensen, A., M.P. Rabbitt, C.A. Gregory, and A. Singh. 2016. *Household food security in the United States in 2015, ERR-215*. Washington, DC: U.S. Department of Agriculture, Economic Research Service.

Conrad, Z., M.T. Niles, D.A. Neher, E.D. Roy, N.E. Tichenor, and L. Jahns. 2018. Relationship between food waste, diet quality, and environmental sustainability. *PLoS ONE* 13(4):e0195405.

Copyright National Academy of Sciences. All rights reserved.

Cox, J., S. Giorgi, V. Sharp, K. Strange, D.C. Wilson, and N. Blakey. 2010. Household waste prevention—A review of evidence. *Waste Management Research* 28(3):193-219.

EPA (Environmental Protection Agency). 2019. *Advancing sustainable materials management: 2017 fact sheet*. Available: https://www.epa.gov/sites/production/files/2019-11/documents/2017_facts_and_figures_fact_sheet_final.pdf.

———. 2020. *Food: Material-specific data*. Available: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/food-material-specific-data.

FAO (Food and Agriculture Organization of the United Nations). 2014. *Foodwastage footprint: Full cost-accounting. Final report*. Available: http://www.fao.org/publications/card/en/c/5e7c4154-2b97-4ea5-83a7-be9604925a24.

———. 2015. *Food wastage footprint & climate change*. Available: http://www.fao.org/documents/card/en/c/7338e109-45e8-42da-92f3-ceb8d92002b0.

———. 2019. *The state of food and agriculture 2019: Moving forward on food loss and waste reduction*. Rome: FAO.

Fjeldsoe, B., M. Neuhaus, E. Winkler, and E. Eakin. 2011. Systematic review of maintenance of behavior change following physical activity and dietary interventions. *Health Psychology* 30(1):99-109.

Geiger, J.L., L. Steg, E. van der Werff, and A.B. Ünal. 2019. A meta-analysis of factors related to recycling. *Journal of Environmental Psychology* 64:78-97.

Gillick, S., and T.E. Quested. 2018. *Household food waste: Restated data for 2007-2015*. Wasted Resources Action Programme in the United Kingdom.

Graham-Rowe, E., C.J. Donna, and S. Paul. 2014. Identifying motivations and barriers to minimising household food waste. *Resources, Conservation & Recycling* 84:15-23.

Gunders, D. 2017. *Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill*. New York: Natural Resources Defense Council.

Gustavsson, J., C. Cederberg, U. Sonesson, R. Van Otterdijk, and A. Meybeck. 2011. Global food losses and food waste. Rome: Food and Agriculture Organization of the United Nations.

Hall, K.D., J. Guo, M. Dore, and C.C. Chow. 2009. The progressive increase of food waste in America and its environmental impact. *PLoS ONE* 4(11):e7940.

Hanson, C., B. Lipinski, K. Robertson, D. Dias, I. Gavilan, P. Greverath, S. Ritter, J. Fonseca, R. VanOtterdijk, T. Timmermans, J. Lomax, A. Dawe, V. Berger, M. Reddy, D. Somogyi, B. Tran, B. Leach, and T.E. Quested. 2016. *Food loss and waste accounting and reporting standard*. Available: https://flwprotocol.org.

Hargreaves, T. 2011. Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change. *Journal of Consumer Culture* 11(1):79-99.

Heller, M.C., and G.A. Keoleian. 2015. Greenhouse gas emission estimates of U.S. dietary choices and food loss. *Journal of Industrial Ecology* 19(3):391-401.

Hoover, D., and L.C. Moreno. 2017. *Estimating quantities and types of food waste at the city level*. Available: https://www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf.

IFIC (International Food Information Council Foundation). 2019. *A survey of consumer behaviors and perceptions of food waste*. Available: https://foodinsight.org/wp-content/uploads/2019/09/IFIC-EPAL-Food-Waste-Deck-Final-9.16.19.pdf.

IOM (Institute of Medicine) and NRC (National Research Council). 2015. *A framework for assessing effects of the food system*. Washington, DC: The National Academies Press.

Ivanova, D., K. Stadler, K. Steen-Olsen, R. Wood, G. Vita, A. Tukker, and E.G. Hertwich. 2016. Environmental impact assessment of household consumption. *Journal of Industrial Ecology* 20(3):526-536.

Kling, M., and I. Hough. 2010. *The American carbon foodprint: Understanding your food's impact on climate change*. Brighter Planet. Available: https://kohalacenter.org/HISGN/pdf/carbofoodprint.pdf.

Copyright National Academy of Sciences. All rights reserved.

Koop, S.H.A., A.J. Van Dorssen, and S. Brouwer. 2019. Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics. *Journal of Environmental Management* 247:867-876.

Lipinski, B., C. Hanson, J. Lomax, L. Kitinoja, R. Waite, and T. Searchinger. 2013. *Reducing food loss and waste. Working paper, installment 2 of creating a sustainable food future*. Available: https://wriorg.s3.amazonaws.com/s3fs-public/reducing_food_loss_and_waste.pdf.

MacInnis, D.J., and B.J. Jaworski. 1989. Information processing from advertisements: Toward an integrative framework. *Journal of Marketing* 53(4):1-23.

Marteau, T.M. 2017. Towards environmentally sustainable human behaviour: Targeting nonconscious and conscious processes for effective and acceptable policies. *Philosophical Transactions. Series A, Mathematics, Physical and Engineering Sciences* 375(2095).

Mattioni, D., A.M. Loconto, and G. Brunori. 2020. Healthy diets and the retail food environment: A sociological approach. *Health & Place* 61:102244.

McDermott, C., D. Elliott, A. Johnson, K. Hunter, and C. de Venecia. 2018. *2017 Oregon Wasted Food Study: Residential sector waste sort, diary, and survey study.* Available: https://www.oregon.gov/deq/mm/Documents/ResKitchenDiarySurvey.pdf.

McDermott, C., L.C. Moreno, C. Mulder, D. Elliott, and R. Broderson. 2019. *Oregon Wasted Food Study: Summary of findings*. Available: https://www.oregon.gov/deq/mm/food/Pages/Wasted-Food-Study.aspx.

Meadows, D.H. 1999. *Leverage points: Places to intervene in a system*. Hartland, VT: Published by the Sustainability Institute.

Meadows, D.H. 2008. *Thinking in systems: A primer*. White River Junction, VT: Chelsea Green Publishing.

Mourad, M. 2016. Recycling, recovering and preventing "food waste": Competing solutions for food systems sustainability in the United States and France. *Journal of Cleaner Production* 126:461-477.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2019. *Reducing impacts of food loss and waste: Proceedings of a workshop*. Washington, DC: The National Academies Press.

Nemecek, T., N. Jungbluth, L.M.I. Canals, and R. Schenck. 2016. Environmental impacts of food consumption and nutrition: Where are we and what is next? *The International Journal of Life Cycle Assessment* 21(5):607-620.

Quested, T.E., and P. Luzecka. 2014. *Household food and drink waste: A people focus*. Wasted Resources Action Programme in the United Kingdom. Available: https://www.wrap.org.uk/content/household-food-drink-waste-people-focus.

Quested, T.E., E. Marsh, D. Stunell, and A.D. Parry. 2013. Spaghetti soup: The complex world of food waste behaviours. *Resources, Conservation, and Recycling* 79:43-51.

Read, Q.D., S. Brown, A.D. Cuéllar, S.M. Finn, J.A. Gephart, L.T. Marston, E. Meyer, K.A. Weitz, and M.K. Muth. 2020. Assessing the environmental impacts of halving food loss and waste along the food supply chain. *Science of The Total Environment* 712:136255.

Reckwitz, A. 2002. Toward a theory of social practices: A development in culturalist theorizing. *European Journal of Social Theory* 5(2):243-263.

ReFED (Rethink Food Waste Through Economics and Data). 2016. *A roadmap to reduce U.S. food waste by 20 percent*. Available: https://www.refed.com/downloads/ReFED_Report_2016.pdf.

Roe, B.E., J.W. Apolzan, D. Qi, H.R. Allen, and C.K. Martin. 2018. Plate waste of adults in the United States measured in free-living conditions. *PLoS ONE* 13(2):e0191813.

Samdal, G.B., G.E. Eide, T. Barth, G. Williams, and E. Meland. 2017. Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. *International Journal of Behavioral Nutrition and Physical Activity* 14(1):42.

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Schanes, K., K. Dobernig, and B. Gözet. 2018. Food waste matters—A systematic review of household food waste practices and their policy implications. *Journal of Cleaner Production* 182:978-991.

Scott, A., C. Oates, and W. Young. 2015. A conceptual framework of the adoption and practice of environmental actions in households. *Sustainability (Switzerland)* 7(5):5793-5818.

Shove, E., M. Pantzar, and M. Watson. 2012. *The dynamics of social practice: Everyday life and how it changes*. London, UK: Sage.

Soma, T. 2019. Space to waste: The influence of income and retail choice on household food consumption and food waste in Indonesia. *International Planning Studies*. Available: https://doi.org/10.1080/13563475.2019.1626222.

Southerton, D., and L. Yates. 2015. Exploring food waste through the lens of social practice theories: Some reflections on eating as a compound practice. In *Waste management and sustainable consumption*, edited by K. Ekstrom. New York, NY: Routledge. Pp. 133-159.

Spang, E.S., L.C. Moreno, S.A. Pace, Y. Achmon, I. Donis-Gonzalez, W.A. Gosliner, M.P. Jablonski-Sheffield, M.A. Momin, T.E. Quested, K.S. Winans, and T.P. Tomich. 2019. Food loss and waste: Measurement, drivers, and solutions. *Annual Review of Environment and Resources* 44(1):117-156.

Stancu, V., P. Haugaard, and L. Lahteenmaki. 2016. Determinants of consumer food waste behaviour: Two routes to food waste. *Appetite* 96:7-17.

Stefan, V., A.A. Tudoran, E. van Herpen, and L. Lahteenmaki. 2013. Avoiding food waste by Romanian consumers: The importance of planning and shopping routines. *Food Quality and Preference* 28(1):375-381.

Stern, P. 2000. Toward a coherent theory of environmentally significant behaviour. *Journal of Social Issues* 56(3):407-424.

Stern, P.C., T. Dietz, T. Abel, G.A. Guagnano, and L. Kalof. 1999. A value-belief-norm theory of support for social movements: The case of environmentalism. *Human Ecology Review*: 6(2)81-97.

Sweet, S.N., and M.S. Fortier. 2010. Improving physical activity and dietary behaviours with single or multiple health behaviour interventions? A synthesis of meta-analyses and reviews. *International Journal of Environmental Research and Public Health* 7(4):1720-1743.

Thomson, C.A., and J. Ravia. 2011. A systematic review of behavioral interventions to promote intake of fruit and vegetables. *Journal of the American Dietetic Association* 111(10):1523-1535.

Varotto, A., and A. Spagnolli. 2017. Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology* 51:168-188.

van der Werf, P., J.A. Seabrook, and J.A. Gilliland. "Reduce food waste, save money": Testing a novel intervention to reduce household food waste. *Environment and Behavior* 0(0):0013916519875180.

Van Geffen, L.E.J., E. van Herpen, and J.C.M. van Trijp. 2016. *Causes & determinants of consumers food waste. Refresh deliverable 1.1*. Available: https://eu-refresh.org/causes-determinants-consumers-food-waste.

Visschers, V.H.M., N. Wickli, and M. Siegrist. 2016. Sorting out food waste behaviour: A survey on the motivators and barriers of self-reported amounts of food waste in households. *Journal of Environmental Psychology* 45:66-78.

Warde, A. 2005. Consumption and theories of practice. *Journal of Consumer Culture* 5(2):131-153.

Xue, L., G. Liu, J. Parfitt, X. Liu, E. Van Herpen, A. Stenmarck, C. O'Connor, K. Ostergren, and S. Cheng. 2017. Missing food, missing data? A critical review of global food losses and food waste data. *Environmental Science and Technology* 51(12):6618-6633.

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2

Understanding Food Waste, Consumers, and the U.S. Food Environment

The context in which consumers waste food is complex. To understand the drivers of food waste behavior and possible ways to reduce it, it is important to understand the elements of the interconnected food system mentioned in Chapter 1. This chapter provides an overview of U.S. consumers' proximal interactions with parts of the food system, including where and how they purchase food and what they know about food. The chapter also describes efforts already under way to address consumer food waste.

The committee notes that the COVID-19 pandemic, which developed as work on this report was being completed, has disrupted the food system and is affecting consumer behavior in numerous ways both large and small. As this report goes to press, the pandemic is still developing, and researchers have not yet had time to document all these changes and assess their impact, but doing so will undoubtedly be a vital contribution to the understanding of consumer food waste in the future.

THE U.S. CONSUMER WITHIN THE FOOD SYSTEM

U.S. consumers are diverse across virtually any dimension; gender, race, ethnicity, economic status, and cultural traditions are but a few examples. Their food practices, including the wasting of food, are influenced not only by individual and interpersonal factors, such as income, attitudes, knowledge, and relationships, but also by the complex, dynamic food system. The food system comprises a range of individuals, groups, organizations,

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and industries whose actions (e.g., enacting policy, informing the public, selecting and marketing products) can influence consumer behavior and the likelihood of food waste. The system also encompasses cultural, social, and economic drivers that operate at the community, state, and federal levels (Contento, 2016). These elements are key to strategies that can change behavior and reduce food waste at the consumer level. A sampling of important stakeholders is listed in Box 2-1.

Consumers' individual characteristics naturally have implications for their food waste behavior: people respond in varying ways to situations in which decisions about food are made. For example, Aschemann-Witzel and colleagues (2018) found that among those consumers who thought about food waste at the grocery store, the top reason for doing so was saving money, but many also considered the goal of reducing waste overall, environmental concerns, or the need to ensure food access for all. For others, avoiding food waste may have become a habit.

Researchers have suggested that consumers can be divided into five segments based on their food waste practices (Aschemann-Witzel et al., 2018). In this categorization, one group likes cooking, considers price and taste important, but does not plan in advance, and reports a medium level of food waste. Another group is concerned with price but dislikes cooking;

BOX 2-1
Stakeholders in the Food System

- Community advocates
- Consumers
- Educators
- Farmers
- Federal government
- Food industry (e.g., manufacturers, retail)
- Food rescues
- Funders
- Hospitality/food service industry
- Influencers (e.g., chefs, religious leaders)
- Innovators/entrepreneurs
- International institutions
- Media
- Municipal/local governments
- Nutrition/food safety advocates
- Policy makers
- Researchers
- Schools, colleges, universities
- Technology industry
- Waste management companies

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this group reports low levels of food waste. A third group is very engaged in cooking, is concerned about price and taste, and plans in advance, and reports low levels of food waste. The fourth group does not consider price but is interested in taste, food safety, and optimal choice, and reports a medium level of food waste. Finally, the fifth group is not very involved with food and has a low level of interest in cooking, food safety, or the price–quality relationship; this group reports the highest level of food waste. The complexity of these segments illustrates that reducing food waste involves more than simply raising consumer awareness. For example, consumers with low levels of interest in food and food waste are not likely to be swayed by economic, normative, or ethical appeals designed to increase awareness but may respond best to structural interventions such as "nudges[1]" (Thaler and Sunstein, 2008).

An important question is how income level influences the wasting of food, although the available research on this question is not conclusive. For example, some studies have suggested that households with higher income waste more (e.g., Filipová et al., 2017; Soma, 2019; Verma et al., 2020), while other work suggests that households with low income may waste more of certain items, such as lower-quality foods purchased in bulk (Setti et al., 2016). Investigating questions about the role of income level in food waste is challenging, in part because many consumers with low income lack access to the digital connections researchers use for online data collection, and they, like other consumers, may also lack familiarity with ordinary survey instruments. Thus, reaching them to learn about their motivations and experiences is difficult. Researchers can turn to other methods, such as ethnographic analysis, to better understand how people, particularly those with low incomes, interact with food and food waste.

The relative expense of food is much higher for low-income than for higher-income consumers, even though the food available in their communities may be of lower quality and less varied. Also, the food available through government allocations, food banks, and charities is different in many ways from that available to more affluent consumers. These are just two of the ways food may have different meanings for consumers with low-incomes and higher-incomes, and reasons they may respond differently to interventions to reduce food waste. However, the existing research on food waste and equity focuses primarily on the role of donations to feed those who are food insecure, rather than on identifying drivers or long-term

[1] A nudge is a modification of the way choices are presented (choice architecture) that influences behavior by such means as removing external barriers, expediting access, or altering the structure of the environment. In the context of food waste, a nudge might, for example, shift perception of the quantity of food (e.g., changing plate sizes); shift the appeal or quality of food (e.g., increasing the appeal of healthy foods); or make a behavior easier (e.g., offering healthy food in a cafeteria at the beginning of the line).

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solutions related to improving equity or reducing food waste (Riches, 2011; Tarasuk and Eakin, 2005; Warshawsky, 2015).

The fact that low-income and more affluent consumers may respond to issues related to food waste differently suggests that they may need to be considered separately. However, multiple factors, including race, gender, and education level, intersect with poverty in ways that are important for food waste research, as for almost any social science research. The diverse motivations, contexts, and responses that influence all consumers call for a nuanced approach to research on both drivers of food waste behavior and interventions to change that behavior to take these differences into account. One way to do this is to apply the segmentation approaches used by food marketers to appeal to individual food preferences.

Where and How Consumers Buy Food

Researchers focus on how consumers behave in various settings to understand what may influence their decisions about food acquisition and consumption. Thus they examine how and where consumers interact with food they obtain from food retailers, charities and other sources of free food, or online, or in food service venues.

Food Retailers

Supermarkets and supercenters

Supermarkets and supercenters (hypermarkets) are the dominant sources of food for Americans, with pharmacies and dollar stores increasingly becoming sources as well (Caspi et al., 2017). Supermarkets are relatively scarce in rural and some urban areas and also on American Indian reservations, however (Bird Jernigan et al., 2018). African American neighborhoods at all poverty levels have 40–70 percent fewer chain supermarkets per census tract relative to high-income white neighborhoods; Hispanic neighborhoods have only 14–40 percent as many supermarkets as non-Hispanic neighborhoods (Bower et al., 2014); and many individuals living on American Indian reservations depend on convenience stores for groceries (Bird Jernigan et al., 2018).

Different marketing, food assortment, and store design approaches can result in more or less food waste at the consumer level. Several studies have found that modern supermarket and supercenter formats have a tendency to encourage consumers to overpurchase, resulting in more food waste, compared with traditional or smaller retail outlets (Lee, 2018; Soma, 2019). Overpurchasing can be stimulated by such features as retail loyalty programs that hold a significant amount of consumer data and offer nudges

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(e.g., redeemable rewards designed to entice them to make more purchases) (Carolan, 2018). Globally, an estimated 1.5 billion people have registered for such programs (Carolan, 2018). Other reasons for overacquisition are the ubiquity of promotional and "buy one, get one free" offers, the availability of many varieties of food, and offers that encourage stocking up (Lee, 2018; Soma, 2019). Although prompts, cues, and nudge-like strategies often encourage increased acquisition, these strategies could be redesigned to encourage consumers to buy "smarter," which could reduce food waste.

In addition to marketing strategies and the variety of foods offered, store design approaches, such as a store's social dimensions or atmosphere, can encourage consumers to shop at a store (Baker et al., 2002). Attractive displays and a festive environment, for example, serve as cues to consumers to spend more time and buy more (Sneed, 2014).

Other Places to Acquire Food

In addition to conventional retail outlets, consumers have other options for purchasing food. For example, approximately 12 percent of American adults shop for food at farmers' markets, a rate that is increasing (Dimitri and Effland, 2018). Consumers who frequent farmers' markets are interested in more than food; they are also seeking social connections in the community, better connections with growers, sustainable foods, and ways to support the local economy (Zepeda, 2009).

Food cooperatives, which are user owned, user controlled, and focused on distributing benefits to their members, are another alternative to corporate or multinational retail outlets (Curl, 2012). According to Zitcer (2015), sales at these venues have tripled in the past 10 years. Community-supported agriculture (CSA), another outlet for acquiring food based on membership, offers a direct connection to farmers. The number of CSAs has increased significantly, rising from 1,700 in 2005 (Weise, 2005) to 7,398 in 2015, when CSAs contributed $226 million in direct farmer-to-consumer sales (USDA, 2016).

Charities, including food banks, soup kitchens, and food pantries,[2] are part of the emergency food sector, serving the food insecure (more than 37 million people in the United States) (Coleman-Jensen et al., 2019). Food banks generally acquire their inventories through donations, government foods, and institutional purchases. Donations generally make up the greatest proportion of their inventories, and may include retail or farm surplus donations (Ross et al., 2013). One of the challenges associated with food bank donations is that they may not consist of culturally appropriate foods for their location, which may result in wasted food.

[2] Food banks serve as warehouses and food pantries serve the community by distributing food from those warehouses.

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Finally, a small group of Americans acquire food from dumpster diving, identifying themselves as "freegans." Others, especially in rural or remote communities, rely on hunting, fishing, and farming or acquire much of their produce from gardening. According to Ganglbauer and colleagues (2013), the benefits of gardening with respect to reducing food waste include that the food is readily available when needed. In addition, the work of cultivating, harvesting, and preserving (e.g., freezing and canning) food gives consumers a greater connection to its production, which has been shown to increase its perceived value and to reduce waste (Ganglbauer et al., 2013).

New Models: Online-based Food Acquisition

Online grocery shopping for food that is delivered to the consumer's doorstep or made available for store pickup is becoming increasingly popular. Prior to the COVID-19 pandemic, it was projected that 70 percent of U.S. shoppers could be purchasing their groceries online as early as 2022 (FMI and Nielsen, 2018). The pandemic may accelerate the use of online shopping (IFIC Foundation, 2019a), although there are many uncertainties regarding its trajectory and its effects on the food system.

In general, online grocery shoppers tend to make more repeat and frequent purchases, as well as to place larger orders, relative to traditional (nonfood) online shoppers (Yuan et al., 2016). Several features of online grocery shopping make these consumers a promising target for strategies to reduce food waste. For example, such nudges as "recommender systems" are core to online grocery shopping. Recommender systems expose consumers to new items that help them find complementary and relevant items quickly (Yuan et al., 2016). Like many emotional cues used by marketers, however, these systems can also lead to unreflective exploratory behaviors and impulse buying that increase the likelihood of food waste. Further, the combination of recommendations and low search costs can prompt consumers to purchase food that does not match their preferences (Diehl, 2005), as has been seen with other types of products. In addition, the greater variety available online may prompt consumers to have higher expectations about product quality, leading to subsequent disappointment and a greater propensity to discard relative to smaller offline assortments (Diehl and Poynor, 2010). Online shopping also has the potential to affect consumers' psychological distance from food and its meaning.

Eating away from Home: The Influence of the Food Service Industry

Before the COVID-19 pandemic made social distancing a health imperative, Americans were eating out more than ever before, with expenditures

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on food away from home surpassing those on food at home in 2010 (Okrent et al., 2018) (Figure 2-1). As of this writing, the closing of food service venues during the pandemic to minimize transmission of the virus has forced consumers to eat at home more and likely affected other food-related practices. The pandemic, which has disrupted all levels of the food system, is novel and unprecedented, so projections about eating away from home or other food-related behaviors are not possible. Before these changes occurred, however, individuals aged 22–37 were the group most likely to eat away from home; exhibited a greater preference for convenience foods, including ready-to-eat foods; and spent less time and money preparing food at home. Even when they did eat at home, they were more likely to purchase prepared foods (Kuhns and Saksena, 2017).

In general, the popularity of eating away from home has resulted in a substantial increase in plate waste in U.S. restaurants over the past 30 years (Gunders, 2017). Although this is not a recent trend, academic research on drivers of consumer food waste has focused largely on drivers inside the home. The drivers operating at home and away from home are likely to differ significantly (see Chapter 3).

Educational institutions are particularly promising venues for reducing food waste, not only because they are places of learning where lifelong

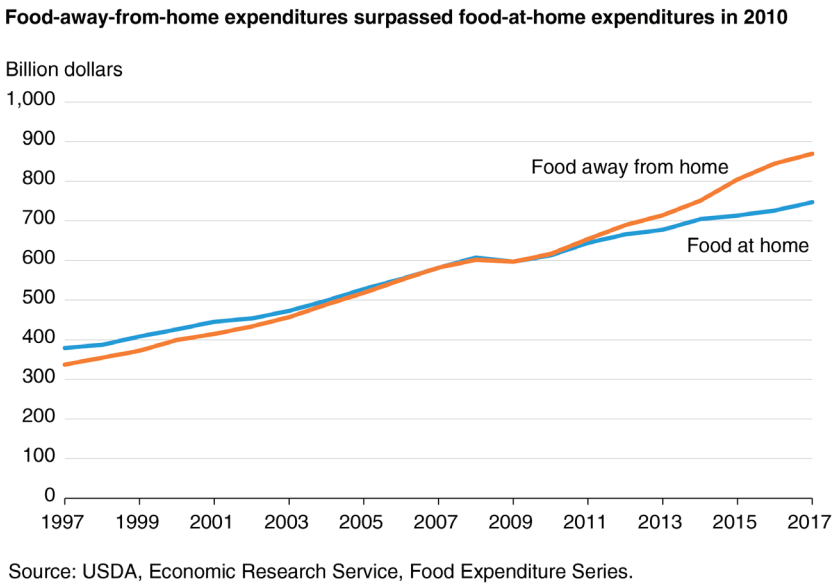

FIGURE 2-1 In 2010, expenditures on food away from home surpassed those on food at home.
SOURCE: USDA/ERS (Elitzak and Okrent, 2018).

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habits are formed, but also because of the number of meals served. For example, the U.S. Department of Agriculture's (USDA's) Food and Nutrition Service, through the National School Lunch Program and School Breakfast Program, serves more than 31 million children per day in approximately 100,000 schools in the United States (95 percent of all schools and residential care institutions). The National School Lunch Program is usually administered by state education agencies, which operate the program through agreements with school food authorities.

Changing Trends in Consumer Payment

Financial trends and economic structures influence consumer practices. The advent of modern payment systems, such as digital wallet payments, and the increasing number of retailers and restaurants discouraging cash-based payment or going completely cashless (Olson and Sweet, 2019) have resulted in increased consumer purchasing (Bourke et al., 2019). In a 2018 survey of 1,222 American consumers, 23 percent of respondents reported using credit cards at supermarkets, while 62 percent said they used debit cards and only 13 percent cash (TSYS, 2019). Research has shown two results of the use of cashless payment: decreased awareness of spending with the absence of the physical aspect of exchanging cash for a product and reduced attention to price cues (Greenacre and Akbar, 2019; Prelec and Simester, 2001). It is reasonable to consider whether the growing use of card-based digital payment also contributes to overpurchasing of food and food waste.

From a retail perspective, card-based payment can be combined with loyalty programs and tied to purchasing nudges (Carolan, 2018), such as reward points or discounts. For example, in a 2017 study of 1,200 consumers, 68 percent of American respondents cited vendors' use of reward programs as the most attractive feature of paying by credit card, an increase from 55 percent in 2015 (TSYS, 2018). Some of the largest food retailers, including Target, Walmart, Costco, Amazon/Whole Foods, and Trader Joe's, also offer reward points when consumers use the retailers' own branded credit cards to make purchases at their stores. Accordingly, a better understanding of trends in the interaction among financial systems, consumer purchasing, and food consumption decisions is critical to understanding consumer practices related to food waste.

The Role of Technology

Broadly speaking, food processing (e.g., freezing, canning, packaging) can be defined as any intentional change to a food occurring between the point of origin and availability for consumption. For consumers, processing

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of food can increase its safety, quality, convenience, and nutritional value. The application of food technology in the manufacturing sector allows foods to be processed in ways that directly influence how consumers buy, prepare, and store their food. In this way, food technology has a profound impact on the amount of wasted food: it directly contributes to longer shelf lives for foods and to the availability of single-serve portions and prepared meals that can result in less potential for waste.

A recent review examines technologies that can be implemented by the food manufacturing sector to decrease food waste at the consumer level, related to the design of the food itself, its processing, and its packaging (Tavill, 2020). For example, foods can be designed with formulas (e.g., preservatives) and processes (e.g., freeze-dried) that result in longer shelf lives. Food packaging, including the use of modified-atmosphere packaging, can also increase shelf life. Food waste can also be reduced by such features as dispensing caps and reclosable zippers that can reduce accidental spillage. Still other technologies may help consumers navigate lack of time and energy and the cognitive demands of everyday life. These technologies include apps and other devices (e.g., online gamification tools, smart grocery carts) to help consumers with food planning during the acquisition, preparation, and storage and increase their awareness of their own food waste levels. As researchers continue to explore the efficacy of these technologies in reducing food waste, it will be important to consider other issues as well, such as consumer acceptability and access, safety, environmental impacts, and equity impacts.

Consumers' Food Literacy

Food literacy is a multidimensional concept that has been defined in many ways. For example, it has been defined from a nutrition and health perspective as referring to food-related knowledge, skills, and behaviors associated with "navigating the food system and using it in order to ensure a regular food intake that is consistent with nutrition recommendations" (Vidgen and Gallegos, 2014, p. 50). Others have characterized food literacy as encompassing such interconnected attributes as food and nutrition knowledge, food skills, self-efficacy, and confidence, as well as people's food decisions and the influence of external factors (e.g., the food system, social determinants of health, sociocultural influences, and eating practices). For the purposes of this report, food literacy is defined as a set of knowledge and skills that help people with the daily preparation of healthy, tasty, affordable meals for themselves and their families. That is, it includes both conceptual knowledge about food and the skills needed to plan, acquire, prepare, and store food.

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Aspects of food literacy most relevant to minimizing food waste are related to planning, preparing and cooking, and storing food. Food literacy has a significant influence on these behaviors because it is associated with a number of drivers of food waste at the consumer level (see Chapter 3). Because it is likely to be closely related to the root causes of food waste, its improvement should result in less food waste. For example, better knowledge about food safety and of improved methods for preparing and storing food allows people to maximize the life of their food. This section describes the most common sources of food and nutrition information in the United States. It also explains how some important knowledge gaps and misconceptions, particularly about food safety, are likely to relate to food waste at the consumer level.

Sources of Food and Nutrition Information

Food literacy varies greatly among consumers, partly because they acquire information about food through a variety of sources, settings, and personal experiences. Some aspects of food literacy (e.g., knowing what parts of a food are edible) relate to culture and social norms.

A frequent source of food and nutrition information is product marketing at the physical or online store. In these settings, consumers face a challenging communication environment, including symbols on packages and a multitude of messages, some based on big data and personalized. Further, the messages encountered differ depending on the setting. Thus, for example, people with access to farmers' markets and full-size grocery stores with a wide array of fresh and prepared foods may receive different information about food than do people with access only to convenience stores (NASEM, 2016).

American consumers are also increasingly influenced by a growing industry centered on food-related television programming, celebrity chefs, and celebrities. For some consumers, this industry has facilitated a growing focus on the relationship between food and health and additional knowledge about food preparation and planning, while for others it has encouraged spending less time planning and preparing meals (e.g., the use of meal kits) (NASEM, 2016).

Government sources (e.g., the U.S. Centers for Disease Control and Prevention [CDC], the U.S. Food and Drug Administration [FDA], USDA) offer information to increase consumers' knowledge about a variety of food-related topics, such as the health benefits of fruits and vegetables and food safety. Additional guidance for consumers can come from mobile apps, such as FoodKeeper, developed by USDA to help maximize food freshness and quality through storage advice for specific foods; the FDA's Nutrition Facts label; or books (Gunders, 2015; Hard, 2018; James Beard

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Foundation, 2018; Lightner, 2018). In one study, consumers reported that they often rely on more than one source for food-related information, but put the most trust in registered dietitian nutritionists and health care professionals, followed by scientific studies, wellness and fitness professionals, and government agencies. Least trusted were food manufacturers and news articles. And younger adults were more trusting of technology-based sources compared with older Americans (IFIC Foundation, 2018). Recently, the COVID-19 pandemic has driven many consumers to place more trust in government agencies, scientific studies, health care professionals, and friends and family (IFIC Foundation, 2019b). Still, consumers are much less likely to be exposed to government and evidence-based messages than to those from the food industry or influencers.

Increasingly, food literacy is being taught in schools. In the years following World War II, home economics programs that included cooking skills slowly disappeared, but many U.S. schools have started developing food literacy-related curricula involving school gardens and cooking programs (Blair, 2009). University courses have also emerged as an opportunity to develop food literacy. With a focus on literacy about food waste, the Food Waste Warrior Toolkit[3] was developed by the World Wildlife Fund (WWF) to provide lessons, activities, and resources informing children of different ages about the effect of food waste on the planet. For children, family members are a frequent source of information, but the reverse is also true: children can be a vehicle for improving food literacy in the family by introducing skills learned in school.

Consumers receive an immense volume and diversity of information about food through social and digital media and many other means. This information includes opinions, advice, and scientific information, and it can be contradictory, confusing consumers. American consumers need accurate and consistent information about how to plan, shop for, prepare, and store food, particularly at this pivotal moment as the food system's supply chain continues to shift in response to the COVID-19 pandemic.

Myths about Food and Nutrition

A workshop held by the National Academies in 2016 addressed the growing gap between cultural interest in food and actual scientific food literacy, due in part to "pop culture nutrition noise" that has created a disconnect between science and food-related behaviors (NASEM, 2016, p. 23). A few misperceptions—or myths—about food quality, food safety, composting, and food production practices in particular influence food waste behaviors.

[3] See https://www.worldwildlife.org/teaching-resources/toolkits/food-waste-warrior-toolkit.

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Awareness about Wasted Food

Neff and colleagues (2015) studied U.S. consumers' awareness, attitudes, and behaviors related to food waste using an online survey. Forty-two percent of respondents had seen information about food waste. About 62 percent described themselves as "very" or "fairly" knowledgeable about the subject; 69 percent reported discarding 10 percent or less of their food and only 10 percent reported discarding 30 percent or more. When asked how much of their household's food waste could be avoided, only 29 percent responded "a fair amount" or "a lot." These results are at odds with current estimates of overall food waste at the consumer level, suggesting that consumers underreport their waste and that awareness of the problem could be improved. Worries about food poisoning and the desire to eat only the freshest food were the top reasons people cited for discarding food (see Figure 2-2), results that align with those of a 2019 survey that identified spoilage or staleness as the top reason foods end up in the garbage (83%) (IFIC Foundation, 2019a). That survey also revealed that among the motivations for reducing food discards, environmental concerns was last, highlighting the possible lack of knowledge in this area and an opportunity to intervene.

Food Safety and Quality

Although the CDC, FDA, and USDA all provide clear information regarding food preparation and safety, handling foods in a safe manner can be counterintuitive and a challenge in practice. For example, an FDA

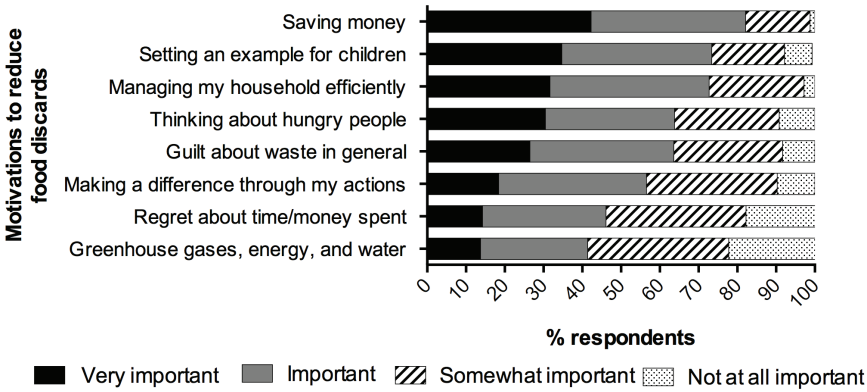

FIGURE 2-2 Responses regarding eight possible reasons for discarding food.
NOTES: Percentages indicate the proportion of respondents who chose each response. Restricted to respondents reporting in a separate question that they compost at least some of their food; percentages for all other motivations reflect the entire sample.
SOURCE: Neff et al., 2015.

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survey found that, despite their concerns about raw chicken (66%) and raw beef (41%) being contaminated, as many as 68 percent of consumers said they always washed raw chicken parts before cooking them, a practice not recommended by food safety experts because it increases the risk of cross-contamination of other foods and surfaces (FDA, 2016b). In another example, although proper food storage to maximize shelf life is the most common way consumers try to reduce wasted food (60%) (IFIC Foundation, 2019a), studies have shown that consumers are confused about the meaning of shelf-life labels (i.e., date labels) (see Box 2-2). In terms of food quality, the 2019 IFIC Food and Health Survey cited above showed that having trust in a brand, recognizing the product ingredients, and knowing where their food comes from are all highly important for consumers (IFIC Foundation, 2019b). In addition, as described in Box 2-2, consumers often judge the quality of a food by its appearance, which results in the wasting of high-quality food.

Environmental Sustainability

The 2019 IFIC Food and Health Survey found that while environmental sustainability was the lowest-rated of the purchase drivers included in the survey, 6 in 10 consumers said it was difficult to determine whether the food choices they made were environmentally sustainable, and 63 percent of those respondents said environmental sustainability would have a greater influence on their choices if this information was clearer (IFIC Foundation, 2019b). This lack of clarity is exemplified by two myths that may increase food waste: the perceptions that all packaging is bad for the environment and that composting is the best option for managing excess household food (Box 2-3).

Nutrition

The 2019 IFIC Food and Health Survey found that 60 percent of consumers had seen the MyPlate graphic, a USDA tool designed to communicate dietary information. However, only 1 in 4 consumers surveyed said they sought health benefits from food (IFIC Foundation, 2019b). It is encouraging that in the 2014 FDA Health and Diet Survey, 77 percent of U.S. adult respondents reported using the Nutrition Facts label when buying food products (FDA, 2016a). Nevertheless, consumers appear to be confused about the benefits and risks of food processing; the misperception that fresh products provide more essential nutrients relative to processed products is particularly pervasive (see Box 2-4). This perception likely results in higher amounts of food waste, as consumers may favor perishable foods over frozen or canned foods.

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BOX 2-2
Myths about Food Safety and Quality

All date labels are related to food safety. Most packaged foods in the United States carry a date label. The first generation of code dates on labels, which were largely "blind" to consumers, allowed producers to better manage and rotate their inventories, track production performance and quality metrics, respond to consumer complaints or inquiries, and identify recall products. In the 1990s, with the advent of the Nutrition Labeling and Education Act (NLEA), producers began to see more demand for product transparency and pressure to "decode" their date labels. Although the NLEA guidelines set clear requirements for nutrition labeling, consumer-facing date labeling was to be defined and implemented voluntarily by the food industry. As a result, companies chose certain language based on package space constraints, marketing purposes (e.g., Budweiser's "born on" date), or personal preference. This lack of standardization has contributed to consumer confusion. According to one survey, for example, the majority of consumers have the misconception that the phrase "use by" indicates the last date the food is safe for consumption, and fewer than half of respondents correctly defined "sell by" date. Therefore, although many people throw food away once the date on the label passes, for most foods the date is a manufacturer's best guess as to how long the product will be at its peak quality (Broad Lieb et al., 2016). Most products are still perfectly edible for days (milk, yogurt), weeks (cereal, salty snacks), or even months (frozen and canned goods) past the date on the label.

"Ugly" produce is not as good for you as* produce of *"perfect" quality. Produce's appearance (e.g., shape, color) is often erroneously taken to be a signal of its internal quality, whether evaluated in terms of nutrition or taste. Interpersonal perception research has established the existence of a robust belief that external beauty is an indicator of internal goodness (Dion et al., 1972; Eagly et al., 1991) across many different types of products, from financial documents (Townsend and Shu, 2010) to packaged goods (Raghubir and Greenleaf, 2006). In the domain of foods, this finding would suggest that consumers would assume food that fails to conform to typical appearance expectations (e.g., a carrot with appendages) is of a lesser quality. Moreover, consumers may show confirmatory bias that reinforces this myth: because they expect ugly produce to taste worse, they may experience the taste of that produce more negatively. Even when researchers assure consumers that undamaged food (not bruised or punctured) is safe to eat, its ugliness alone can be interpreted as a sign of reduced quality. Grewal and colleagues (2018) also found that unless external forces either bolstered consumers' self-esteem or directed them to discount the attractiveness of food, they interpreted consumption of unattractive produce as a signal that they themselves were of lesser worth. Thus, the myth that what is beautiful is good (and what is ugly is bad) affects not only consumption tendencies but also the consumer's self-image.

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BOX 2-3
Myths about Food and the Environment

Disposing of packaging is worse for the environment than disposing of food.

According to a 2015 study by Sealed Air,[a] 9 in 10 consumers incorrectly believed that all packaging is worse for the environment than is discarded food. Misperceptions of the environmental impacts of packaging relative to the environmental investment in food obscures the fact that packaging can play an important role in reducing food waste (AMERIPEN, 2018). According to a 2016 study by Rethink Food Waste Through Economics and Data (ReFED), packaging is one of three food waste prevention strategies that has the greatest economic and environmental impact (ReFED, 2016). Packaging can play a critical role in sustainable food systems, protecting products from damage, spoilage, and contamination all along the value chain, from where it is grown to the point of consumption, whether at home or away from home.

Disposing of food that I don't eat is not bad for the environment because I am composting it. Composting is a better choice as a discard destination for uneaten food relative to disposal in a landfill in terms of environmental consequences (EPA, 2020) because it produces dramatically fewer greenhouse gas emissions. In addition, the resulting compost material can be put to use in a number of excellent ways, such as fertilizer replacement, water retention, and carbon sequestration. Despite these advantages, composting is not the best approach to managing edible but uneaten food: the benefits of reducing food waste by acquiring only what will be consumed and consuming all the edible parts, which include saving resources and reducing the environmental impacts of food production, far outweigh the benefits of composting. However, researchers have found that 41 percent of people feel less guilty about discarding food if they compost it rather than throw it away (Neff et al., 2015). This so-called "licensing effect" can be characterized as a myth in the sense that consumers' misunderstanding of the appropriate use of composting can result in greater environmental impacts.

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[a] Personal communication. Sealed Air. 2017. *Internal life cycle study. Emails with Terry Grill and Ron Cotterman.*

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BOX 2-4
Myths about Nutrition

Only fresh fruits and vegetables provide the necessary nutrients for a healthy diet. Marketing and education programs often present fresh fruits and vegetables as the best source of quality nutrients. This assertion can lead to unintended consequences, such as consumers questioning the nutritional quality of other forms of produce. Yet perishables are more likely to be discarded than frozen and canned products because of their shorter shelf lives. They also often travel from other states or even other countries, which affects their freshness and nutritional content. Grocers and other retail outlets offer flash frozen and canned produce that could help many Americans meet dietary recommendations. These products are convenient; generally are less expensive than their fresh counterparts; and, important to this report, have a much longer shelf life. A study by Michigan State University Extension found that canned fruits and vegetables are just as nutritious as fresh or frozen. Moreover, fiber found in legumes becomes more soluble during canning, making canned beans a more acceptable choice for those consumers who have difficulty digesting legumes (Miller and Knudsen, 2014).

EFFORTS TO ADDRESS CONSUMER FOOD WASTE

The past decade has seen significant momentum to address food waste, in part because the publication of several seminal reports raised awareness of the substantial rates of waste across the food system (e.g., Gunders, 2017). Researchers and other stakeholders have not only communicated the magnitude of the problem but also sought approaches for addressing it.

The problem has generated great interest among the food industry (e.g., the Food Waste Reduction Alliance [FWRA]); environmental organizations (e.g., the Natural Resources Defense Council, WWF, the World Resources Institute); food justice groups (e.g., Feeding America); and others. Each of these groups has different goals, including increasing food production efficiencies, decreasing greenhouse gas emissions, improving resource efficiencies, and ensuring food security in communities. Groups focused exclusively on the mission of reducing food waste have produced important reports to raise awareness and provide roadmaps and practical solutions (e.g., ReFED in the United States, the Waste and Resources Action Programme in the United Kingdom). Many organizations have developed guidelines to help institutions and consumers reduce food waste (see Table C-2 in Appendix C).

The 2015 United Nations Agenda for Sustainable Development specifically addressed food waste, calling for a 50 percent per capita reduction in wasted food at the retail and consumer levels and a reduction in food

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losses along the supply chain by 2030 (United Nations, 2020). According to projections, those reductions would have vast effects on food security, land available for agriculture, and greenhouse gas emissions (Searchinger et al., 2018; Springmann et al., 2018). Another noteworthy international initiative is Champions 12.3, a coalition of leaders from government, business, international organizations, research institutions, farmer groups, and civil society dedicated to "inspiring ambition, mobilizing action, and accelerating progress toward achieving SDG [Sustainable Development Goals] Target 12.3 by 2030."[4] This group convenes to assess progress, share experiences in overcoming barriers and success stories, and identify opportunities. Many other governmental and nongovernmental initiatives in countries around the world are contributing to the momentum.

U.S. Government Initiatives

In addition to their individual activities related to food waste (e.g., educational material on date labels, support for research), relevant U.S. federal agencies have engaged in interagency collaborations to address the problem. In 2015, EPA and USDA called for a first national goal of a 50 percent reduction in food loss and waste by 2030, which stimulated great motivation to act among businesses and organizations. Of note is the creation of the Food Loss and Waste 2030 Champions voluntary program, which features businesses and organizations that have committed to reducing food loss and waste in their own operations in the United States by 50 percent by 2030 (see examples of their work in Table C-3 in Appendix C).

Federal government efforts resulted in the announcement of the 2019 U.S. interagency (EPA, USDA, and FDA) Winning on Reducing Food Waste Initiative, which recently published a strategic plan (EPA, 2019).[5] In Congress, changes to federal policy are being considered, such as the Food Date Labeling Act, which would standardize the language on date labels at the national level so consumers would better understand their meaning. Other proposed federal legislation, the School Food Recovery Act, would provide resources for schools to implement food waste education programs.

Motivated by the 2030 goal, many state and local governments have adopted policies and plans for reducing the amount of food that is wasted in their jurisdictions (Gorski et al., 2017). Many of these efforts have focused on recycling wasted food by encouraging composting and instituting landfill bans. As many as one-fourth of communities in the United States have implemented unit-based pricing policies whereby residents pay for

[4] See https://champions123.org/about/.

[5] See https://www.epa.gov/sustainable-management-food/winning-reducing-food-waste-federal-interagency-strategy.

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the removal of municipal solid waste per unit of waste collected rather than through a fixed fee or property taxes (EPA, 2016). These policies have been successful at reducing food waste (see also Chapter 4). Although not directly intended for source reduction, policies that ban the disposal of organic materials in landfills, introduced in six states and seven municipalities as of 2019 (Sandson and Broad Leib, 2019), may help reduce food waste. These initiatives and programs are relatively new and have not been in place long enough for their effects on reducing the amount of wasted food in the United States to be evaluated (see Box C-1 in Appendix C for some examples).

U.S. Food Industry Efforts

Like consumers, the U.S. food industry is diverse across many dimensions, including culture and philosophy. At many companies, however, reducing food waste is viewed as the right thing to do and as a component of an overall sustainability strategy. For example, advancing packaging and processing technologies to make food last longer has long been a priority in the manufacturing sector. Although originally designed to improve safety, convenience, and quality, these technologies are now at the core of reducing food waste throughout the food system, including at the consumer level. Numerous manufacturers are working to improve these technologies and their acceptability to consumers.

The retail and food service industries interact with consumers in varied and complex ways. These businesses have direct relationships with consumers and seek to earn and retain their trust, loyalty, and patronage. They also have reason to prompt consumers to purchase more and different foods, and they use their understanding of consumers' motivations related to acquiring food, as well as marketing tactics, to influence consumers' purchases.

Although retaining consumers and selling more food are sensible goals for businesses, many of the tactics they use may have unintended consequences, including unnecessary food waste by consumers. For example, larger serving sizes are particularly appealing to value-oriented consumers, regardless of the potential for excess food to be wasted. The fear of losing customers may discourage many businesses, particularly restaurants, from offering smaller serving sizes. In the retail sector, such strategies as nonlinear pricing schemes that promote the purchase of larger sizes have been used as a means of nudging consumers toward choices that yield greater profit (Dobson and Gerstner, 2010). Further, food delivery services, which have become even more popular during the COVID-19 pandemic, have virtually no incentive to encourage consumers to eat already-purchased foods, since this waste-reducing behavior might compromise their growth.

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Nevertheless, most companies in the food industry (manufacturers, retailers, and food service venues) recognize the importance of reducing food waste within their own operations. Empirical data show that food businesses can reap economic benefits from investing in approaches to reduce food waste (Hanson and Mitchell, 2017). It may be counterintuitive, however, for businesses to strive to help consumers waste less food if they believe doing so might decrease appeal to customers and profits. Moreover, leaders might not be aware of the important nonfinancial reasons for reducing food loss and waste, related to food security, environmental sustainability, stakeholder relationships, and a sense of ethical responsibility.

There are opportunities for the food industry to promote consumer behaviors that result in reductions in food waste while maintaining economic sustainability. The adoption of voluntary environmental programs (e.g., Carbon Disclosure Project, Global Reporting Initiative, Leadership in Engineering and Environmental Design, International Standard for Organization [ISO] 14001, or the Certified Green Restaurant standard) that are administered by third-party organizations can bring increased customer loyalty (Borck and Coglianese, 2009). Being able to communicate credibly that they are taking action to support waste reduction or other beneficial goals (e.g., pollution control) may make companies more attractive to potential consumers. Despite their effectiveness,[6] however, these certification programs are largely silent on specific actions businesses can take to decrease waste that might be generated by their consumers as a consequence of their operations. Even in the case of the Certified Green Restaurant standard, only two of the hundreds of qualifying practices support reducing waste created by consumers (e.g., offering smaller reduced-price versions for at least half of all entrees or offering bread only upon request).

Three sectors of the food industry—manufacturers, retailers, and restaurants—have collaborated on efforts to reduce food waste in their operations through the FWRA, which was initiated in 2011 and focused initially on assessing food waste and associated practices. Recently, the FWRA entered a formal agreement with USDA, EPA, and FDA to support the interagency Winning on Reducing Food Waste Initiative.

Thus far, most industry efforts have focused on businesses' operations, with less attention to decreasing consumer food waste. However, some individual companies have already publicly committed to increasing their efforts to reduce food waste, for example, by offering trayless dining

[6] ISO 14001, for example, is a standardized environmental management system (EMS) that has been implemented by more than 300,000 organizations globally. An EMS helps organizations develop a holistic approach to identifying, managing, monitoring, and controlling aspects of operations that can affect the natural environment. Firms that have adopted the ISO 14001 EMS may be certified by third-party certifiers who can then credibly communicate firm adoption and adherence. For evidence of the effectiveness of ISO 14001, see Boiral et al. (2018).

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or smaller portion sizes (see Table C-3 in Appendix C for additional examples). In addition, the Consumer Brands Association (formerly known as the Grocery Manufacturers Association) and FMI-The Food Industry Association (formerly the Food Marketing Institute) have collaborated to develop a set of voluntary standards for date labeling to help consumers make better decisions about acquiring and utilizing food, which could result in less disposal of wholesome food. An example of a relevant initiative is guidance developed in the United Kingdom for retailers on how to develop food promotions that will not contribute to increased food waste.[7]

At the regional level, such initiatives as the West Coast Voluntary Agreement to Reduce Wasted Food,[8] which recently called for the engagement of food retailers and their supply chain partners to reduce and prevent food waste by 50 percent by 2030, show promise. At the global level, the Consumers Goods Forum,[9] a global association of 400 companies representing $2.7 trillion in combined annual sales, has committed to halving food waste by 2025.

SUMMARY AND CONCLUSIONS

A systems approach to reducing consumer food waste is premised on the fact that consumers are embedded within multiple systems (natural, economic, political, and technological) and that positively influencing consumer practices requires an understanding of interactions within these systems. Therefore, addressing the problem requires moving beyond consumers and examining the myriad influences on their food waste behaviors within the larger food system. This chapter serves as the foundation for the discussion in Chapter 3 of the drivers of consumer behavior that have been identified in the scientific literature, which operate at the individual, intrapersonal, and interpersonal levels, as well as the broader, societal level.

CONCLUSION 2-1: Consumers' decisions about food are influenced by such individual factors as income, attitudes, and knowledge. Consumers are also embedded within a food system that includes natural, economic, political, social, and technological contexts. The drivers of consumer food waste need to be understood in the context of interactions within the food system, including the manufacturing, retail, and food service sectors, as well as food-related media and advertising.

[7] See https://www.wrap.org.uk/sites/files/wrap/Food%20Promotions-%20Guidance%20for%20Retailers.pdf.

[8] See http://pacificcoastcollaborative.org.

[9] See https://www.theconsumergoodsforum.com.

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CONCLUSION 2-2: Consumers' knowledge and attitudes with respect to food safety and quality, nutrition, and food waste are influenced by norms and culture, as well as information from many sources, including government, marketing, social media, public campaigns, and other sources that are not always accurate and evidence-based or culturally appropriate. Addressing consumers' misconceptions about food is a promising goal for any effort to reduce food waste.

CONCLUSION 2-3: Individual companies, government entities, industry and public–private partnerships, and nonprofit organizations have undertaken significant efforts to reduce food waste, but few of these efforts have targeted consumer-level food waste, and the efforts have not been coordinated or systematically evaluated.

CONCLUSION 2-4: The food industry, including retailers, food service providers, and manufacturers, has a substantial influence on consumers' decisions about food, which can be used to reduce food waste at the consumer level. Identifying business and marketing practices that can serve customers and generate profits while also discouraging food waste is a promising goal for food waste reduction efforts.

REFERENCES

AMERIPEN. 2018. *Quantifying the value of packaging as a strategy to reduce food waste in America*. Available: https://www.ameripen.org/general/custom.asp?page=foodwastereport.

Aschemann-Witzel, J., I.E. de Hooge, V.L. Almli, and M. Oostindjer. 2018. Fine-tuning the fight against food waste. *Journal of Macromarketing* 38(2):168-184.

Baker, J., A. Parasuraman, D. Grewal, and G.B. Voss. 2002. The influence of multiple store environment cues on perceived merchandise value and patronage intentions. *Journal of Marketing* 66(2):120-141.

Bird Jernigan, V.B., A.L. Salvatore, M. Williams, M. Wetherill, T. Taniguchi, T. Jacob, T. Cannady, M. Grammar, J. Standridge, J. Fox, J. Tingle Owens, J. Spiegel, C. Love, T. Teague, and C. Noonan. 2018. A healthy retail intervention in Native American convenience stores: The Thrive community-based participatory research study. *American Journal of Public Health* e1-e8.

Blair, D. 2009. The child in the garden: An evaluative review of the benefits of school gardening. *Journal of Environmental Education* 40(2):15-38.

Boiral, O., L. Guillaumie, I. Heras-Saizarbitoria, and C.V. Tayo Tene. 2018. Adoption and outcomes of ISO 14001: A systematic review. *International Journal of Management Reviews* 20(2):411-432.

Borck, J.C., and C. Coglianese. 2009. Voluntary environmental programs: Assessing their effectiveness. *Annual Review of Environment and Resources* 34(1):305-324.

Bourke, N., T. Roche, and R. Siegel. 2019. *Rise of cashless retailers problematic for some consumers. Cash remains important payment option for many*. Available: https://www.pewtrusts.org/en/research-and-analysis/articles/2019/11/08/rise-of-cashless-retailers-problematic-for-some-consumers.

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Bower, K.M., R.J. Thorpe, Jr., C. Rohde, and D.J. Gaskin. 2014. The intersection of neighborhood racial segregation, poverty, and urbanicity and its impact on food store availability in the United States. *Preventive Medicine* 58:33-39.

Broad Leib, E., C. Rice, R. Neff, M. Spiker, A. Schklair, and S. Greenberg. 2016. Consumer perceptions of date labels: National survey. Available: http://www.chlpi.org/wp-content/uploads/2013/12/Consumer-Perceptions-on-Date-Labels_May-2016.pdf.

Carolan, M. 2018. Big data and food retail: Nudging out citizens by creating dependent consumers. *Geoforum* 90:142-150.

Caspi, C.E., K. Lenk, J.E. Pelletier, T.L. Barnes, L. Harnack, D.J. Erickson, and M.N. Laska. 2017. Association between store food environment and customer purchases in small grocery stores, gas-marts, pharmacies and dollar stores. *International Journal of Behavioral Nutrition and Physical Activity* 14(1):76.

Coleman-Jensen, A., M.P. Rabbitt, C.A. Gregory, and A. Singh. 2019. *Household food security in the United States in 2018, ERR-270*. Washington, DC: U.S. Department of Agriculture, Economic Research Service.

Contento, I.R. 2016. Determinants of food choice and dietary change: Implications for nutrition education. In *Nutrition education. Linking research, theory, and practice*. Third ed., edited by I.R. Contento. Burlington, MA: Jones and Bartlett Learning. Pp. 30-58.

Curl, J. 2012. *For all the people: Uncovering the hidden history of cooperation, cooperative movements, and communalism in America*. Oakland, CA: PM Press.

Diehl, K. 2005. When two rights make a wrong: Searching too much in ordered environments. *Journal of Marketing Research* 42(3):313-322.

Diehl, K., and C. Poynor. 2010. Great expectations?! Assortment size, expectations, and satisfaction. *Journal of Marketing Research* 47(2):312-322.

Dimitri, C., and A. Effland. 2018. From farming to food systems: The evolution of US agricultural production and policy into the 21st century. *Renewable Agriculture and Food Systems* 1-16.

Dion, K., E. Berscheid, and E. Walster. 1972. What is beautiful is good. *Journal of Personality and Social Psychology* 24(3):285-290.

Dobson, P.W., and E. Gerstner. 2010. For a few cents more: Why supersize unhealthy food? *Marketing Science* 29(4):770-778.

Eagly, A.H., R.D. Ashmore, M.G. Makhijani, and L.C. Longo. 1991. What is beautiful is good, but…: A meta-analytic review of research on the physical attractiveness stereotype. *Psychological Bulletin* 110(1):109-128.

Elitzak, H., and A. Okrent. 2018. New U.S. food expenditure estimates find food-away-from-home spending is higher than previous estimates. *Amber Waves*. Available: https://www.ers.usda.gov/amber-waves/2018/november/new-us-food-expenditure-estimates-find-food-away-from-home-spending-is-higher-than-previous-estimates.

EPA (U.S. Environmental Protection Agency). 2016. *Communities. 2006 PAYT programs*. Available: https://archive.epa.gov/wastes/conserve/tools/payt/web/html/06comm.html.

EPA. 2019. *Winning on Reducing Food Waste. FY 2019-2020 federal interagency strategy*. Available: https://www.epa.gov/sustainable-management-food/winning-reducing-food-waste-fy-2019-2020-federal-interagency-strategy.

EPA. 2020. *Sustainable management of food. Reducing the impact of wasted food by feeding the soil and composting*. Available: https://www.epa.gov/sustainable-management-food/reducing-impact-wasted-food-feeding-soil-and-composting.

FDA (U.S. Food and Drug Administration). 2016a. *2014 health and diet survey*. Available: https://www.fda.gov/food/cfsan-constituent-updates/fda-releases-2014-health-and-diet-survey-findings.

FDA. 2016b. *2016 FDA food safety survey*. Available: https://www.fda.gov/food/cfsan-consumer-behavior-research/2016-food-safety-survey-report.

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Filipová, A., V. Mokrejšová, Z. Šulc, and J. Zeman. 2017. Characteristics of food-wasting consumers in the Czech Republic. *International Journal of Consumer Studies* 41(6):714-722.

FMI (Food Marketing Institute) and Nielsen. 2018. *The digitally engaged food shopper*. Available: https://www.fmi.org/newsroom/latest-news/view/2018/01/29/fmi-and-nielsen-report-70-of-consumers-will-be-grocery-shopping-online-by-2024.

Ganglbauer, E., G. Fitzpatrick, and R. Comber. 2013. Negotiating food waste: Using a practice lens to inform design. *ACM Trans Computer-Human Interact* 20(2):Article 11.

Gorski, I., S. Siddiqi, and R. Neff. 2017. *Governmental plans to address waste of food*. Available: https://clf.jhsph.edu/sites/default/files/2019-01/governmental-plans-to-address-waste-of-food.pdf.

Greenacre, L., and S. Akbar. 2019. The impact of payment method on shopping behaviour among low income consumers. *Journal of Retailing and Consumer Services* 47:87-93.

Grewal, L., J. Hmurovic, C. Lamberton, and R.W. Reczek. 2018. The self-perception connection: Why consumers devalue unattractive produce. *Journal of Marketing* 83(1):89-107.

Gunders, D. 2015. *Waste-free kitchen handbook: A guide to eating well and saving money by wasting less food*. San Francisco, CA: Chronicle Books.

Gunders, D. 2017. *Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill*. New York: Natural Resources Defense Council.

Hanson, C., and P. Mitchell. 2017. *The business case for reducing food loss and waste*. Washington, DC: Champions 12.3.

Hard, L.-J. 2018. *Cooking with scraps: Turn your peels, cores, rinds, and stems into delicious meals*. New York: Workman Publishing Company, Inc.

IFIC (International Food Information Council) Foundation. 2018. *2018 food and health survey*. Available: https://foodinsight.org/wp-content/uploads/2018/05/2018-FHS-Report-FINAL.pdf.

IFIC Foundation. 2019a. *A survey of consumer behaviors and perceptions of food waste*. Available: https://foodinsight.org/wp-content/uploads/2019/09/IFIC-EPAL-Food-Waste-Deck-Final-9.16.19.pdf.

IFIC Foundation. 2019b. *2019 food and health survey*. Available: https://foodinsight.org/2019-food-and-health-survey.

James Beard Foundation. 2018. *Waste not: How to get the most from your food*. New York: Rizzoli International Publications, Inc.

Kuhns, R., and M. Saksena. 2017. *Food purchase decisions of millennial households compared to other generations, EIB-186*. Washington, DC: U.S. Department of Agriculture, Economic Research Service.

Lee, K.C.L. 2018. Grocery shopping, food waste, and the retail landscape of cities: The case of Seoul. *Journal of Cleaner Production* 20(172):325-334.

Lightner, J. 2018. *Scraps, peels, and stems: Recipes and tips for rethinking food waste at home*. Seattle, WA: Skipstone.

Miller, S.R., and W.A. Knudson. 2014. Nutrition and cost comparisons of select canned, frozen, and fresh fruits and vegetables. *American Journal of Lifestyle Medicine* 8(6):430-437.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2016. *Food literacy: How do communications and marketing impact consumer knowledge, skills, and behavior? Workshop summary*. Washington, DC: The National Academies Press.

Neff, R.A., M.L. Spiker, and P.L. Truant. 2015. Wasted food: U.S. Consumers' reported awareness, attitudes, and behaviors. *PLoS ONE* 10(6).

Okrent, A., E. Howard, T. Park, and S. Rehkamp. 2018. *Measuring the value of the U.S. Food system: Revisions to the food expenditure series, TB-1948*. Washington, DC: U.S. Department of Agriculture, Economic Research Service.

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Olson, A., and K. Sweet. 2019. *As cashless stores grow, so does the backlash*. Available: https://business.financialpost.com/pmn/business-pmn/as-cashless-stores-grow-so-does-the-backlash.

Prelec, D., and D. Simester. 2001. Always leave home without it: A further investigation of the credit-card effect on willingness to pay. *Marketing Letters* 12(1):5-12.

Raghubir, P., and E.A. Greenleaf. 2006. Ratios in proportion: What should the shape of the package be? *Journal of Marketing* 70(2):95-107.

ReFED (Rethink Food Waste Through Economics and Data). 2016. *A roadmap to reduce U.S. food waste by 20 percent*. Available: https://www.refed.com/downloads/ReFED_Report_2016.pdf.

Riches, G. 2011. Thinking and acting outside the charitable food box: Hunger and the right to food in rich societies. *Development in Practice* 21(4/5):768-775.

Ross, M., E.C. Campbell, and K.L. Webb. 2013. Recent trends in the nutritional quality of food banks' food and beverage inventory: Case studies of six California food banks. *Journal of Hunger and Environmental Nutrition* 8(3):294-309.

Sandson, K., and E. Broad Leib. 2019. *Bans and beyond: Designing and implementing organic waste bans and mandatory organics recycling laws*. Cambridge, MA: Harvard Law School Food Law and Policy Clinic; Center for EcoTechnology.

Searchinger, T., S. Wirsenius, T. Beringer, and P. Dumas. 2018. Assessing the efficiency of changes in land use for mitigating climate change. *Nature* 564(7735):249-253.

Setti, M., L. Falasconi, A. Segrè, I. Cusano, and M. Vittuari. 2016. Italian consumers' income and food waste behavior. *British Food Journal* 118(7):1731-1746.

Sneed, C.T. 2014. *Local food purchasing in the farmers' market channel: Value-attitude behavior theory.* Available: https://trace.tennessee.edu/utk_graddiss/3168.

Soma, T. 2019. Space to waste: The influence of income and retail choice on household food consumption and food waste in Indonesia. *International Planning Studies*. Available: https://doi.org/10.1080/13563475.2019.1626222.

Springmann, M., M. Clark, D. Mason-D'Croz, K. Wiebe, B.L. Bodirsky, L. Lassaletta, W. de Vries, S.J. Vermeulen, M. Herrero, K.M. Carlson, M. Jonell, M. Troell, F. DeClerck, L.J. Gordon, R. Zurayk, P. Scarborough, M. Rayner, B. Loken, J. Fanzo, H.C.J. Godfray, D. Tilman, J. Rockstrom, and W. Willett. 2018. Options for keeping the food system within environmental limits. *Nature* 562(7728):519-525.

Tarasuk, V., and J.M. Eakin. 2005. Food assistance through "surplus" food: Insights from an ethnographic study of food bank work. *Agriculture and Human Values* 22(2):177-186.

Tavill, G. 2020. Industry challenges and approaches to food waste. *Physiology and Behavior* 223:112993.

Thaler, R.H., and C.R. Sunstein. 2008. *Nudge: Improving decisions about health, wealth, and happiness*. New Haven, CT: Yale University Press.

Townsend, C., and S.B. Shu. 2010. When and how aesthetics influences financial decisions. *Journal of Consumer Psychology* 20(4):452-458.

TSYS. 2018. *2017 U.S. consumer payment study.* Available: https://www.tsys.com/Assets/TSYS/downloads/rs_2017-us-consumer-payment-study.pdf.

TSYS. 2019. *2018 U.S. consumer payment study.* Available: https://www.tsys.com/Assets/TSYS/downloads/rs_2018-us-consumer-payment-study.pdf.

United Nations. 2020. *Sustainable development goals. Goal 12: Ensure sustainable consumption and production patterns*. Available: https://www.un.org/sustainabledevelopment/sustainable-consumption-production.

USDA (U.S. Department of Agriculture). 2016. *Direct farm sales of food: Results from the 2015 local food marketing practices survey.* Available: https://www.nass.usda.gov/Publications/Highlights/2016/LocalFoodsMarketingPractices_Highlights.pdf.

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Verma, M., L. de Vreede, T. Achterbosch, and M.M. Rutten. 2020. Consumers discard a lot more food than widely believed: Estimates of global food waste using an energy gap approach and affluence elasticity of food waste. *PLoS ONE* 15(2):e0228369.

Vidgen, H.A., and D. Gallegos. 2014. Defining food literacy and its components. *Appetite* 76:50-59.

Warshawsky, D.N. 2015. The devolution of urban food waste governance: Case study of food rescue in Los Angeles. *Cities* 49:26-34.

Weise, E. 2005. Support from city folk takes root on the farm. *USA Today*, May 12.

Yuan, M., Y. Pavlidis, M. Jain, and K. Caster. 2016. Walmart online grocery personalization: Behavioral insights and basket recommendations. In *International conference on conceptual modeling*. Springer, Cham. Pp. 49-64.

Zepeda, L. 2009. Which little piggy goes to market? Characteristics of US farmers' market shoppers. *International Journal of Consumer Studies* 33(3):250-257.

Zitcer, A. 2015. Food co-ops and the paradox of exclusivity. *Antipode* 47(3):812-828.

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3

Drivers of Food Waste at the Consumer Level and Implications for Intervention Design

The reasons that consumers waste food are diverse and complex, but understanding them is critical to identifying effective ways to reduce food waste. As in many behavioral domains, consumers' actions in this area are driven by cultural, personal, political, geographic, biological, and economic factors that influence conscious and unconscious decisions. Researchers refer to the influences from all of these factors as the "drivers" of individual consumer behavior (see Chapter 1). Clearly, these factors are not always within the individual's control. This report uses "drivers" as a general term that encompasses causal factors; factors that may be statistically correlated; and "intervening factors," sometimes termed "mediators" or "moderators" that help explain causal pathways. In addition, drivers can include both the *presence* of factors that tend to promote a given behavior, such as, in the case of food waste, large portion sizes offered at restaurants, and the *absence* of factors that discourage a behavior, such as lack of knowledge of the negative consequences of an action.

Researchers from diverse disciplines, including psychology, economics, public health, and sociology, have made contributions to understanding the drivers of consumer behaviors, and identified numerous links between particular influences and actions, as discussed in Chapter 1. To make actionable recommendations for food waste reduction strategies as directed by the study charge (Box 1-1 in Chapter 1), the committee first sought evidence about the drivers of consumer behavior from research in six related fields: energy conservation, recycling, water conservation, waste prevention, diet change, and weight management. Conclusions from this work allowed us

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to note lessons learned in other domains that may be applicable to future food waste research and intervention design.

The committee then turned to identifying drivers specific to food waste both at and away from home. We identified 160 specific drivers supported by the literature, which we then clustered into 11 categories—types of drivers that may realistically be modified. This process allowed us to examine the characteristics of those drivers best supported by the literature, in terms of both the mechanism by which they operate (motivation, opportunity, and/or ability; see Chapter 1 and Appendix E) and the contexts in which they operate (at or away from home; related to food acquisition, consumption, or disposal). The chapter closes with the committee's conclusions about drivers particularly likely to be useful in the design of interventions to reduce consumer food waste.

UNDERSTANDING DRIVERS OF BEHAVIOR IN OTHER DOMAINS

The committee conducted literature searches across the six related domains, focusing on systematic reviews and meta-analyses. These searches, conducted in ProQuest Research Library, PubMed, and Scopus, yielded a total of 406 reviews; the search process and method for analyzing the results are described in Appendix B. Some selected original studies with relevant insights were also reviewed. This section presents the committee's insights about the drivers of consumer behavior at or away from home with potential relevance for wasted food and a few general observations.

Motivation, Opportunity, and Ability Work Together to Drive Behavior

Chapter 1 details reasons why the motivation-opportunity-ability (MOA) framework provides a valuable approach for analyzing drivers of food waste behavior and considering interventions to change that behavior. This first section highlights empirical evidence that supports the validity of this framework. In the context of water conservation, for example, households were found to be more likely to adopt desired behaviors when they felt capable, were motivated, and had the opportunity to participate in the targeted behavior (Addo et al., 2018; Geiger et al., 2019). A meta-analysis of the causal mechanisms of water conservation behavior showed that opportunity was a moderate predictor of behavior, followed by motivation and then ability; the three together explained 37 percent of the variance in household behavior (Addo et al., 2018). This evidence reinforces the idea that combinations of drivers that address motivation, opportunity, and

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ability should be considered jointly in both understanding behavior and designing potential interventions.

Sociodemographic Variables Are Often Insufficient or Poor Predictors of Behavior

Sociodemographic factors may alter consumers' motivation, opportunity, or ability to behave in certain ways, and thus might appear to be important drivers to consider in the food waste and other domains. However, significant cultural variation at every socioeconomic level results in a wide range of routines, norms, and beliefs related to food. Further, some demographic characteristics are relatively fixed, while others can change. Often, therefore, these factors can obscure more than they clarify, and meaningful inferences will be based on examination of specific relationships among factors.

Research findings on the extent to which sociodemographic factors predict proenvironmental behavior are mixed. While some studies show correlation between specific behaviors and sociodemographic variables (e.g., Addo et al., 2018; Cox et al., 2010; Whitmarsh et al., 2018), others show different results, such as that sociodemographic variables have no significant influence on proenvironmental behavior (Li et al., 2019); that only income predicts recycling behavior (Miafodzyeva and Brandt, 2013); or that while well-educated people are generally more committed to resource conservation, they actually consume more (Koop et al., 2019).

Although there are trends in how sociodemographic variables may be associated with behaviors, many studies indicate that these variables contribute little to understanding of proenvironmental behavior and that psychological factors are more successful in predicting behavior and behavior change (Li et al., 2019). One meta-analysis suggests that, according to the studies examined, there was no need to tailor recycling interventions to different groups, in particular to households, students, or employees, because similar factors appeared to underlie the behavior of all of these groups (Geiger et al., 2019). Other studies within the six domains have illustrated that as a behavior (e.g., recycling) becomes habit, sociodemographic variables may no longer predict or significantly influence behavior (Miafodzyeva and Brandt, 2013; Soderhorn, 2010).

These nuanced findings suggest a need for careful attention to the strength of evidence about the roles of the different sociodemographic factors in the food waste literature, as well as consideration of whether any observed associations are causal or reflect the fact that demographics sometimes serve as partial proxies for other, more relevant factors. In the

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food waste domain, the effect of sociodemographic factors has not been studied in depth. (A few inconclusive studies are mentioned in Chapter 2.)

Some Motivational Factors Are More Effective Drivers of Behavior than Others

It is tempting to think that simply having enough information about a given behavior or its impacts will change individuals' choices. However, research in the six related domains shows that knowledge or information alone is insufficient as a predictor of people's ability (i.e., knowledge for action) to change and maintain behavior (Abrahamse and Steg, 2013). By contrast, motivational factors, such as altered attitudes toward outcomes, values, agency, or perceived control, and social norms have been found to be more effective drivers of behavior (Li et al., 2019; Miafodzyeva and Brandt, 2013; Samdal et al., 2017). This is particularly true when consumers have baseline knowledge or can readily obtain it, with sufficient motivation.

Further, not all motivational factors are egocentric: several meta-analyses illustrate that proenvironmental behavior is driven more by normative (and sometimes environmental) concerns than by individual costs and benefits (Geiger et al., 2019; Miafodzyeva and Brandt, 2013). Similarly, environmental attitudes and beliefs, concerns about the future, and an individual's sense of responsibility—all of which can shape motivation—may be more important drivers of proenvironmental behavior relative to sociodemographic variables (Li et al., 2019).

Norms play a particularly important role in behavior change. Moral norms (i.e., when people feel that doing something aligns with an abstract right or wrong); injunctive social norms (i.e., what one ought to do); and descriptive social norms (i.e., perceptions of what most people are doing) have increased in many societies and are strongly correlated with behavior (Miafodzyeva and Brandt, 2013; Whitmarsh et al., 2018). Moreover, activities that are presented as useful, pleasant, important, and widely accepted are more likely to be adopted and sustained than those that are viewed as someone else's responsibility or inconvenient, or those that require a high bar of self-efficacy or locus of control (Cox et al., 2010; Miafodzyeva and Brandt, 2013). One caveat to this finding with relevance to food waste is that it may not always apply to prevention behaviors that are unseen (e.g., changing acquisition behaviors to purchase less in the first place). When an action is not visible—as is frequently the case for those actions categorized as prevention—social norms are unlikely to develop (Cox et al., 2010). Thus, one cannot assume that social norms drive food waste in the same

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way—or should be managed in the same way—as they might in other behavioral contexts.

Contextual Factors[1] Influence, and May Override, Other Drivers

A variety of evidence highlights the important influence of contextual factors and barriers on behavior in the six related domains. Several meta-analyses of household recycling interventions found that although researchers seldom considered such contextual factors as availability of curbside or convenient recycling, a bin at home, or space to store recycling before pickup (Geiger et al., 2019; Varotto and Spagnolli, 2017), they were strong predictors of waste reduction and recycling behavior (Geiger et al., 2019; Whitmarsh et al., 2018). A review of the literature on water conservation behavior found that water pricing was the most important variable explaining differences in domestic consumption in 10 Organisation for Economic Co-operation and Development countries (Koop et al., 2019). Other studies suggest that psychosocial factors, such as attitudes and norms, are insufficient for overriding structural barriers to behavior (Karlin et al., 2015).

Despite the evidence regarding the importance of context, different motivations and barriers operate in different contexts, and people's actions are therefore inconsistent across different times and places (Nash et al., 2017; Verplanken, 2018; Whitmarsh et al., 2018). Similarly, the effects of behavioral drivers may differ over time, both societally and individually, so drivers of food waste should not be considered static across time and contexts. Also, little is known about how drivers may differ at different phases in the behavior change process (Samdal et al., 2017). These findings illustrate that contextual factors vary and that those that change opportunity (e.g., marketing tactics, technology, the built environment, policies) at the food acquisition, consumption, storage, and disposal stages are similarly likely to affect food waste-related behaviors, independent of motivation or ability. Based on the number of and wide variation in contextual factors included among the summative drivers identified by the committee (see below), their importance and interactions with other drivers will need to be assessed for each population and setting.

[1] Contextual factors are characteristics unique to a particular group, community, society, or individual. These factors include, but are not limited to, personal, social, cultural, economic, and political factors that exist in differing ways and have varying impacts across population groups.

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Drivers Related to Habits[2] Play a Key Role in the Way Behaviors Are Initiated, Sustained, or Disrupted

Habits are automatic once created. Although research on habits has implications for food waste, it is important to note that habits (e.g., avoiding the frozen foods areas of a retail store or remaining unaware of wasted food) vary in terms of their costs (e.g., in effort and time) and benefits (e.g., financial, health-related), so each specific habit needs to be examined individually. Nevertheless, there are valuable lessons with respect to habits for efforts to reduce food waste.

Multiple drivers may influence both the breaking of old habits and the establishment and maintenance of new ones, and it is therefore important to consider those drivers both separately and jointly. Drivers that operate through reflective mechanisms—that is, conscious cognitive processes—have received more research attention than have habits. However, there is evidence that the two have different effects; for example, established habits are not easily influenced by values and norms, and they predict and sustain behaviors because they are automatic (Cox et al., 2010; Miafodzyeva and Brandt, 2013; Whitmarsh et al., 2018) (see Chapter 1 for a discussion of reflective versus more automatic behaviors). Behavioral interventions aimed at altering habits have been less effective than interventions aimed at influencing single-action behaviors (e.g., buying an energy-efficient appliance) (Nisa et al., 2019). At the same time, interventions that have been successful in creating a new habit reveal that automatized behaviors are easier to sustain (Nisa et al., 2019).

There is reason to believe that drivers that prompt people to adopt new behaviors are different from those that help people maintain a behavior as part of a new habit, although more research is needed in this area (Miafodzyeva and Brandt, 2013; Samdal et al., 2017). A systematic review of behavioral change theories found that people need at least one sustained motivator to maintain a behavior change, and will often initiate a change when motivation is high and effort is low (Kwasnicka et al., 2016). This study also suggests that when motivation decreases and effort or costs increase, people will often need some way to self-monitor in order to sustain the change; this can be challenging when stress, fatigue, or financial pressures exert countervailing influences. Once a new behavior becomes a habit, external factors (e.g., changes in motivation or effort) are less likely to affect that behavior, and stable contexts can make behavior maintenance easier (Kwasnicka et al., 2016). These findings suggest the importance of

[2] Habits are context–behavior associations in memory that develop as people repeatedly experience rewards for a given action in a given context. Habitual behavior is cued directly by context and does not require supporting goals and conscious intentions (Mazar and Wood, 2018).

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carrying out further work to identify drivers related to the adoption and maintenance of new habits (Nisa et al., 2019) and of considering the role of habits in food waste behaviors and their interaction with the motivation, opportunity, and ability elements of the MOA framework.

UNDERSTANDING CONSUMERS' FOOD WASTE BEHAVIOR

With the above findings from the six related domains in mind, the committee reviewed the literature specific to drivers of food waste, both in the household and away from home (see Appendix B for details on the search approach) to identify drivers and specific causal mechanisms that result in food waste and prioritize them by level of impact. The research focused on food waste is limited and emerging, and as discussed at the close of this chapter, the existing evidence did not support the development of so precise a list. However, the available literature does offer some important insights to guide further exploration of drivers of consumers' food waste behavior from a systems perspective, as well as an approach to guide the design of interventions to reduce food waste at the consumer level and the additional research needed to build on these ideas.

How Consumers Come to Waste Food: Modifiable Drivers

The committee reviewed the literature on food waste at and away from home, including in K–12 school settings, colleges/universities, hospitals, hotels, and restaurants. Three systematic reviews of household food waste were particularly helpful (Roodhuyzen et al., 2017; Schanes et al., 2018; Stangherlin and de Barcellos, 2018). We used peer-reviewed studies with original data only to identify drivers of food waste outside the home because we could find no systematic review on that topic. These peer-reviewed studies focused largely on specific locations where food is discarded, such as schools and colleges, health care facilities, food service and restaurant venues, and cafeterias (e.g., Chen and Jai, 2018; Haas et al., 2014; Lorenz et al., 2017a,b). Through this review, we identified 160 drivers that research has suggested may be important contributors to consumer food waste.

To make their utility for the design of food waste reduction interventions more apparent, we clustered the individual drivers into categories, or summative drivers. Our focus was on identifying clusters of drivers that (1) reflect the importance of motivation, ability, and opportunity; (2) play an important role in determining consumer food waste behavior; and (3) might translate to interventions—that is, would potentially be modifiable. This process resulted in the identification of 11 summative drivers that evidence indicates are promising targets for reducing food waste, listed in Box 3-1.

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BOX 3-1
Summative Drivers of Consumer Food Waste

Food waste is driven by

A. consumers' knowledge, skills, and tools;
B. consumers' capacity to assess risks associated with food waste;
C. consumers' goals with respect to food and nutrition;
D. consumers' recognition and monitoring of their food waste;
E. consumers' psychological distance from food production and disposal;
F. heterogeneity of consumers' food preferences and diets;
G. the convenience or inconvenience of reducing food waste as part of daily activities;
H. marketing practices and tactics that shape consumers' food behaviors;
I. psychosocial and identity-related norms related to food consumption and waste;
J. factors in the built environment (including in household and retail environments) and the food supply chain; and
K. policies and regulations at all levels of government.

Each of these 11 summative drivers represents a cluster of drivers synthesized from evidence across multiple studies covered in our search. Examples of individual drivers identified within each summative driver can be found in Tables 3-1 through 3-11, which are organized using the MOA framework described in Chapter 1. These examples are meant to depict the primary element (i.e., motivation, opportunity, or ability) by which the specific driver works. These examples also show how the drivers relate to the key ways consumers interact with food: acquiring, consuming and storing, and disposing of it. Because the studies we examined relied on a variety of methods it was not possible to estimate effect sizes for each or to prioritize them, a point discussed at the close of the chapter.

The drivers of food waste behavior interact with each other, and it is these more complex interrelationships that will result in an increase or decrease in food waste. For example, while meal planning may reduce food waste for some households, for others it might have the opposite effect, depending on resource availability, such as access to shopping opportunities created by the built environment (summative driver J) or food preferences (summative driver F). Thus, for example, people who can only make one large shopping trip in a distant location may, in planning, err on the side of buying too much, leading to later food waste. On the other hand, for a

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consumer whose preferences simply include a large amount of perishable food, making a firm shopping plan may have little effect on that individual's level of food waste. Because the interactions among the drivers are important, the distinctions among them can sometimes blur; nonetheless, identifying the categories of drivers is important for understanding the full range of drivers (and their mechanisms) influencing food waste behavior.

As in the research from related fields, the food waste literature suggests that it is important to consider underlying contextual factors to gain an understanding of the influence of various drivers on consumers' food waste behavior. Some evidence suggests that drivers influence the generation of wasted food differently, and to varying degrees, depending on whether consumers are at or away from home. The material qualities of the food itself also mediate how multiple drivers influence the generation of wasted food. For example, whether a food item is fresh or frozen can influence relationships with—and thus the drivers of behaviors with—that food because fresh and frozen foods require different skills for storage and preparation and have different shelf lives.

A. Consumers' Knowledge, Skills, and Tools

If they are to reduce waste, consumers need knowledge of what to do; the requisite skills to do it; and tools that do not unintentionally prompt waste (e.g., ability and opportunity), such as trays in a buffet setting or a large casserole dish used in food preparation (Hebrok and Boks, 2017; Roodhuyzen et al., 2017; Schanes et al., 2018) (see examples for specific drivers in Table 3-1). Important knowledge and skills are commonly related to provisioning and preparing the appropriate amount of food (e.g., Secondi et al., 2015); gauging quality; maximizing shelf life (e.g., Farr-Wharton et al., 2014); cooking, including repurposing of leftovers (e.g., Graham-Rowe et al., 2014); and awareness of which parts of food are edible.[3] Consumer tools can be physical objects, informational tools (e.g., recipes), or technological tools (e.g., smartphone apps) that support planning, acquisition, storage, and preparation. Such tools may be transportable and expendable (e.g., storage containers, planning and monitoring tools, appropriately sized cookware or plates [Hebrok and Boks, 2017]). Note that because they may have strong effects on other aspects of the food supply, more durable tools are considered part of the built environment (e.g., refrigerator, cupboard storage) (see summative driver J below), and that tools that facilitate food waste monitoring are included in summative driver D.

[3] Perceptions of which foods are edible are also relevant to food preferences, discussed together with knowledge and cultural norms below.

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TABLE 3-1 Examples of Drivers Related to Knowledge, Skills, and Tools

Stage	Motivation	Opportunity	Ability
Acquisition	Recipes or other tools/information that encourage the purchase and full use of food items to acquire or prepare	Size of plate, cookware, or other item, prompting acquisition or preparation	Knowledge about quantities or food types needed for preparation, including the amount of previously acquired food that is usable
Consumption/ Storage	Recipes, cooking shows, and other information sources that encourage limited consumption of foods	Access to waste-reducing consumption modes (e.g., food sharing) Access to storage tools and methods to maximize shelf life	Knowledge about using "scraps," aging food, leftovers, or edible components of food instead of disposing of them, and ways to maximize shelf life
Disposal		Access to trash cans and other bins for other means of waste management (e.g., composting)	

B. Consumers' Capacity to Assess Risks Associated with Food Waste

People's perceptions of food safety and quality, their sensitivity to guidance about food safety (e.g., Milne, 2012; Soma, 2017), and their knowledge about foodborne illnesses all influence food waste. In a national survey conducted in 2015, food safety and food quality were cited as the top two reasons for discarding food (Neff et al., 2015), although there is often a perceived tension between concerns related to reducing risk and those related to minimizing waste (Watson and Meah, 2013). People use knowledge, tools (e.g., date labels), and their senses to assess whether it is too risky to eat food (Hebrok and Boks, 2017). Assessment of risk affects both disposal and acquisition, and is influenced by such factors as recall of past experiences, norms, prior beliefs, date labels, and the smell and appearance of the food (Hebrok and Boks, 2017).

The process of judging whether food is safe to eat also relates to dietary restrictions (summative driver F), as some people are more risk averse or sensitive with respect to food relative to others. Perception of the risk or desirability of food is also related to psychosocial norms (summative driver I), as decisions related to risk management are also determined by emotions

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and norms, such as the good provider identity[4] (Brook Lyndhurst, 2011). Examples of specific drivers are in Table 3-2.

C. Consumers' Goals with Respect to Food and Nutrition

Consumers must reckon with multiple motivations related to food consumption and waste, including eating more healthfully, reducing environmental impacts, and saving money. Some motivations reinforce each other, while others conflict. For example, the goals of saving money and reducing food waste would appear to be well aligned. However, getting the best value from food purchases through bulk purchasing or taking advantage of reduced prices may at times conflict with suggested food waste prevention techniques that encourage customers to buy only the perishable items they need. Other consumers might be motivated to lose weight, and therefore be more likely to leave edible food on the plate. Examples of specific drivers related to conflicting goals are in Table 3-3).

Consumers resolve such conflicts in a variety of ways. For example, psychological licensing allows individuals to feel justified or even good about discarding food if they engage in such desirable behaviors as composting

TABLE 3-2 Examples of Drivers Related to Capacity to Assess Risks

Stage	Motivation	Opportunity	Ability
Acquisition	Perceptions about which foods/food formats (frozen, canned, fresh) will be safest for the longest time		Knowledge of foods/ formats that will be safest for the longest time
Consumption/ Storage	Sensory cue interpretation and sensitivity		Understanding of sensory cues
	Interpretation of date labels		Understanding of the meaning of date labels
	Previous negative experiences and concerns about food safety		
Disposal			

[4] Good provider identity refers to the need to feel like a "good" provider and minimize any feelings of guilt experienced if individuals fail to meet personal or cultural expectations (e.g., Graham-Rowe et al., 2014).

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(e.g., Qi and Roe, 2017), although this licensing is not inevitable. For example, if an action to reduce food waste activates a positive identity (e.g., makes one see oneself as a "smart consumer" or "food steward"), that self-consistency may be more powerful than the licensing effect, making behavior to reduce food waste more likely (Oyserman, 2015). At the same time, negative emotions about wasting food (e.g., guilt) may paradoxically have a licensing effect, allowing consumers to feel they have compensated for the waste with negative emotions (see, e.g., Russell et al., 2017).

Consumers' motivations can also change through the consumption process. For instance, the motivation to eat healthfully can drive consumers to overpurchase produce that is later wasted when it begins to spoil or ends up not being a preferred item (e.g., Evans, 2011; Watson and Meah, 2013) perhaps because the desire for convenience or comfort comes to the fore after the food has been purchased. However, evidence suggests that health goals may align with waste prevention goals, and could be used to reinforce each other (Quested and Luzecka, 2014; von Massow et al., 2019).

Out-of-home environments trigger different goals relative to in-home environments (e.g., hedonic eating,[5] maximizing the matching of food to the consumers' preference, impression management goals that lean toward "leaving some food on the plate" in public). As a result, consumers' waste reduction goals are often undermined in such contexts.

This cluster of drivers is closely linked to psychosocial and identity factors (summative driver I), which include the good provider identity and the perception that "fresh," or more perishable, food is healthier than other forms of food (Schanes et al., 2018) (e.g., see Chapter 2).

D. Consumers' Recognition and Monitoring of Their Food Waste

People may be unaware of the amount of food they discard and the impact of that waste because they lack the capacity to track what is wasted, and many believe they waste less than other people do (Neff et al., 2015). Consumers who do not perceive their food waste as a problem are unlikely to practice specific behaviors to reduce it (Brook Lyndhurst, 2007; Hebrok and Boks, 2017; Roodhuyzen et al., 2017; Schanes et al., 2018). In addition, although food suppliers may have tools for monitoring or reporting waste amounts, they have little incentive to remind consumers that overacquisition may lead to waste. For example, immediate removal of unconsumed food from the dining area of an out-of-home venue may be a norm that encourages further waste. Moreover, waste estimation is not generally considered part of a positive, hedonic social experience, making

[5] Hedonic eating is the act of eating for pleasure, rather than simply for nourishment, and may cause and perpetuate overconsumption.

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TABLE 3-3 Examples of Drivers Related to Consumers' Food and Nutrition Goals

Stage	Motivation	Opportunity	Ability
Acquisition	Desire to seek variety/ explore new options		
	Beliefs about the relative effects of differently preserved foods on the ability to reach health goals (e.g., perishable fruits and vegetables "healthier" than other preparations)		
Consumption/ Storage	(Mis)match between goals at acquisition (e.g., eating healthier) and goals at consumption (e.g., self-gifting or maximizing individual enjoyment from food)		
	"Healthy" choices in acquisition may license underconsumption of perishable foods		
	Desire to lose weight, which leads to leaving food on one's plate		
Disposal	Composting satisfies environmental and waste-reduction goals, licensing food waste		
	"Virtue" goals are satisfied by guilt about not eating, licensing disposal		
	Discarding or "cleaning out" seen as a healthy, clean, or efficient action		

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it unlikely that the data on waste collected in such venues will be shared with consumers.

The invisibility of food waste may be compounded when other waste is made more visible. For example, consumers who are trying to gauge their food waste may be distracted by the waste generated by bulky packaging, which appears to be of greater magnitude than their wasted food. In this case, consumers may overlook the important role packaging can play in reducing food waste (see also Chapter 2 on myths). Although it is generally agreed that people are unaware of their waste generation, it remains unclear whether this is purely a result of the invisibility of waste generation or is also a result of willful ignorance stemming from a desire to alleviate guilt or other negative emotions associated with wasting food. Examples of specific drivers are in Table 3-4.

TABLE 3-4 Examples of Drivers Related to Individuals' Recognition and Monitoring of Their Food Waste

Stage	Motivation	Opportunity	Ability
Acquisition	Lack of acquisition-proximal, salient reminders of the economic and opportunity costs of personal past food waste Belief that one's own food waste is less than that of others		
Consumption/ Storage	Immediate removal of wasted food from the consumption area, which results in lack of feedback		
Disposal	Removal/processing of food by a third party, which results in lack of feedback Belief that another type of waste (e.g., packaging) is more important than food waste		Use of waste monitoring tools

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E. Consumers' Psychological Distance from Food Production and Disposal

A lack of intellectual, social, and emotional linkage with food—a lack of appreciation of the connections among its production, consumption, and disposal—can result in a lack of awareness of or concern about the consequences of discarding food (e.g., Clapp, 2002; Soma, 2017) (see specific examples in Table 3-5). Moreover, urbanization and the changing structure of the food supply chain have generally resulted in physical distance between where people live and sites of food production (e.g., farms) and disposal (e.g., landfills), further reinforcing this psychological disconnect (see Box 3-2). Consuming food away from home or shopping online, with no personal connection with those who prepared the food, also serves to distance consumers psychologically.

BOX 3-2
Distancing

Distancing is a conceptual framework commonly used in the field of consumption studies to explain the exploitation of resources and the resulting waste in the process of both production and consumption (Princen, 2002). This conceptual framework has increasingly been adopted in food and food waste studies to explain the phenomenon of overconsumption, natural resource exploitation, and food waste (Clapp, 2002; Soma, 2017). Princen (2002) defines distancing as "the separation of primary resource-extraction decisions from final consumption decisions. The greater the distancing on any several dimensions, the greater the likelihood ecological feedback will be severed and a resource overused."

Distancing is a broad umbrella term covering not only the process of geographic distancing (spatial), but also mental distancing. One aspect of distancing is the disconnect between consumers and the primary source of their food. Distancing also helps explain why the impacts of waste are often felt disproportionately by poor or marginalized communities that live close to waste disposal sites (Soma, 2017). Spatial distancing has been tied to the process of urbanization and the disconnect between urban consumers and the source of their food (Soma, 2017) and is one reason why urbanization has been identified as one of the drivers of food waste (Parfitt et al., 2010; Thyberg and Tonjes, 2016).

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TABLE 3-5 Examples of Drivers Related to Consumers' Psychological Distance from Food Production and Disposal

Stage	Motivation	Opportunity	Ability
Acquisition	"Inexpensive food" is overacquired because of devaluation of labor and resources involved in the product life cycle		
Consumption/ Storage	Disconnect from the preparer leads to devaluation of food and lower consumption		
	Consequences of food waste do not affect many personally		
Disposal	Poor awareness of the impacts of disposal		

F. Heterogeneity of Consumers' Food Preferences and Diets

Food preferences are driven by expectations and norms and by the desire for tasty or satisfying food. Preferences can lead to wasted food—for example, the discarding of portions of food, such as broccoli stalks or apple cores, that could be eaten (knowledge of what is edible is also closely linked to consumers' knowledge and skills, discussed above). As noted previously, the classification of food as edible or inedible is shaped by both material and sociocultural factors that vary significantly among and within cultures (Gillick and Quested, 2018; Moreno et al., 2020; Papargyropoulou et al., 2014). Therefore, these attitudes offer a leverage point for interventions to motivate consumers to reduce food waste.

Children's limited palates and their often picky and unpredictable eating habits are commonly cited as a reason for wasting food (Hebrok and Boks, 2017; Roodhuyzen et al., 2017; Schanes et al., 2018). As children develop their eating habits, they often need to try foods—especially vegetables and other foods considered to be healthy—several times before liking them (Wardle et al., 2003). As a result, it may be socially optimal to allow some level of food waste as children develop their palates, especially if it results in healthier overall eating habits. Specific examples of drivers are listed in Table 3-6.

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TABLE 3-6 Examples of Drivers Related to Heterogeneity of Consumers' Food Preferences and Diets

Stage	Motivation	Opportunity	Ability
Acquisition	Desire to match heterogeneous preferences and diets		
Consumption/ Storage	Rejection of previously purchased food in light of changes in diet or preference	Specific foods needed to account for dietary restrictions	Adoption of unfamiliar foods or diets
		Limited palates of children	
	Dislike of consuming leftovers or certain food parts		
	Desire to alter one's diet		
Disposal			

G. The Convenience or Inconvenience of Reducing Food Waste as Part of Daily Activities

Contexts, priorities, and other characteristics of households and individuals—including the many demands associated with working and maintaining a household—influence consumer choices with respect to food waste (see some examples of drivers in Table 3-7). These factors are affected in turn by dynamics within a household and communication among household members (e.g., Evans, 2011; Ganglbauer et al., 2013; Hebrok and Heidenstrøm, 2019). See Box 3-3 for more on how consumers make decisions and establish priorities.

Several behavior-related theories and mechanisms have been proposed to explain these influences (Becker, 1965; Reid, 1934). A key insight of this work is that transforming market goods (e.g., packages of food) into home-produced goods (e.g., a meal) requires household members' time, which could otherwise be used to generate income through paid work, engage in other aspects of home production, or enjoy leisure activities. Further, household members' skill in household production can alter the trade-off and eventual decisions made with respect to allocating scarce time across market and home activities. The time available for food acquisition and preparation and the skills of household members therefore determines the motivation, opportunity, and ability to decrease food waste.

The household production theory (Becker, 1965) has been used to model households' food waste (Lusk and Ellison, 2017), guide systems-based

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BOX 3-3
The Role of Emotions, Heuristics, and Biases in Consumer Decision Making

Consumers rely on various cognitive shortcuts to make decisions and guide their behaviors, particularly when they are under pressure. Emotions also may be sources of nonrational input into decision making. Indeed, the more complex life becomes, the more consumers are likely to rely on emotions, heuristics (simple rules), and biases. For example, emotions and heuristics may guide a busy consumer's perception as to whether a waste behavior is acceptable. Researchers have suggested that consumers can be profiled in terms of their feelings about waste, and that this profiling is more helpful for understanding waste behavior than are sociodemographic factors (Amato et al., 2019).

Another powerful heuristic that can drive waste behavior is the idea that "beautiful is good" (see Chapter 2). Numerous researchers have shown that consumers are less likely to purchase aesthetically unappealing produce relative to more aesthetically appealing produce (e.g., Aschemann-Witzel et al., 2018; Grewal et al., 2019), and that this effect is driven by a belief that unattractive products are of lower quality. Although such effects have been studied primarily in stores, it follows that individuals will rely on similar heuristics when deciding what to prepare at home, so that as goods age and decline in appearance, the likelihood that they will be wasted will increase.

assessments of the economic impacts of wasted food (Muth et al., 2019), develop hypotheses about household changes in the amount of food wasted in response to changes in food prices and policies (Hamilton and Richards, 2019), and devise tax schemes to reduce food waste (Katare et al., 2017). This framework has also supported efforts to estimate the amount of wasted food generated by a household based on detailed information about food purchases and demographic profiles (Landry and Smith, 2018; Yu and Jaenicke, 2018).

H. Marketing Practices and Tactics that Shape Consumers' Food Behaviors

Consumer choice is significantly influenced by product branding, pricing, promotions, and other actions of retailers, restaurant operators, and other away-from-home food providers (examples of specific drivers are in Table 3-8). Marketing research has identified both online and in-store tactics that encourage overacquisition or suboptimal acquisition that may shape both at- and away-from-home behaviors. Marketing strategies that relate to food waste in particular include special offers, multiple-unit pricing, packaging, signage and displays, large portion sizes, bundled deals, and

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TABLE 3-7 Examples of Drivers Related to the Convenience or Inconvenience of Reducing Food Waste as Part of Daily Activities

Stage	Motivation	Opportunity	Ability
Acquisition	Intermittent scarcity of resources (e.g., money) and time leads to stockpiling		In-store/restaurant overload prompts satisficing[a]/use of heuristics Cognitive availability biases estimation of desire/need
Consumption/ Storage	Substitution of food delivery for food preparation because of preference	Meal plan abandonment due to variation in needs and circumstances	Cognitive load or stress leads to reliance on memory, and food is not consumed if it is not visible
Disposal	Reliance on affect heuristics to determine freshness or usability	Cost and ease of use of disposal and discard options	Time pressure leads to disposal before consumption is complete

[a] Satisficing is a decision-making strategy that aims for a satisfactory or adequate result, rather than an optimal solution.

cues to seek variety or shop in an exploratory manner. For example, low prices and deep discounts, while increasing consumers' spending power, also can lead to stockpiling. Past research has shown that promotions with high quantity anchors (e.g., limit of 10 mangoes) cue consumers to purchase more of the promoted product than they otherwise might (Wansink et al., 1998). Retailers also often encourage consumers to seek variety, which can increase the likelihood that they will purchase nonpreferred foods that are more likely to go to waste (Ratner et al., 1999).

Marketing tactics operate at both conscious and nonconscious levels (e.g., Kahneman, 2011). For example, buy one, get one free deals can lead consumers to purchase—and waste—more, through a decision of which they are conscious. Other tactics, however, such as those that rely on high purchase anchors, may nudge consumers to buy more without their being aware of the influence on their decision. Likewise, larger carts and larger servings may lead to waste in both conscious and unconscious ways, as consumers may recognize the effects of such tactics on their propensity to buy food that will go uneaten but still be influenced.

Similar tactics can be used to reduce waste if developed wisely. For example, marketing researchers have shown that granular, modular packaging, which allows consumers to eat smaller portions of a food without

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leaving the entire quantity open to decay, will reduce the likelihood of waste. Because this tactic will also increase packaging and thus nonfood waste, however, this potential trade-off should be accounted for in evaluation of the intervention's efficacy. Innovative processing technologies are continually being developed to meet various objectives (e.g., food safety), and they directly influence how consumers buy, prepare, and store their food. Many of these technologies have made an impact in increasing shelf life and thereby decreasing food waste (see Chapter 2). Other marketing factors, however, have not been widely used to shape waste during the consumption or disposal stage, so there is an opportunity to use marketing tactics that have both a conscious and unconscious influence on food waste.

I. Psychosocial and Identity-Related Norms Relevant to Food Consumption and Waste

Consumers' motivation to reduce food waste is shaped by social norms, identity, and habit (examples of drivers related to norms are in Table 3-9). Factors that create identity and habit play an important role (e.g., Russell et al., 2017). These include formative life experiences, such as food scarcity, exposure to food production (e.g., through gardening or hunting), and local culture. Habits (actions performed automatically) also play a key role in many of the psychosocial and identity-related behaviors related to wasting food (Quested et al., 2011; Russell et al., 2017).

Norms[6]—social expectations that define the appropriate behavior in a given situation (Schwartz, 1977)—appear to be particularly influential and have been the most extensively studied among this cluster of factors. When norms are activated, often outside of conscious awareness, they influence information processing and decision making. Norm activation theory would suggest, for example, that a food acquisition situation may activate expectations about the desirability of larger shopping baskets, the benefits of bulk buying or abundance, or the acceptability of excess that influence the likelihood that individuals will acquire more than they need. Norms that can lead to waste include the good provider identity discussed earlier (e.g., Graham-Rowe et al., 2014), gender roles, consumerism (the idea that consumption of goods is positive), acceptance of wasting food as "normal," lack of acceptance of imperfect foods (e.g., Aschemann-Witzel et al., 2018), and preferences for fresh food. Stern (2000) argues that because the role of norms in food-related behavior is so substantial, it is critical not only to

[6] "Norms" in this context refers to moral norms (i.e., when people feel that doing something aligns with an abstract right or wrong), injunctive social norms (i.e., feelings about what one ought to do), and descriptive social norms (i.e., perceptions of what most people are doing) that are strongly correlated with behavior.

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TABLE 3-8 Examples of Drivers Related to Marketing Practices and Tactics

Stage	Motivation	Opportunity	Ability
Acquisition	High promotional anchors (e.g., purchase limit 10, 10 for $10) and price promotions Novelty promotions promoting purchase of atypical/unfamiliar foods Messaging that emphasizes freshness, abundance, attractive presentation, minimal packaging, or organic products without regard to effects on waste Packaging and product offerings that result in acquiring more than desired Retail standards that promote only aesthetically appealing food		
Consumption/ Storage			No packaging information provided related to preparation, storage, or usage Packaging not optimized for storage
Disposal			

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discuss explicit attitudes and knowledge but also to address more implicit religious and moral norms.

Some research indicates that individuals may face conflicting norms in the domain of food waste. For example, consumers may regard accumulation of goods as important to personal happiness and social status but also hold religious norms about the value of temperance (Petrescu-Mag et al., 2019) or find waste generally aversive (Arkes, 1996). Thus, norm activation theory suggest that waste may be reduced if planful shopping (Stefan et al., 2013) or an "ethic of thrift" (Waston and Meah, 2013) is made normative. Other research, however, suggests that norms may play a less important a role in food waste relative to such factors as price and convenience (Aschemann-Witzel et al., 2018).

Although survey and experimental data are often focused on the decisions individuals make on their own, food acquisition and consumption decisions are often made in dyadic or group contexts, in which acquisition and consumption decisions are likely to be radically different from those made individually. For example, it has been suggested that individuals making decisions in groups or when others can observe are likely to differentiate themselves from others (e.g., not order an item another individual in the group has ordered) and to signal their own personality by seeking variety across food choices (Ariely and Levav, 2000; Ratner et al., 1999). Choosing items for reasons other than preference increases the likelihood of waste, although acquisition and consumption in groups may also serve to reduce waste in that when acquisition choices are observed by others, more communal consumers may be prompted to exert self-control, thus tempering their acquisition tendencies (Kurt et al., 2011).

J. Factors in the Built Environment and the Food Supply Chain

The built environment[7] and the food supply chain play a key role in food waste through factors ranging from the household or community level (e.g., layout of home kitchen, refrigerator capacity, access to retail food sources) to the societal level (e.g., urbanization, characteristics of the food supply chain). For example, space constraints in the refrigerator or cupboards can make it difficult to organize items, thus making them more difficult to find and therefore less likely to be eaten (e.g., Schanes et al., 2018) (see additional examples in Table 3-10). Individuals often have

[7] "Built environment" refers to the human-made environment that provides the setting for human activity, ranging in scale from buildings to cities and beyond. It has been defined as "the human-made space in which people live, work and recreate on a day-to-day basis (Roof and Oleru, 2008).

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TABLE 3-9 Examples of Drivers Related to Psychosocial and Identity-Related Norms

Stage	Motivation	Opportunity	Ability
Acquisition	Social and gender norms related to abundance, special occasions, and the good provider identity		
	Individual aversion to scarcity (i.e., acquiring too much as "insurance")		
	Acquisition as a marker of status/consumerism		
	Lack of acceptance of imperfect or suboptimal foods		
Consumption/ Storage	Norms related to the good provider identity, abundance, and "good" food		
	Acceptance of imperfect or suboptimal foods		
	Acceptance of food sharing		
	Eating leftovers perceived by some as sacrifice or thrift		
	Desire to impress eating companions (e.g., taking leftovers instead of leaving them)		
	Prior experiences and local food cultures that influence habit creation		
Disposal	Waste acceptance norms		
	Guilt associated with waste		

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limited control over these factors, which shape the context for many kinds of food choices.

Aspects of the built environment and the food supply chain can be addressed through policies or technological improvements, but intervening in a complex system brings a risk of unintended consequences. System-wide responses may offset a positive original intent or expected impact, through rebound effects, for example. This point is illustrated in the context of energy conservation by the introduction of technology that enables people to afford to drive more by using less fuel for each trip. Furthermore, if enough drivers experience this improved efficiency, the market price of fuel will likely decline, making additional trips even less expensive.[8]

In the context of food waste, interventions that successfully reduce the amount of wasted food could result in a smaller reduction in greenhouse gas emissions than expected (unintended consequence) because consumers who spend less on food may redirect their spending to other consumer goods that generate greenhouse gases (Druckman et al., 2011). Other unintended consequences might include a rise in demand for electricity and an increase in greenhouse gas emissions if standard refrigerator temperatures are lowered. Thus, it is important that the entire food system be considered when factors in the built environment and the food supply chain are used to address food waste.

K. Policies and Regulations at All Levels of Government

Policies and goals related to food and waste, including date labeling, waste management systems and regulations, urban planning choices, agricultural subsidies, and other market-based instruments, have a key role to play in reducing food waste (some examples related to policy and regulations are listed in Table 3-11). Such elements of the food supply system as the cost of food and access to waste management services provide the context within which consumers and industry make choices. Some policies may directly target waste, while others are related to food quality, prices, or other factors and may indirectly influence the generation of wasted food. Broadly, policies have the potential to both drive and prevent the generation of wasted food, as well as to address equity issues, or the possibility that groups of people may be disproportionately affected by changes (e.g., through regressive taxes). One policy recently recognized as important is date labeling on packages (e.g., Milne, 2012; Neff et al., 2019; Thompson

[8] Since Jevons hypothesized that improved efficiency of coal engines might actually lead to an increase in coal use (Jevons, 1866), economists and engineers have hypothesized about and documented such offsetting responses, largely in the context of energy conservation initiatives (Binswanger, 2001; Chan and Gillingham, 2015; Greening et al., 2000; Khazzoom, 1980).

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A National Strategy to Reduce Food Waste at the Consumer Level

TABLE 3-10 Examples of Drivers Related to the Built Environment and the Food Supply Chain

Stage	Motivation	Opportunity	Ability
Acquisition		Urban planning factors, including access to transportation	
		Access to, types of, and distance from retail outlets	
		Available food supply, including access to garden or other food production	
Consumption/ Storage		Access to and layout of home refrigerator and refrigerator or freezer design, including capacity	
Disposal		Access to waste management products and services	

et al., 2018; Wilson et al., 2017). Another is waste management. These policies focus on what happens to food once it has been wasted by the consumer, but they can influence choices made along the entire supply chain. Commonly suggested waste management policies include imposing higher costs for landfill disposal (e.g., through a tipping fee), banning organic materials (including food waste) from landfills (e.g., Sandson and Broad Leib, 2019), requiring mandatory collection of compostable materials, and using pricing schemes that charge customers by the amount of waste generated. Relatively little is known, however, about the direct impact of specific policies and regulations on the generation of wasted food (Schanes et al., 2018; Spang et al., 2019).

SUMMARY AND CONCLUSIONS

The committee examined a wide range of research on factors that influence consumer behavior to identify those that may promote behaviors that limit food waste. These factors operate both at the individual, intrapersonal, and interpersonal levels and at the broad community, state, and federal levels, and they interact with one another.

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TABLE 3-11 Examples of Drivers Related to Policies and Regulations

Stage	Motivation	Opportunity	Ability
Acquisition	Agricultural subsidies, tariffs, and import restrictions that influence price and availability	Unregulated or inconsistent date labeling	
	Economic trends that influence purchasing and consumption patterns		
	Requirements of retailers and food sellers to disclose information about food (e.g., calorie count) or provide food in a certain way		
Consumption/ Storage			
Disposal	Economic trends that influence waste production	Access to waste management services and restrictions on (e.g., organic bans) or requirements for (e.g., pay-as-you-throw) discard	

The MOA framework offers possibilities for analyzing this complex array of drivers of food waste behavior. As discussed in Chapter 1, this framework posits that behavioral changes occur as a result of the interplay of these three influences. In the context of consumer behavior related to wasting food, the MOA framework suggests that if consumers are to reduce food waste, they need to have the opportunity and ability to do so, and also be motivated to do so. At the same time, the framework highlights that many other factors that increase or decrease food waste—particularly nonconscious influences, habits, and contextual and psychosocial factors—may be at play when motivation, opportunity, or ability is low. The MOA framework is flexible enough to support comparison of findings across diverse literatures and thereby allow for consideration of these additional mediating factors.

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Analysis of findings from the literature on drivers of consumer behavior with the MOA framework in mind yielded the following overall observations.

Drivers of food waste collectively influence consumer behavior regarding food acquisition, consumption and storage, and disposal. Although some drivers, such as marketing factors, shape primarily acquisition tendencies, others, such as the built environment, play strong roles in shaping acquisition, consumption, and disposal. Thus, drivers can emerge at different stages of a consumer's experience with food, and can play different roles depending on the stage in which they appear. The fact that drivers operate differently at different points in a process can make it difficult to make clear prescriptions about the likely effects of any single intervention strategy. However, it also highlights the potential benefits of addressing multiple points through a single driver or small number of drivers—for example, promoting efficient acquisition and maximizing of consumption while working to prevent the discarding of food in particular situations. As a systems analysis would suggest, all influences on the consumer's experience, including those that operate long before the actual decision to discard occurs, should be taken into account so that addressing a driver in one stage of the consumer's experience with food will not create problems in another (e.g., altering acquisition in ways that promote more disposal).

The largest proportion of drivers addressed by research relate to motivation, but it is clear that drivers may also affect opportunity and ability. While the importance of motivation is clear, behavior cannot be disconnected from opportunity and ability. Findings from the six related domains explored by the committee show that motivations are crucial drivers of behavior, but that they work in concert with opportunity and ability. The focus on opportunity and ability is particularly important in the context of automatic behaviors or habits, and the need to sustain—not just initiate—desired behaviors. However, research in the food waste domain has not systematically compared drivers of automatic versus reflective behavior, or distinguished between drivers that support initiation as opposed to maintenance of behavior.

The existing research does not cover all potential drivers of consumer behavior across settings. While this chapter has attempted to suggest possible drivers of food waste behavior that may operate in away-from-home consumption, little empirical research has focused on these drivers explicitly or systematically. Similarly, research in the six related domains has

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not adequately explored how drivers differ over time and across settings. Research in the other domains also indicates the importance of understanding contextual factors, which may reveal a given driver's operation or change the way any given driver works. Further, examining drivers in only one setting makes it more difficult to understand how a single driver may operate in others. For example, if it is possible to address drivers that prompt away-from-home food waste, consumers may internalize changes in practices and mindsets that affect the drivers existing at home. Additional research may broaden investigation into how drivers identified in this report—and others yet to be identified—operate within different contexts, as well as across settings.

Examination of underlying psychological and contextual drivers may provide deeper understanding than can sociodemographic factors. Researchers in the six related domains have found that sociodemographic variables by themselves are often inadequate or poor predictors of environment-related behaviors, and the same appears to be true for food waste behaviors (see Chapter 2). Many drivers of food waste behavior, such as social norms, tool availability, and the built environment, may be correlated with sociodemographic factors, but the former are most likely to explain the behavior.

The research reviewed does not support prioritizing some drivers above others, but it does provide clues for identifying and using drivers that might be operating in a given situation. Because methods and measures used in this research vary so widely, it is difficult to compare effect sizes across studies. Further, as few studies consider more than one driver simultaneously, the committee was unable to conduct a systems analysis that would account for dynamics and relationships. The 11 summative drivers identified in this chapter each affect at least one of the three elements of the MOA framework—motivation, opportunity, and ability, as illustrated in Figure 3-1.

With this in mind, the committee proposes that findings in this chapter can be used to identify and target drivers on which to focus interventions for reducing consumer-level food waste. To identify the relevant drivers, designers of interventions for a specific setting or community could conduct formative research in that community to identify the cognitive process driving a food waste behavior (e.g., reflective or automatic) and which element(s) of the MOA framework are predominant.

In a hypothetical case, individuals in a community may report both a high sense of psychological distance from a food source and a conscious willingness to discard food once it has become aesthetically imperfect. In this case, researchers may find that, for these individuals, psychological distance results in the lack of motivation to use the food and thus food waste. This behavior appears to be more reflective than automatic, and

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other drivers are therefore likely at play because reflective behaviors require activation of all three elements of the MOA framework. Thus, although it may be tempting to launch a messaging campaign focused solely on enhancing motivation to reduce the discarding of food, the intervention designer should also search for drivers in the community that may be resulting in the high ability (e.g., low food literacy) and easy opportunity (e.g., lack of incentives to save food) to discard food. In this way, the most promising intervention for this context would not only change the psychological distance from food through motivational cues, but also address drivers related to opportunity and ability that might be promoting food waste.

On the other hand, consider a hypothetical case in which food waste is likely to be driven predominantly by automatic processes. In contrast with the above case, food waste here is occurring without the consumer's awareness (so that researchers might find, for example, a large gap between self-reported and objective measures of food waste); opportunity and ability, rather than motivation, are likely to be at play. For example, researchers might find large, convenient trash bins placed near refrigerators, indicating that individuals have high opportunity to discard the food; removing such sources of easy opportunity might prompt consumers to process their options more reflectively. Intervention designers might also look for evidence of a link between habits and a given event or cue. If that link could be disrupted, the interventionist might then engage consumers in more active behavioral change. As an example, researchers might find that some individuals dispose of food too soon because of a calendar cue to clean the refrigerator on the first of the month, the calendar itself triggering the habit and the reward of a clean, spacious refrigerator. In this case, this old habit could be replaced with a new one. An intervention could be designed to interrupt the connection between the cue (the calendar) and the behavior (cleaning out the refrigerator)—for example, by renaming the first of the month "Leftover Day" and providing rewards for using rather than discarding leftovers and creative recipes for using the food.

In both of these examples, successful interventions are likely to result from a systematic approach to addressing multiple drivers of consumers' food waste behavior. Further, it may not always be simple to determine whether waste is occurring only automatically or reflectively, and in any given community, both are likely to occur. Research that captures the drivers and the relative prevalence of such processes is critical to understanding how interventions should be bundled.

CONCLUSION 3-1: Consumer behaviors regarding food acquisition, consumption, storage, and disposal are complex; depend on context; and are driven by multiple, interacting individual, sociocultural, and material factors within and outside the food system. These drivers of

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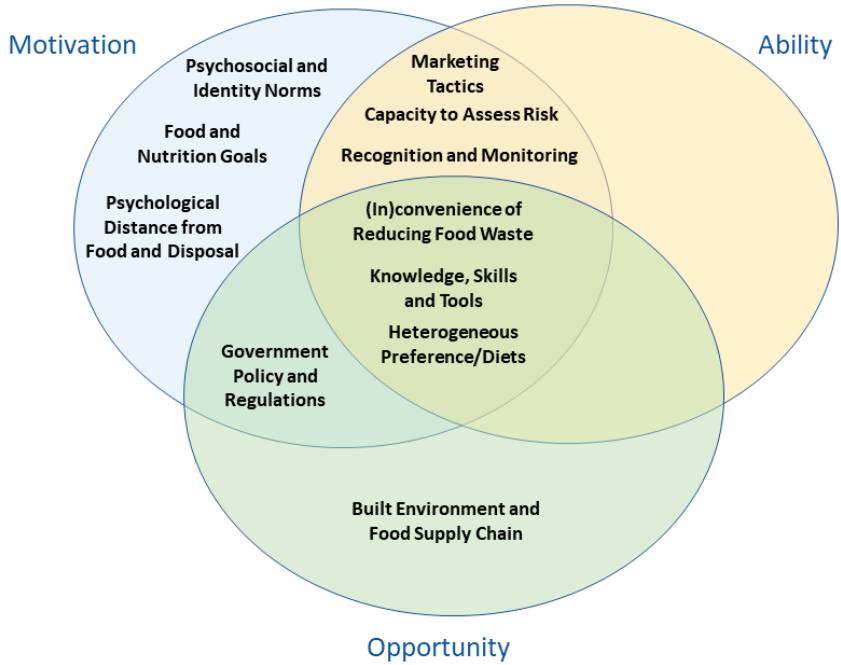

FIGURE 3-1 Interactions between drivers of food waste at the consumer level and the elements of the motivation-opportunity-ability (MOA) framework.

behavior can best be understood as affecting consumers' motivation, ability, and opportunity to reduce food waste, through both reflective and automatic processes.

CONCLUSION 3-2: The incomplete and limited research on drivers of food waste at the consumer level does not support prioritization of particular drivers of consumers' food waste behaviors over others, but understanding of how the 11 summative drivers identified in Box 3-1 combine to influence those behaviors can reveal promising targets for interventions to reduce food waste at the consumer level.

REFERENCES

Abrahamse, W., and L. Steg. 2013. Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change* 23(6):1773-1785.

Addo, I.B., M.C. Thoms, and M. Parsons. 2018. Household water use and conservation behavior: A meta-analysis. *Water Resources Research* 54(10):8381-8400.

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Amato, M., R. Fasanelli, and R. Riverso. 2019. Emotional profiling for segmenting consumers: The case of household food waste. *Calitatea* 20(S2):27-32.

Ariely, D., and J. Levav. 2000. Sequential choice in group settings: Taking the road less traveled and less enjoyed. *Journal of Consumer Research* 27(3):279-290.

Arkes, H.R. 1996. The psychology of waste. *Journal of Behavioral Decision Making* 9(3):213-224.

Aschemann-Witzel, J., A. Giménez, and G. Ares. 2018. Convenience or price orientation? Consumer characteristics influencing food waste behaviour in the context of an emerging country and the impact on future sustainability of the global food sector. *Global Environmental Change* 49:85-94.

Becker, G.S. 1965. A theory of the allocation of time. *The Economic Journal* 75(299):493-517.

Binswanger, M. 2001. Technological progress and sustainable development: What about the rebound effect? *Ecological Economics* 36(1):119-132.

Brook Lyndhurst. 2007. *Food Behaviour Consumer Research: Quantitative Phase*. Available: https://www.wrap.org.uk/sites/files/wrap/Food%20behaviour%20consumer%20research%20quantitative%20jun%202007.pdf.

Brook Lyndhurst. 2011. *Consumer Insight: Date Labels and Storage Guidance*. Available: https://www.wrap.org.uk/sites/files/wrap/Technical%20report%20dates.pdf.

Chan, N., and K. Gillingham. 2015. The microeconomic theory of the rebound effect and its welfare implications. *Journal of the Association of Environmental and Resource Economists* 2:133-159.

Chen, H.S., and T.M.C. Jai. 2018. Waste less, enjoy more: Forming a messaging campaign and reducing food waste in restaurants. *Journal of Quality Assurance in Hospitality and Tourism* 19(4):495-520.

Clapp, J. 2002. The distancing of waste: Overconsumption in a global economy. In *Confronting Consumption*, edited by T. Princen, M. Maniates and K. Conca. Cambridge, MA: The MIT Press. Pp. 155-176.

Cox, J., S. Giorgi, V. Sharp, K. Strange, D.C. Wilson, and N. Blakey. 2010. Household waste prevention: A review of evidence. *Waste Management and Research* 28(3):193-219.

Druckman, A., M. Chitnis, S. Sorrell, and T. Jackson. 2011. Missing carbon reductions? Exploring rebound and backfire effects in UK households. *Energy Policy* 39(6):3572-3581.

Evans, D. 2011. Beyond the throwaway society: Ordinary domestic practice and a sociological approach to household food waste. *Sociology* 46(1):41-56.

Farr-Wharton, G., M. Foth, and J.H.-J. Choi. 2014. Identifying factors that promote consumer behaviours causing expired domestic food waste. *Journal of Consumer Behaviour* 13(6):393-402.

Ganglbauer, E., G. Fitzpatrick, and R. Comber. 2013. Negotiating food waste: Using a practice lens to inform design. *ACM Transactions on Computer-Human Interaction* 20(2):Article 11.

Geiger, J.L., L. Steg, E. van der Werff, and A.B. Ünal. 2019. A meta-analysis of factors related to recycling. *Journal of Environmental Psychology* 64:78-97.

Gillick, S., and T.E. Quested. 2018. *Household Food Waste: Restated Data for 2007-2015*. WRAP. Available: https://www.wrap.org.uk/sites/files/wrap/Household%20food%20waste%20restated%20data%202007-2015%20FINAL.pdf.

Graham-Rowe, E., C.J. Donna, and S. Paul. 2014. Identifying motivations and barriers to minimising household food waste. *Resources, Conservation and Recycling* 84(84):15-23.

Greening, L.A., D.L. Greene, and C. Difiglio. 2000. Energy efficiency and consumption: The rebound effect—A survey. *Energy Policy* 28(6):389-401.

Grewal, L., J. Hmurovic, C. Lamberton, and R.W. Reczek. 2019. The self-perception connection: Why consumers devalue unattractive produce. *Journal of Marketing* 83(1):89-107.

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Haas, J., L. Cunningham-Sabo, and G. Auld. 2014. Plate waste and attitudes among high school lunch program participants. *Journal of Child Nutrition and Management* 38(1):n1.

Hamilton, S.F., and T.J. Richards. 2019. Food policy and household food waste. *American Journal of Agricultural Economics* 101(2):600-614.

Hebrok, M., and C. Boks. 2017. Household food waste: Drivers and potential intervention points for design: An extensive review. *Journal of Cleaner Production* 151:380-392.

Hebrok, M., and N. Heidenstrøm. 2019. Contextualising food waste prevention: Decisive moments within everyday practices. *Journal of Cleaner Production* 210:1435-1448.

Jevons, W.S. 1866. *The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-Mines*. London: Macmillan.

Kahneman, D. 2011. *Thinking, Fast and Slow*. New York: Macmillan.

Karlin, B., J.F. Zinger, and R. Ford. 2015. The effects of feedback on energy conservation: A meta-analysis. *Psychological Bulletin* 141(6):1205-1227.

Katare, B., D. Serebrennikov, H. H. Wang, and M. Wetzstein. 2017. Social-optimal household food waste: Taxes and government incentives. *American Journal of Agricultural Economics* 99(2):499-509.

Khazzoom, J.D. 1980. Economic implications of mandated efficiency in standards for household appliances. *The Energy Journal* 1(4):21-40.

Koop, S.H.A., A.J. Van Dorssen, and S. Brouwer. 2019. Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics. *Journal of Environmental Management* 247:867-876.

Kurt, D., J.J. Inman, and J.J. Argo. 2011. The influence of friends on consumer spending: The role of agency–communion orientation and self-monitoring. *Journal of Marketing Research* 48(4):741-754.

Kwasnicka, D., S.U. Dombrowski, M. White, and F. Sniehotta. 2016. Theoretical explanations for maintenance of behaviour change: A systematic review of behaviour theories. *Health Psychology Review* 10(3):277-296.

Landry, C., and T. Smith. 2018. *Household Food Waste: Theory and Empirics*. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3060838.

Li, D., L. Zhao, S. Ma, S. Shao, and L. Zhang. 2019. What influences an individual's pro-environmental behavior? A literature review. *Resources, Conservation and Recycling* 146:28-34.

Lorenz, B.A., M. Hartmann, S. Hirsch, O. Kanz, and N. Langen. 2017a. Determinants of plate leftovers in one German catering company. *Sustainability (Switzerland)* 9(5):807.

Lorenz, B.A.-S., M. Hartmann, and N. Langen. 2017b. What makes people leave their food? The interaction of personal and situational factors leading to plate leftovers in canteens. *Appetite* 116:45-56.

Lusk, J.L., and B. Ellison. 2017. A note on modelling household food waste behaviour. *Applied Economics Letters* 24(16):1199-1202.

Mazar, A., and W. Wood. 2018. Defining habit in psychology. In *The Psychology of Habit: Theory, Mechanisms, Change, and Contexts*, edited by B. Verplanken. Cham, Switzerland: Springer International Publishing. Pp. 13-29.

Miafodzyeva, S., and N. Brandt. 2013. Recycling behaviour among householders: Synthesizing determinants via a meta-analysis. *Waste and Biomass Valorization* 4(2):221-235.

Milne, R. 2012. Arbiters of waste: Date labels, the consumer and knowing good, safe food. *The Sociological Review* 60(2 suppl):84-101.

Moreno, L.C., T. Tran, and M.D. Potts. 2020. Consider a broccoli stalk: How the concept of edibility influences quantification of household food waste. *Journal of Environmental Management* 256:109977.

Muth, M.K., C. Birney, A. Cuéllar, S.M. Finn, M. Freeman, J.N. Galloway, I. Gee, J. Gephart, K. Jones, L. Low, E. Meyer, Q. Read, T. Smith, K. Weitz, and S. Zoubek. 2019. A systems approach to assessing environmental and economic effects of food loss and waste interventions in the United States. *Science of the Total Environment* 685:1240-1254.

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Nash, N., L. Whitmarsh, S. Capstick, T. Hargreaves, W. Poortinga, G. Thomas, E. Sautkina, and D. Xenias. 2017. Climate-relevant behavioral spillover and the potential contribution of social practice theory. *Wiley Interdisciplinary Reviews: Climate Change* 8(6):e481.

Neff, R.A., M.L. Spiker, and P.L. Truant. 2015. Wasted food: U.S. consumers' reported awareness, attitudes, and behaviors. *PLoS ONE* 10(6).

Neff, R.A., M. Spiker, C. Rice, A. Schklair, S. Greenberg, and E. Broad Leib. 2019. Misunderstood food date labels and reported food discards: A survey of U.S. consumer attitudes and behaviors. *Waste Management* 86:123-132.

Nisa, C.F., J.J. Belanger, B.M. Schumpe, and D.G. Faller. 2019. Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. *Nature Communications* 10(1):4545.

Oyserman, D. 2015. Identity-based motivation. In *Emerging Trends in the Social and Behavioral Sciences: An Interdisciplinary, Searchable, and Linkable Resource*, edited by R.A. Scott, S.M. Kosslyn, and M.C. Buchmann. Hoboken, NJ: John Wiley & Sons.

Papargyropoulou, E., R. Lozano, J.K. Steinberger, N. Wright, and Z. bin Ujang. 2014. The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production* 76:106-115.

Parfitt, J., M. Barthel, and S. Macnaughton. 2010. Food waste within food supply chains: Quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365(1554):3065-3081.

Petrescu-Mag, R.M., D.C. Petrescu, and G.M. Robinson. 2019. Adopting temperance-oriented behavior? New possibilities for consumers and their food waste. *Journal of Agricultural and Environmental Ethics* 32(1):5-26.

Princen, T. 2002. Distancing: Consumption and the severing of feedback. In *Confronting Consumption*, edited by T. Princen, M. Maniates, and K. Conca. Cambridge: Massachusetts Institute of Technology. Pp. 103-131.

Qi, D., and B.E. Roe. 2017. Foodservice composting crowds out consumer food waste reduction behavior in a dining experiment. *American Journal of Agricultural Economics* 99(5):1159-1171.

Quested, T.E., and P. Luzecka. 2014. *Household Food and Drink Waste: A People Focus*. WRAP. Available: https://www.wrap.org.uk/content/household-food-drink-waste-people-focus.

Quested, T.E., A. Parry, S. Easteal, and R. Swannell. 2011. Food and drink waste from households in the UK. *Nutrition Bulletin* 36(4):460-467.

Ratner, R.K., B.E. Kahn, and D. Kahneman. 1999. Choosing less-preferred experiences for the sake of variety. *Journal of Consumer Research* 26(1):1-15.

Reid, M.G. 1934. *Economics of Household Production*. Madison, WI: John Wiley & Sons.

Roodhuyzen, D.M.A., P.A. Luning, V. Fogliano, and L.P.A. Steenbekkers. 2017. Putting together the puzzle of consumer food waste: Towards an integral perspective. *Trends in Food Science and Technology* 68:37-50.

Roof, K., and N. Oleru. 2008. Public health: Seattle and King County's push for the built environment. *Journal of Environmental Health* 71(1):24-27.

Russell, S.V., C.W. Young, K.L. Unsworth, and C. Robinson. 2017. Bringing habits and emotions into food waste behaviour. *Resources, Conservation and Recycling* 125:107-114.

Samdal, G.B., G.E. Eide, T. Barth, G. Williams, and E. Meland. 2017. Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults: Systematic review and meta-regression analyses. *International Journal of Behavioral Nutrition and Physical Activity* 14(1).

Sandson, K., and E. Broad Lieb. 2019. *Bans and beyond: Designing and implementing organic waste bans and mandatory organics recycling laws*. Harvard Law School Food Law and Policy Clinic, Center for EcoTechnology. Available: https://www.chlpi.org/wp-content/uploads/2013/12/Organic-Waste-Bans_FINAL-compressed.pdf.

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Schanes, K., K. Dobernig, and B. Gözet. 2018. Food waste matters: A systematic review of household food waste practices and their policy implications. *Journal of Cleaner Production* 182:978-991.

Schwartz, S.H. 1977. Normative influences on altruism. In *Advances in Experimental Social Psychology*, vol. 10, edited by L. Berkowitz. Poole, UK: Academic Press. Pp. 221-279.

Secondi, L., L. Principato, and T. Laureti. 2015. Household food waste behaviour in EU-27 countries: A multilevel analysis. *Food Policy* 56:25-40.

Soderhorn, P. 2010. *Environmental Policy and Household Behavior: Sustainability and Everyday Life*. Abingdon, UK: Earthscan.

Soma, T. 2017. Gifting, ridding and the "everyday mundane": The role of class and privilege in food waste generation in Indonesia. *Local Environment* 22(12):1444-1460.

Spang, E.S., L.C. Moreno, S.A. Pace, Y. Achmon, I. Donis-Gonzalez, W.A. Gosliner, M.P. Jablonski-Sheffield, M.A. Momin, T.E. Quested, K.S. Winans, and T.P. Tomich. 2019. Food loss and waste: Measurement, drivers, and solutions. *Annual Review of Environment and Resources* 44(1):117-156.

Stangherlin, I.C., and M.D. de Barcellos. 2018. Drivers and barriers to food waste reduction. *British Food Journal* 120(10):2364-2387.

Stefan, V., E. van Herpen, A.A. Tudoran, and L. Läteenmäki. 2013. Avoiding food waste by Romanian consumers: The importance of planning and shopping routines. *Food Quality and Preference* 28(1):375-381.

Stern, P. 2000. Toward a coherent theory of environmentally significant behaviour. *Journal of Social Issues* 56(3):407-424.

Thompson, B., L. Toma, A.P. Barnes, and C. Revoredo-Giha. 2018. The effect of date labels on willingness to consume dairy products: Implications for food waste reduction. *Waste Management* 78:124-134.

Thyberg, K.L., and D.J. Tonjes. 2016. Drivers of food waste and their implications for sustainable policy development. *Resources, Conservation and Recycling* 106:110-123.

Varotto, A., and A. Spagnolli. 2017. Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology* 51:168-188.

Verplanken, B. 2018. *Psychology of Habit: Theory, Mechanisms, Change, and Contexts*. Cham, Switzerland: Springer International Publishing.

von Massow, M., K. Parizeau, M. Gallant, M. Wickson, J. Haines, D. Ma, A. Wallace, N. Carroll, and A. Duncan. 2019. Valuing the multiple impacts of household food waste. *Frontiers in Nutrition* 6:143.

Wansink, B., R.J. Kent, and S.J. Hoch. 1998. An anchoring and adjustment model of purchase quantity decisions. *Journal of Marketing Research* 35(1):71-81.

Wardle, J., M.L. Herrera, L. Cooke, and E.L. Gibson. 2003. Modifying children's food preferences: The effects of exposure and reward on acceptance of an unfamiliar vegetable. *European Journal of Clinical Nutrition* 57(2):341-348.

Watson, M., and A. Meah. 2013. Food, waste and safety: Negotiating conflicting social anxieties into the practices of domestic provisioning. *The Sociological Review* 61:102.

Whitmarsh, L.E., P. Haggar, and M. Thomas. 2018. Waste reduction behaviors at home, at work, and on holiday: What influences behavioral consistency across contexts? *Frontiers in Psychology* 9:2447.

Wilson, N.L.W., B.J. Rickard, R. Saputo, and S.-T. Ho. 2017. Food waste: The role of date labels, package size, and product category. *Food Quality and Preference* 55:35-44.

Yu, Y., and E.C. Jaenicke. 2018. The effect of sell-by dates on purchase volume and food waste. *SSRN Electronic Journal*. Available: https://doi.org/10.1016/j.foodpol.2020.101879.

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4

Interventions to Reduce Food Waste at the Consumer Level

In the past decade, policy makers, researchers, nonprofit organizations, and industry leaders have focused increasing attention on efforts to reduce the wasting of food at the consumer level (see Chapter 2), but research on the effectiveness of interventions[1] to reduce such waste is still relatively new. The committee searched the relevant literature for insights that can support the development of effective interventions to reduce food waste. As with the research on drivers of consumer behavior (see Chapter 3), we looked first at the literature from the six related domains (energy conservation, water conservation, waste prevention/management, recycling, diet change, and weight management), with a focus on ideas that may allow food waste researchers to leapfrog forward on the basis of findings that may transfer across domains. We then turned to the available studies that have assessed the efficacy of interventions to reduce food waste at the consumer level. We developed a process for filtering the available research to identify those ideas supported by research with the strongest evidentiary methodological rigor, as well as the impacts that have been documented and the populations and contexts in which the interventions were assessed. We then considered the alignment of the ideas that emerged from this body of work with the motivation-opportunity-ability (MOA) framework and summarized key findings about the primary types of interventions that have been studied (details about selected studies are in Appendix D). This chapter presents the results of that analysis, as well as a discussion of the

[1] An intervention is defined as a combination of program elements designed to produce behavior changes among individuals or an entire population (Michie et al., 2011).

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limitations of the existing literature and the themes that emerged from these two bodies of work.

LESSONS LEARNED FROM RELATED DOMAINS

Work from the six related domains offers insights about ways to modify behavior that may be useful for understanding and contextualizing the literature on food waste interventions. Although these fields differ in their goals and methods and use different terminology (see Chapter 1), common themes emerged across the literatures. The committee explored systematic reviews, narrative reviews, and meta-analyses to identify findings that would potentially be useful in the context of reducing consumer food waste. A few selected studies with empirical data were also reviewed. (The findings from this research are described more fully in Appendix E.) We identified four broad lessons about interventions to change behavior, which, not surprisingly, overlap with the lessons learned from these six fields about drivers of consumer behavior.

Multifaceted interventions that take advantage of more than one intervention strategy may be more effective than a single strategy alone. While it can be difficult to measure, depict, and disaggregate which strategies influence which behaviors, there is reason to believe that, in general, a combination of strategies is more likely than a single strategy to result in ample and sustained change in complex behaviors (e.g., Cox et al., 2010; Koop et al., 2019; Marteau, 2017; Sharp et al., 2010; Thomson and Ravia, 2011; Varotto and Spagnolli, 2017). A related point is highlighted by a meta-analysis from the weight management domain, which suggests that targeting multiple behaviors (in this case, dietary behaviors and physical activity) may be more effective than targeting single behaviors at stimulating weight loss (Sweet and Fortier, 2010). Similarly, a meta-analysis of behavior change interventions related to weight loss suggests that addressing motivation (e.g., with a communication style that addresses the motivation) along with ability (e.g., offering skills for "how to") can be effective in initiating and sustaining behavior change (Samdal et al., 2017). Further, a systematic review of studies of solid waste management efforts shows that, although they can help increase societal awareness, public education interventions alone (without addressing beliefs, motivations, or attitudes) are insufficient to change behavior (Ma and Hipel, 2016). An important exception is identified in a recent review by Nisa and colleagues (2019) showing that for certain structured settings, simple alterations to choice architecture (i.e., nudges) can yield efficacy and effectiveness.

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Contextual factors can play a key role in supporting or undermining behavior change. Research on efforts to reduce waste through recycling suggests that characteristics of the context or environment in which a behavior is occurring may have as great an influence on that behavior as individual-level factors, and that that there are many barriers to change, particularly outside the household context. External factors may either support or override individuals' desire to waste less, or undermine efforts they make to consume or waste less (Cox et al., 2010). Two studies illustrate this point. The first, a small-scale study, examines waste reduction behaviors at home, at work, and on vacation, and shows that in the latter two contexts, people are less motivated to act proenvironmentally and perceive that they have less control over barriers to such behaviors than they do at home (Whitmarsh et al., 2018). The authors conclude that having a proenvironmental identity as a motivator is not a significant predictor of cross-contextual consistency. The second study, a systematic review and meta-analysis of psychological strategies for promoting household recycling, shows that environmental alterations that minimize the effort required (such as adding bins for waste sorting) are the second most effective strategy in changing behavior, after social modeling[2] (Varotto and Spagnolli, 2017).

Effective interventions may stimulate different types of cognitive processing. Meta-analyses show that effective interventions appeal to one or more of three types of cognitive processing: reflective, semireflective, or automatic.[3] Generally, interventions designed to appeal to reflective processing (e.g., those to increase a person's knowledge about reasons for performing a behavior or to appeal to their self-efficacy) have been found to be insufficient to promote behavior change (Koop et al., 2019; Sharp et al., 2010; Thomson and Ravia, 2011; Varotto and Spagnolli, 2017). However, it has also been found, in the context of household recycling, that if people are already motivated to act, encouraging them to reflect on how to act may promote a desired behavior (Varotto and Spagnolli, 2017).

[2] The authors define social modeling interventions as those that include any kind of passing of information via demonstration or discussion in which the initiators indicate that they personally engage in the targeted behavior.

[3] "Reflective processing" refers to conscious processing of information where attitudes are formed in light of rational arguments, relevant experiences, and knowledge. Tactics for interventions that appeal to this type of processing include knowledge transfer designed to increase self-efficacy. "Semireflective processing" refers to the formation of attitudes through rules of thumb and simple heuristics or cues. Tactics for interventions that appeal to this type of processing include those focused on social norms, framing, and tailoring. "Automatic processing" refers to choices made on the basis of an automatic response, without the intervention of cognition. Tactics for interventions that appeal to this type of processing include emotional shortcuts, priming, and nudging.

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A review of empirical studies in the context of water conservation suggests that interventions designed to stimulate semireflective processing (i.e., using simple cues that help people with making choices) can support long-term behavior change (Koop et al., 2019). Based only on small, short-duration studies, the same review also suggests that interventions intended to stimulate automatic cognitive processes using emotional cues, primes, and nudges have the potential to produce behavior change (Koop et al., 2019). Similarly, a meta-analysis of mechanisms for promoting household action on climate change (i.e., choice architecture, social comparison, information, appeals, and engagement) shows that those using social architecture approaches (i.e., nudges) have the highest effect sizes (Nisa et al., 2019).

Understanding the types of cognitive processing being targeted will help with the design of interventions. Most recently, researchers have begun to create study designs that take more than one processing type into account.

Interventions fall into broad categories in terms of how they operate. Research across the six related domains has produced a range of findings about the efficacy and effectiveness of specific kinds of interventions. These findings suggest that tailoring combinations of interventions to particular circumstances is important because the strengths and weaknesses of interventions may be more or less significant in different contexts. Several scholars have proposed ways of categorizing types of interventions designed to change behaviors to facilitate identifying and leveraging their relative strengths. The committee adopted the following categorization of the types of interventions based on terminology used frequently in other domains (see, e.g., Nisa et al., 2019)[4] to organize and interpret and compare the results of the studies (see definitions in Appendix G):

- appealing to values,
- engaging consumers,
- evoking social comparison,
- providing feedback,
- providing financial incentives,
- modifying the choice architecture (i.e., nudges), and
- providing how-to information.

Applying this categorization illustrates that the types of interventions identified as most effective in the literature from the six domains are varied, and suggests that many types can be effective depending on the context. For example, Nisa and colleagues (2019) found that, overall, interventions

[4] Appendix E describes other categorizations proposed (e.g., by construct, by strategy, by process).

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in the categories of modifying the choice architecture (i.e., nudges, removing external barriers) and evoking social comparison (i.e., comparing one's behavior with others) were more efficacious for behavior change than such traditional interventions as providing information (e.g., statistics, simple messages, energy labels); appealing to values (e.g., requests to change behavior for the benefit of humanity); and engaging consumers (e.g., targeting goal setting, implementation intentions). A deeper exploration of this literature (see Appendix E) suggests that each of the seven types of intervention can play an important role but that nuances need to be considered.

Caution is necessary in attributing effectiveness to any particular type of intervention: each is most effective when targeted appropriately to context, populations, and goals. For example, although information interventions are generally less effective than other types, communication campaigns providing information about health can be effective, particularly when aimed at changing one-time or infrequent behaviors, but generally are less effective at changing habits (Snyder, 2007). Research on financial incentives to motivate behavior also illustrates the need to understand the full effects of an intervention, including short- and long-term effects. While research suggests that using financial incentives to stimulate behavior change can be effective (e.g., for changing diets [Niebylski et al., 2015] or for reducing solid waste disposal at the residential level [Skumatz, 2008]), over the long term it may negatively affect individuals' intrinsic motivation to change the targeted behavior (Delmas et al., 2013; Soderholm, 2010).

REVIEW OF THE EVIDENCE FROM THE FOOD WASTE LITERATURE

The committee conducted an extensive literature search to identify studies that assessed the effects of interventions intended to reduce food waste at the consumer level. Taking into consideration the upstream and system-level aspects of food waste, we examined interventions that target both individuals directly and components of the food supply chain, including such businesses as food service venues and food retailers. We developed a procedure for sorting the results of this search and assessing the strength of the evidentiary support for the findings it yielded. The next step was to consider the fit of the MOA framework to this body of work. We organized studies according to the above seven types of interventions and assessed the evidence.

Process for Reviewing the Literature

The literature search initially covered the period 2005 through June 2019, and was augmented thereafter as committee members and staff

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became aware of additional qualifying studies. The search yielded a total of 64 peer-reviewed intervention studies. Some non-peer-reviewed literature on relevant interventions was also examined. (Appendix B provides a more detailed description of the literature search.)

Quality Criteria Applied to Peer-Reviewed Studies

The quality of the studies identified varied substantially, so the committee established four criteria, which align with evidence standards endorsed for research in prevention science (Gottfredson et al., 2015), for assessing the weight we would give each study in interpreting the evidence:

1. Was an intervention implemented?
2. Was wasted food measured (not just changes in intentions to waste or in behaviors that could reduce food waste)?
3. Did the study design permit analyses to isolate the causal effect of the intervention?
4. Were statistical analyses adequate for determining statistical significance?

Table 4-1 shows how these criteria were applied. We designated studies that met all four criteria as tier 1, and those that met fewer than four criteria as tier 2.

The committee used criterion 1 (an intervention was implemented) to ensure that it would rely only on studies assessing newly implemented practices, rather than comparisons across sites or groups with different preexisting practices. Studies that meet criterion 2 (wasted food was measured, either directly or using such proxies as diaries) yield stronger evidence because they describe interventions that produced actual changes in behavior.

TABLE 4-1 Criteria for Identifying Tier 1 Studies

Criteria (All Must Be Met for Tier 1)	Examples of Not Meeting Criterion
1. An intervention was implemented	Comparing locations with preexisting differences in practices where one practice matches the proposed intervention
2. Wasted food was measured	Intended waste was measured; actions that could lead to reduced waste were measured (e.g., leftover bag use, ugly food purchases)
3. Causal effect can be attributed	Pre- vs. postintervention analysis without an appropriate control group
4. Adequate statistical analyses	Study fails to assess statistical significance

NOTE: Tier 2 studies fail to meet at least one of these four criteria.

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Considerable research has shown that estimated effect sizes in studies of interventions aimed at altering household behaviors are significantly larger when the outcomes measured were changes in attitudes or intentions rather than actual behaviors (Andreasen, 2012; Webb and Sheeran, 2006).

Criterion 3 (causal effect can be attributed) excludes studies whose design and implementation do not permit clear identification of causal effects. One frequently observed design that fails to meet criterion 3 involves pre/post comparisons of food waste with no control group. Without well-designed control groups, there could be many reasons for observed reductions in food discards (e.g., seasonal changes in rates of food waste that happen to coincide with implementation of an intervention). Criterion 4 (adequate statistical analyses) limits the studies on which the committee relied to those in which the calculation and reporting of effect sizes are consistent with established practice and suitably clear for assessing the evidence; that is, statistical significance and relevant magnitudes can be ascertained from the published material.

Together, these four criteria helped the committee identify evidence supporting claims that interventions demonstrated merit across several dimensions of validity (internal, external, construct, and statistical conclusion validity; see Shadish et al. [2002]). We note that use of the term "quality" for tier 1 studies is not intended to imply that studies outside this tier are necessarily of low quality or not informative; researchers may use diverse approaches and methods depending on various factors, including their goals and resources.

Comments on the Evidence

The interventions covered in the committee's review were designed to operate in a range of contexts: at the household level; at establishments where individuals eat (i.e., food service settings); at other levels of the supply chain that could influence consumer behavior (e.g., food retailers or farmers' markets); and in some cases, outside the food supply chain (e.g., community, media). About three-quarters of the studies were conducted outside the United States, so we judged their applicability to the U.S. context based on the similarity of relevant cultural and value aspects (e.g. the value of food).

Figure 4-1 shows the distribution of peer-reviewed studies by tier and intervention setting. There are five times as many tier 2 studies as tier 1 studies, and about half of the studies in each tier focus on food service settings. All the studies considered are described in Appendix D.

The empirical studies that meet the committee's inclusion criteria all rely on linear approaches to assessment instead of the systems approach endorsed by the committee (see Chapter 1). Because of the burden of

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A National Strategy to Reduce Food Waste at the Consumer Level

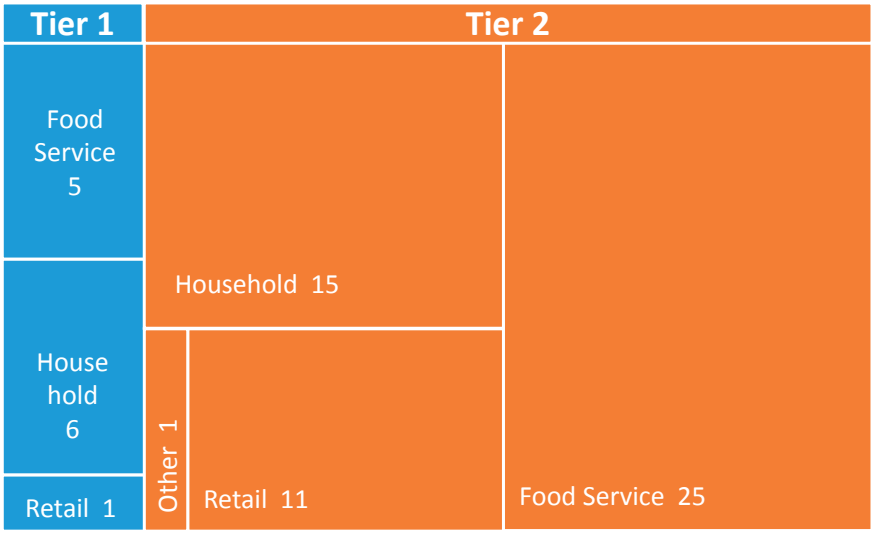

FIGURE 4-1 Peer-reviewed studies by tier and setting.

implementation and tracking, most intervention studies focus on a single stage in the consumer process (e.g., purchase, home meal preparation, consumption, discard) rather than on circumstances that involve multiple components of the food system. Therefore, although these studies suggest causal relationships between interventions and reductions in food waste, they do not include assessment of the more complex feedbacks that would be expected from interventions designed with a systems approach. However, many of the studies examine designs that make use of more than one intervention type; many also address more than one of the three elements of the MOA framework. Although the available studies do not address multiple stages within the food supply chain, they do support the idea that multiple strategies may reinforce each other in an effort to effect change.

The committee also reviewed key modeling studies, which, rather than providing empirical assessments of interventions, depict how interventions may affect food waste and other variables of interest across the food supply chain. Modeling studies are particularly useful for exploring potential systems-level effects. Such effects include spillovers (such as impacts on other parts of the food supply chain or society) and unintended effects (such as shifting waste from one part of the system to another). Modeling studies also support predictions about behavioral and organizational responses that arise at points in the food supply chain not directly targeted by an intervention, as well as the associated costs and benefits. Typically, such studies are based on assumptions about the structural relationships among key system

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components and rely on previously available empirical data to calibrate these relationships. They can generate fresh insights and broaden the focus from the effects of singular interventions to wider impacts and multiple outcomes. For example, the broadest modeling study found (Chitnis et al., 2014) explores system-wide rebound effects of food waste reduction efforts together with other proenvironmental behaviors that households might undertake. The authors assess the implications of food waste reduction efforts for greenhouse gas emissions by estimating from secondary data how households would spend the money they save by wasting less food.

In addition, the committee reviewed selected non-peer-reviewed (gray literature) intervention and modeling studies. We considered these studies as additional information in our overall discussion of the evidence.

Applying the MOA Framework

The committee next considered the relationship between the seven intervention types listed earlier (appealing to values, engaging consumers, evoking social comparison, providing feedback, providing financial incentives, modifying the choice architecture [i.e., nudges], and providing how-to information) and the three elements of the MOA framework (see Figure 4-2). Several intervention types are broad enough to be linked with two or more elements of this framework. For example, nudges can affect both opportunity (e.g., by reducing plate size) and motivation (e.g., by changing when school meals are served relative to children's recess periods).

The MOA framework highlights the importance of implementing interventions that address more than one of its three elements to support behavior change. For example, as discussed previously, although interventions that increase motivation can change behavior, motivation alone is generally insufficient to lead to participation in that behavior. When ability and opportunity to change behavior are not present, interventions that increase them also are needed. Thus, for example, even if individuals wish to reduce food waste, refrigerators that are set at the wrong temperature can increase the perishability of food, making it more difficult to translate that motivation into a desired outcome.

Another advantage of the MOA framework, emphasized in Chapter 1, is that it allows for consideration of automatic behaviors, such as habits and norms that are not reliant on explicit individual motivation (Kwasnicka et al., 2016). That is, when motivation, opportunity, or ability is low, consumers are likely to be influenced by factors related to routine, choice context, nonconscious factors, or social norms, and that addressing individual, group, and societal cues will increase the chances of achieving sustained behavioral change.

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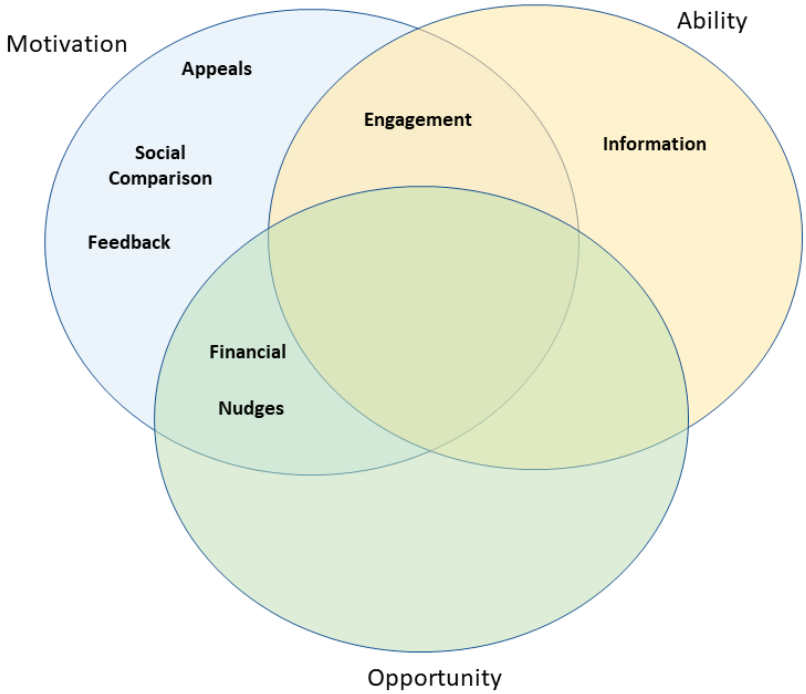

FIGURE 4-2 Relationship between intervention types and the elements of the motivation-opportunity-ability (MOA) framework.
NOTE: The placement of an intervention type in the intersection of multiple circles usually means that the category encompasses some interventions within one element and some within another. However, some interventions may affect multiple elements simultaneously.

Review of Interventions by Type

Figure 4-3A shows the distribution of intervention types by the strength of the evidence supporting them (by study tier) while Figure 4-3B shows their distribution by study setting (at or away from home). Together, these figures reveal several patterns. First, about half of the studies reviewed address multiple interventions, and therefore, the count of intervention types exceeds the number of studies (e.g., 25 intervention types are addressed in the 12 tier 1 studies; see Figure 4-3A). While this multi-intervention approach may be beneficial, many of these studies do not allow for the segmentation of results to yield clear insight into the roles of the different intervention types. Second, both figures highlight the dominance of intervention types that operate to increase consumer motivation (i.e., appeals, social comparison, feedback): more than half the studies reviewed feature at least one intervention linked to motivation. Third, among studies of

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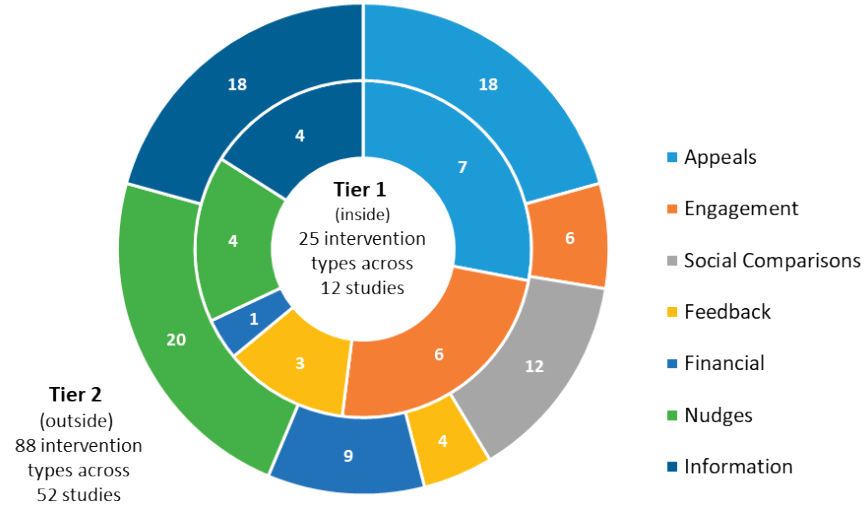

FIGURE 4-3A Strength of the evidence base for the seven types of intervention.

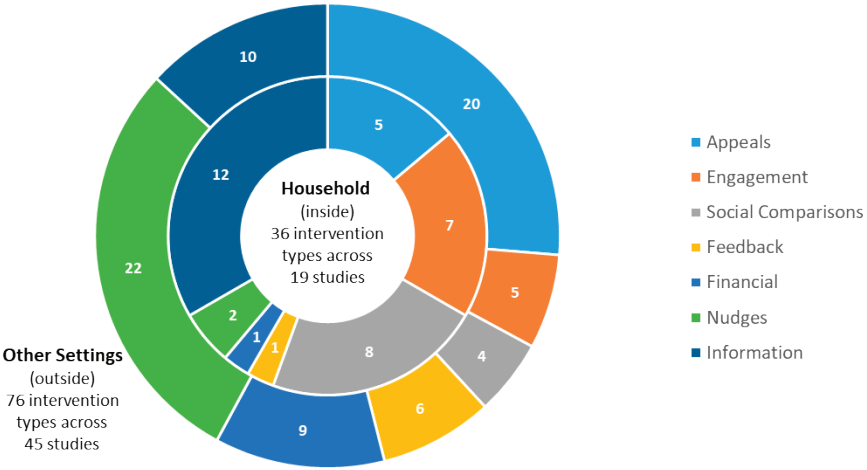

FIGURE 4-3B Distribution of intervention studies by setting (in-home versus retail and food service).

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interventions focused on opportunity (i.e., nudges), the majority fall into tier 2 and were conducted outside the home. Studies of interventions focused on ability (e.g., information messages to build knowledge and skills) focus primarily on households.

Overall, this body of work addresses primarily intervention efficacy (the extent to which an intervention produces the desired results under ideal circumstances) and, to a lesser extent, effectiveness (the extent to which an intervention is shown to achieve its aims in laboratory conditions or real-world settings). Few of the studies explore implementation factors, such as cost, feasibility, and ease of implementation, that play a role in selecting interventions; the need to address this gap is discussed in Chapter 6. Also, few of the studies explore additional systems effects of interventions, such as system-wide feedbacks, rebound effects, and cobenefits or coharms for nonwaste outcomes. None of the studies consider the implications of interventions for income inequality or other distributional concerns.

Appeals

Appeal interventions encourage consumers to change their behavior to achieve a social benefit. Explicit appeals, which request action directly, are distinct from implicit appeals, which do not make a request. Implicit appeals may be based on a presumption that the facts will tap into existing attitudes or values, or may serve as prompts to action by raising awareness. Explicit appeals build on those mechanisms and also activate the human tendency to respond to requests, particularly when they align with values, when the requestor is valued, or when something is owed to the requestor (reciprocity). Twenty-five of the 64 studies reviewed by the committee included appeal interventions: 13 that used explicit appeals, 3 that used implicit appeals, and 9 that used both and other intervention types. The largest number of interventions presented signage or other messaging in food service venues, often in universities. Other interventions provided messages directly to study participants or engaged participants in creating messages; one pair of studies involved delivering messages to the general public.

One tier 1 study (Ellison et al., 2019) found a null effect for the appeal component, and one found an overall null intervention effect (Liz Martins et al., 2016), but it was not possible to isolate the appeal component. All but three of the tier 2 studies found statistically significant impacts, with the magnitude of effect varying. A few tier 2 studies involved comparing appeal interventions with other types, such as providing information (Collart and Interis, 2018) and feedback (Whitehair et al., 2013), with results favorable to appeal interventions. In at least a quarter of the studies, it was not possible to disentangle the results of the appeal intervention from

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those of other interventions included in the study. Few studies looked at maintenance of impact across time.

Engagement

Engagement interventions change psychological processes by engaging the consumer in, for example, setting goals, establishing implementation intentions, making a commitment, or increasing mindfulness toward the target behavior. Twelve studies (six in tier 1) featured such interventions, which are often multifaceted, operating through multiple drivers. Thus, the results of this type of intervention may be manifested in a variety of ways. These interventions have a mixed record in delivering significant reductions in food waste, which makes it difficult to provide a summary evaluation. For example, engagement interventions delivered in the home included diverse mechanisms: systematically engaging individuals to reconsider household food routines (Devaney and Davies, 2017, tier 2); providing tools to support changes in meal planning or preparation (Romani et al., 2018, tier 1); and using gamification to accelerate and deepen learning about wasted food (Soma et al., 2020, tier 1).

Several food service interventions were also comprehensive, involving food service personnel and patrons (Strotmann et al., 2017, tier 2) or both food service personnel and student customers (Prescott et al., 2019, tier 1). The results of these studies suggest that interventions aimed at reprogramming base processes that drive food waste hold promise, but the lack of consistent reductions implies that formulating the multiple elements common to this approach may be difficult. Furthermore, the complex and multifaceted nature of these interventions impedes assessment of which individual strategy or subset of strategies drives efficacy.

Social Comparison

Social comparison interventions operate on principles of social influence. Twelve studies, all tier 2, included such interventions. The interventions studied were diverse, focusing on social desirability, public commitment, social media communications, communication of social norms, food sharing, and such situations as workshops in which a peer group might influence behavior. The authors of only three of these studies provide quantitative results that make it possible to distinguish the effects of the social comparison intervention from those of other interventions in the study. Two of these three focused on restaurant leftovers. Hamerman and colleagues (2018) and Stockli and colleagues (2018) found that messages designed to invoke social norms (i.e., saying a majority of patrons request to take food home) were not more effective than informative messages. Hamerman and colleagues

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(2018) found that study participants were significantly more likely to request to take home leftovers when they envisioned dining with friends versus dining with someone they wanted to impress. Five of the studies used qualitative or mixed-method approaches, with all but one suggesting that social comparison was beneficial in preventing waste. However, findings from Lazell (2016) echo those from Hamerman et al. (2018), suggesting that the effectiveness of social comparison interventions can depend on participants' views about what behavior is normative and about the social groups with which they are comparing themselves. Overall, the evidence regarding social comparison interventions is inconclusive, and the research suggests a need for nuanced intervention development and careful selection of social groups for comparison and messaging.

Feedback

Feedback interventions shape targeted behaviors by providing information that reinforces or corrects those behaviors. Seven of the studies reviewed (three tier 1) featured feedback interventions, largely as part of multifaceted interventions implemented in food service settings. Thus, it was difficult to identify the individual impact of the feedback strategies. A common strategy was to offer cafeteria patrons feedback concerning the average waste created by other patrons, although studies using such strategies as part of a multifaceted intervention revealed little success. Personalized feedback, often generated for elementary and middle school students in cafeteria settings as part of a multifaceted intervention, showed some statistically significant effects (e.g., Liz Martins et al., 2016, tier 1; Prescott et al., 2019, tier 1). Feedback delivered among different food service worker stations within a large hospital facility showed promise as part of a multifaceted intervention that significantly reduced waste (Strotmann et al., 2017, tier 2). And a qualitative assessment of the use of home cameras to track waste suggests that such approaches could stimulate waste reduction by invoking feelings of shame (Comber and Thieme, 2013, tier 2). Overall, feedback interventions have a mixed record, with weaker effects when feedback is not individualized.

Financial Incentives

Interventions providing financial incentives alter the monetary consequences of behaviors that can influence the amount of food consumers waste. One tier 1 study in South Korea found financial penalties that increase with amount of wasted food generated at the household level to be more effective at reducing the amount of wasted food than financial penalties tied to community level waste amounts (Lee and Jung, 2017). The

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authors, however, noted illegal dumping as a potential unintended consequence. It has been well documented that overall household waste disposal (food plus nonfood waste) declines when households are forced to pay more for additional amounts of waste (Bel and Gradus, 2016). Nine tier 2 studies featured other financial interventions. Most involved comparing the effects of retail price reductions with those of other approaches used to encourage consumers to purchase suboptimal (ugly or expired) food that might otherwise be wasted. These studies yielded statistically significant evidence that price reductions can increase purchase intentions. However, alternative motivational approaches, such as highlighting the environmental consequences of food waste, often yielded changes similar to those seen in purchase intentions or enhanced the effectiveness of price discounts.

Two studies focused on quantity (e.g., large-pack or multipack) discounts (LeBorgne et al. 2018, tier 2; Petit et al., 2019, tier 2). These studies showed that giving consumers information about how such deals can translate to greater waste had less effect on purchase intentions relative to simply lowering unit costs for certain foods. Two studies in food service settings showed mixed results for comparison of the efficacy of imposing fines for excessive plate waste and emphasizing environmental benefits to reduce plate waste (Chen and Jai, 2018, tier 2; Kuo and Shih, 2016, tier 2).

Overall, financial incentives are a promising way to discourage behaviors that are precursors to food waste and to increase motivation for overall home waste reduction. However, linking financial incentives to decision points specific to wasting food may prove difficult, and establishing efficacy and implementation feasibility will require considerable additional research.

Nudges

Nudge interventions alter the choice architecture faced by consumers in a manner designed to encourage targeted behaviors without engaging conscious (reflective) decision making (see Chapter 1). The committee reviewed 24 studies (four tier 1) that involved such interventions, most of which addressed food service settings. The nudge interventions studied operated by means of diverse mechanisms, including shifting perceived quantity, altering appeal, or changing the default/easiest action. The interventions assessed in about 40 percent of the studies focused on shifting consumers' perceptions of quantity through changes to portion size, package size, plate size, or tray availability. Most of the studies found significant reductions in waste attributable to quantity manipulations, although only two such studies were tier 1. Three studies (Kim and Morawski, 2013, tier 1; Sarjahani et al., 2009, tier 2; Thiagarajah and Getty 2013, tier 2) focused on removal of cafeteria trays, which limits quantity by making it more difficult for

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patrons in buffet settings to carry multiple plates. All three of these studies (plus several non-peer-reviewed studies) found significant reductions in plate waste. In contrast, one recent non-peer-reviewed study (Cardwell et al., 2019) found no effect.

Another 40 percent of studies involved altering the appeal of food with the intent of decreasing waste by encouraging increased consumption. Several tier 2 studies enhanced appeal directly by improving meal quality or better matching meal components to patrons' preferences; a majority of those studies showed a significant reduction in waste for these interventions. Other studies, including two tier 1 studies (Ilyuk, 2018; Williamson et al., 2016), involved nudges to increase appeal less directly, including by altering the quality of the material of the plate used; providing priming messages to subtly enhance the self-esteem of customers considering the purchase of suboptimal foods; making purchasing require more effort to enhance the consumer's psychological ownership of food; and providing cafeteria meals after recess, when students' appetites would be greater. All four studies found significant effects.

The remaining studies (all tier 2) involved forcing changes to consumers' default behaviors. Two studies focused on date labels, with one altering descriptive phrases (e.g., changing "sell by" to "use by") to stimulate different processing of date information (no effect) and the other removing dates to force different evaluation approaches for product freshness (significant reduction). One study (Manzocco et al., 2017, tier 2) considered how lowering ambient refrigerator temperatures might help consumers discard less produce. Modeling studies also highlight the potential benefits of improving refrigeration design (see details in Appendix D). Extending the time period at which food remains at peak quality is among the most promising approaches to preventing waste at all levels of the food supply chain, and such approaches have particular utility for helping consumers navigate scheduling shifts that prevent using purchased food when planned. Although considerable technological design effort exists in that space, such as packaging, including modeling studies assessing potential impacts, they are seldom tested in interventions that specifically assess the impact on consumer discards; and thus other studies did not qualify for this review. Policies that ban organic waste from landfills can also change default behaviors (Sandson and Broad Leib, 2019), although none of the studies reviewed examined such interventions.

Overall, the evidence for nudge interventions focused on shifting food quantity and appeal is stronger than that for any of the other intervention types, with statistically significant effect sizes being documented in multiple studies of this intervention type. However, the evidence is mixed, dominated by tier 2 studies, and limited in context (studies of nudges were primarily short-run evaluations carried out in buffet settings). Further, the potential

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for these interventions to be feasible needs to be considered in light of effects of the COVID-19 pandemic, such as how the closing of food service venues during the pandemic will affect other practices related to food.

Information

One of the most common and seemingly intuitive approaches to addressing food waste is providing participants with concrete advice aimed at helping them reduce their waste: a tool for action, such as knowledge or skills regarding how to reduce waste. This category is distinct from appeal and feedback interventions, which also provide forms of information; information interventions entail providing only "how-to" information. Intervention designs of this type are often rooted in the theory of planned behavior (see Chapter 1).

The committee's literature search identified 22 studies that included information interventions, three of which are tier 1 studies. The interventions studied were fairly evenly divided between household and food service settings. In most cases, the guidance provided included multiple how-to tips targeting different strategies for reducing food waste or preserving food longer. The information and tools provided were often designed to be proximate to the point of decision making (e.g., refrigerator magnets and food containers for storage decisions, spreadsheets for use when planning meals). Advice was provided in a variety of modalities, from pamphlets and information packets to films, signage, and social media.

In most cases, the information interventions paired advice with other interventions, such as calls to action, tracking, or communication of social norms. Thus in many of the studies (8 of the 22, including 2 of the 3 tier 1 studies [Liz Martins et al., 2016; van der Werf et al., 2019]), it was not possible to distinguish the effects of the information component itself. The third tier 1 study (Soma et al., 2020) showed a small effect for the information component when the intervention encouraged participants to engage actively with the information through quizzes with rewards, while passive participation or modes that required more coordination to achieve engagement (attending group workshops) failed to produce significant waste reduction.

Six of the tier 2 studies found significant positive effects that could be attributed directly to the information provision. One involved tailoring the information provided based on pretest results, a procedure that significantly improved outcomes (Schmidt, 2016). Two studies found null effects of the information provision (Ahmed et al., 2018; Jagau and Vyrastekova, 2017). In some cases, effects measured reflected intermediate outcomes, such as knowledge. Qualitative studies generally found positive effects for providing information through such means as intensive small-group sessions. The

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committee also reviewed two studies (tier 2) where a UK retailer implemented multiple informational and social approaches using communication techniques, with positive effects on food waste (Young et al., 2017, 2018). Several other reports of large-scale information interventions that had not been peer-reviewed also suggested potential positive impacts for information interventions.

In summary, while some studies suggest significant effects may be achieved with simple informational interventions alone, other studies suggest null effects, and long-term impacts must be assessed. Additionally, as the public grows more knowledgeable about wasted food, the impact of informational approaches may be reduced.

SUMMARY AND CONCLUSIONS

Interventions to address consumer-level food waste address different components of the food system (e.g., food retail, cafeterias in schools and higher education settings, hospitals, and restaurants; households; and government policies) using a wide range of mechanisms. The increased attention to food waste over the past decade (see Chapter 2) and the growing body of research on the drivers of consumer behavior in the food waste and related domains may give the impression that much is already known about how to promote behaviors that reduce food waste. Yet as the evidence discussed in this chapter demonstrates, the literature evaluating interventions to reduce food waste is relatively small, and high-quality experiments are sparse, although rapidly developing. The broader body of research on interventions in the six related domains considered by the committee and the smaller, emerging body of work specific to food waste, are being carried out in a variety of fields and research traditions (see Chapter 1). Thus, integrating and assessing the findings from the literature is challenging. In addition, differences in terminology make it difficult to compare findings in the food waste literature with those from the six related domains. Nevertheless, many tantalizing findings suggest the potential for impacts of high magnitude.

In the research from the six related domains, the committee identified evidence about interventions that appeared to be effective in changing behavior, based on broad findings from across populations and contexts (see Appendix E). Some of those findings were also identified in the emerging food waste literature and they are discussed below.

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Findings about Interventions

The Value of Multifaceted Interventions

Research from the six related domains demonstrates that in general, multifaceted interventions that leverage more than one mechanism may be more effective than those that rely on a single mechanism. Most of the interventions studied in the food waste literature were multifaceted in that they included components reflecting more than one of the seven types of interventions discussed in this chapter—for example, an intervention that both provided information and appealed to consumers' values related to the information given.

One reason a multifaceted intervention is likely to be more effective than a unitary approach is that food waste, like many other behaviors, is driven by multiple influences. The components of the former interventions thus may reinforce each other and amplify the overall power of the effort to effect change. Moreover, the effects of multifaceted interventions can be augmented because the combined interventions can address more than one of the three elements of the MOA framework. Additional benefits can come from combining interventions effective at initiating behaviors with those effective at sustaining behaviors. These observations do not indicate that multifaceted interventions are essential in all case. For example, unitary interventions from the nudge category, such as tray removal and plate size reduction, leverage automatic decision processes and yield significant reductions in waste on their own. Moreover, the food waste literature is not yet substantial enough to support a firm conclusion that bundled interventions are uniformly more effective than single interventions. Nonetheless, the existing evidence certainly suggests the value of integrating multiple intervention types.

The Value of Understanding Cognitive Processes

As mentioned in Chapter 1, early theories characterized human behavior as being predominantly conscious and driven by reason, while more recent work has demonstrated that individual behaviors are responsive to both reflective and automatic processes. The seven intervention types can be thought of in terms of the behavioral processes they target, which fall on a continuum ranging from reflective to semireflective to automatic. Reflective processes can be targeted by interventions featuring information, appeals, feedback, engagement, and financial incentives, in which the objective is for consumers to reflect and reason about their behaviors and decide to alter them. Semireflective processes can be targeted by interventions featuring engagement, social comparison, financial incentive, and in

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some cases, nudges (e.g., plate size as a cue for food acquisition in a buffet). These interventions, which often operate by altering consumers' heuristics, begin to shape behaviors more subtly. Automatic processes are commonly targeted by social comparison and nudge interventions, which are designed to change behavior by altering choice architecture, removing barriers to behavior, or provoking instantaneous responses without necessarily engaging a consumer's reflective processes. As discussed in Chapter 3, knowledge of the drivers of specific food waste behaviors, as well as understanding of the cognitive processes (e.g., reflective or automatic) and elements of the MOA framework involved in those behaviors, can guide the design of future interventions.

Relative Effectiveness of Intervention Types

The types of interventions that have been most effective in the six related domains are varied, suggesting that many types can be effective depending on contextual factors. Among the seven intervention types, those focused on choice architecture (i.e., nudges, removing external barriers) and social comparison (i.e., comparing one's behavior with that of others) have been found to be more efficacious than the other types. However, factors related to the circumstances and domains in which the various intervention types are implemented influence how effective they are. For example, each is most effective when targeted appropriately to context and when such factors as the duration of the intervention, the content of messages, and integration with other interventions are considered. It is also important to consider the target population: for example, financial incentives may be effective with some consumers, but financial disparities can alter how such an intervention is experienced.

The existing evidence does not support an assertion that any interventions are effective across domains or support the identification of combinations of intervention types that are more effective at reducing consumer-level food waste in all contexts and for all populations. For example, while the use of nudges in away-from-home settings (e.g., trayless cafeterias) appears to be effective, nudges in households might require additional strategies (e.g., to motivate consumers to purchase smaller plates). The committee emphasizes that only 11 peer-reviewed food waste studies met all four of its tier 1 evaluation criteria. No intervention types are yet supported by a suite of well-executed studies, carried out with multiple populations and in varied contexts over a suitable duration to support strong conclusions.

CONCLUSION 4-1: Existing research does not yet provide the highest level of support for widespread adoption of specific interventions in multiple contexts. However, there is evidence that some interventions

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may be efficacious at reducing food waste at the consumer level in the short term, and suggestive evidence of the potential benefits of other types of interventions.

Findings supporting this conclusion are summarized in Table 4-2. The committee urges caution, however, in generalizing about the efficacy and effectiveness of interventions based on these findings. The effectiveness of any intervention will depend on its being well designed, tailored to the context and with consideration of various elements of the MOA framework, and well implemented. The additional research needed to evaluate the efficacy and effectiveness of promising interventions is discussed in Chapter 6.

Limitations and Gaps in the Evidence Base

Although the rapid pace of intervention development and competition for the limited funds available to address food waste can make evaluation of interventions appear to be a luxury, evaluation is essential to further progress in reducing consumer-level food waste. The committee notes multiple limitations across the reviewed literature, with even the best available tier 1 studies suffering from such limitations as a lack of long-term evaluation and lack of replication that are impeding progress. These limitations are summarized in this section. The committee's specific research recommendations are presented in Chapter 6.

CONCLUSION 4-2: Although many of the food waste studies reviewed met high standards of quality, the current body of literature has limitations that need attention in future research designs. Those limitations include limited field-based research; the small scale of the studies; lack of long-term evaluation; the diverse approaches used in measuring wasted food; lack of a systems approach, including implementation of diverse intervention types and measurement of trade-offs; lack of attention to distributional and equity considerations; and limited consideration of implementation. Replication in a range of U.S. populations and contexts, which would increase generalizability, is critically lacking.

Because context shapes behavior and is therefore a key factor to consider in studying behavior change, research conducted in the field (e.g., food service and retail store settings) can provide essential insights. On the other hand, field research presents practical difficulties that do not affect laboratory and desk-based research, such as the fact that establishing control groups is not always feasible. Moreover, many food waste interventions are designed to be implemented in settings, such as school cafeterias, food

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TABLE 4-2 Types of Interventions and Examples with Evidence (Tier 1 Studies) and Suggestive Evidence (Tier 2 Studies) of Efficacy in Reducing Food Waste[a,b]

Intervention	**Examples**
Appeals	With evidence: • Delivering materials with appeal combined with other messaging intervention types (such as information, feedback) direct to residents • Providing food systems education to students and having them contribute to the design of a poster with an appeal message • Sharing information about harms of food waste • Requesting diners to reduce portions, take less food, or take more trips to the buffet With suggestive evidence: • Using a self-affirmation intervention to increase receptivity to food waste prevention messages • Displaying posters encouraging university diners not to take food they would not eat • Displaying posters triggering negative social emotions associated with wasting • Linking altruistic or virtue messages with waste prevention
Engagement	With evidence: • Engaging schoolteachers and students through curriculum and related projects to deepen understanding of and personal commitment to reducing food waste • Engaging food service workers, managers, and patrons to deepen understanding of the magnitude and consequences of food waste and to jointly develop solutions customized to their food service setting
Social Comparisons	With suggestive evidence: • Using social interactions and shared values to promote waste reduction among multiple partners in community • Reducing the social stigma of requesting a box for restaurant leftovers by having the server offer it • Using public commitments as a way to be accountable • Using public demonstrations of results through such interventions as bin cameras
Feedback	With suggestive evidence: • Providing personalized feedback about the success of waste reduction efforts as part of a broader set of intervention strategies

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TABLE 4-2 Continued

Intervention	**Examples**
Financial	With evidence: • Paying more as more waste is discarded from the home With suggestive evidence: • Offering price discounts on suboptimal food • Removing discounts for bulk or multiunit purchases
Nudges	With evidence: • Reducing food quantities in buffet settings through the use of smaller plates, smaller portions, or tray removal • Switching serveware from paper to plastic plates • Increasing consumers' psychological ownership of food With suggestive evidence: • Increasing food's appeal through changes in meal quality and timing • Removing date labels • Setting appropriate refrigerator temperatures
Information	With evidence: • Conducting campaigns that provide booklets, refrigerator magnets, informational emails sent directly to participants in home or school settings, generally used as part of a multifaceted intervention combined with appeal or feedback interventions • The above plus providing food storage containers With suggestive evidence: • Tailoring information to respondent needs • Conducting small, intensive workshops • Asking participants to read a single article about food waste • Publicly sharing information through such means as posters, recipes, in-store cooking demonstrations, and social media as part of a multifaceted campaign • Conducting national campaigns providing information and skills to reduce food waste

[a]Tier 1 studies met four criteria: an intervention was implemented, wasted food was measured, causal effect can be attributed, and statistical analysis was adequate. Tier 2 studies failed to meet at least one of those four criteria.

[b]The committee urges caution in extrapolating the information in this table to generalized statements about the efficacy and effectiveness of these interventions, which will depend on many other factors.

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stores, or restaurants that are not accustomed to research partnerships and may not view evaluation as a priority.

Short-Term, Small-Scale Studies

The food waste literature contains very few studies that assess medium- and long-term effects. Most studies evaluate effects on time scales of hours to weeks, but meaningful change in food waste behavior requires impacts on the scale of many years. Moreover, when assessment is only short term, intermittent waste events (e.g., freezer cleanouts) that can dominate total household waste levels may be missed (Parizeau et al., 2015). It is particularly important to replicate small studies that yield intriguing findings, including intervention opportunities that tap into rarely discussed change mechanisms, using longer timeframes and other methodological improvements.

Diverse Approaches to Measuring Wasted Food

Measuring change in the actual waste of food can be costly and presents logistical and methodological challenges. As a result, many studies use alternative outcome measures with varying levels of reliability and validity. In addition, many studies focus on intentions rather than actual wasted food. Findings from the literature in the six related domains indicate clearly that intentions are not a valid proxy for actual behavior.

Lack of Studies Addressing the Full Array of Drivers or Intervention Types by Applying a Systems Approach

Comparing the interventions studied against the drivers of food waste that have been identified in the literature reveals important gaps in the interventions examined. One such gap is that while the majority of research on drivers has focused on behaviors that occur at home, the intervention research addresses largely behavior that occurs away from home, most likely because easier access to consumers in public spaces facilitates both implementation of interventions and evaluation. The committee also notes that interventions related to motivation have been researched more thoroughly relative to interventions related to opportunity and ability. While all 11 of the summative drivers discussed in Chapter 3 have been explored through tier 2 intervention studies, only two of them were components of interventions studied in tier 1 research (see Figure 4-4).

A different approach to identifying gaps in the intervention literature is to consider the types of interventions that have been evaluated in the context of a well-known framework of systems change (Meadows, 1999,

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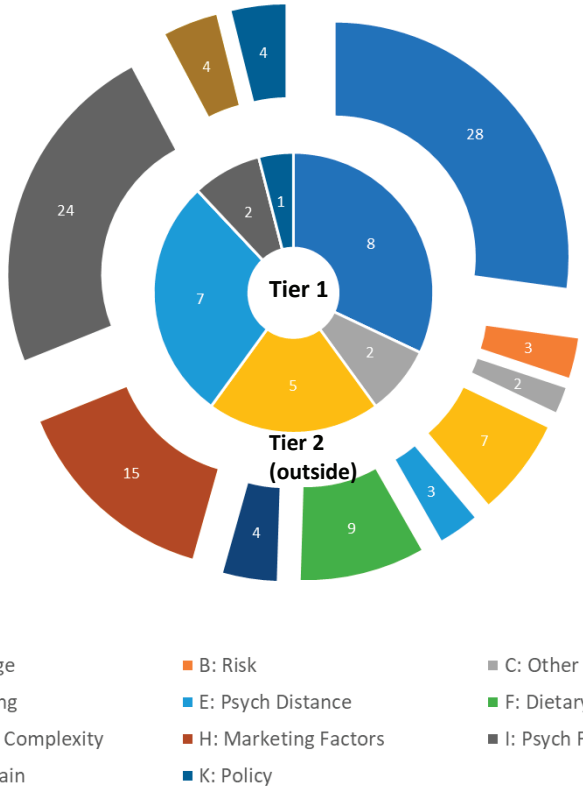

FIGURE 4-4 Count of summative drivers targeted by study tier.
NOTES: Many interventions map to multiple drivers. See Chapter 3 for the list of and descriptions for each summative driver. The letters in the legend correspond to those assigned to the summative drivers in Chapter 3.

2008). Most interventions studied (about two-thirds) focus on the element in that framework of building individual capacity, with the remainder divided among the categories considered more likely to promote more systematic change (design, information flows, rules and structures, and leadership). However, the committee notes that some of the higher-order systems change processes in this framework (such as those oriented toward shifting rules and structures and leadership) would be relatively unlikely to be addressed through formal interventions in general, and that if they were, it could be challenging if not impossible to evaluate the impacts on such processes using traditional evaluation approaches such as those reviewed in this chapter.

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Interventions can also be considered in the context of Mourad's (2016) taxonomy of "strong" and "weak" prevention. "Weak" prevention is depicted as seeking to change individuals, processes, and technologies without fundamental systemic change, and is generally geared toward efficient management of existing surplus across the supply chain and by consumers. By contrast, "strong" prevention interventions address root-cause factors, working to shift patterns of unsustainable production and consumption. Interventions targeting buffets provide one way to think about the distinction between weak and strong prevention, and highlight the importance of spaces and structures that facilitate waste. An all-you-can-eat buffet has a built-in structure for overconsumption. While most buffet interventions target consumer behavior within such facilities (e.g., reducing plate sizes), one type of strong intervention might be to redesign this model of dining.

Lack of Attention to Trade-offs and Implementation of Interventions

The empirical studies that met the committee's inclusion criteria included scarcely any consideration of implementation, feasibility, or cost-effectiveness. That is, while efficacy was explored, the data collection did not encompass effectiveness. In addition, only some of the modeling studies reviewed, and some other studies and reports that did not meet the committee's inclusion criteria, consider or address potential trade-offs, cobenefits, or spillover effects of interventions (e.g., licensing or rebound effects). For example, the relationship among food waste, portion sizes, and obesity needs to be explored because the objectives of reducing waste and eating smaller portions for health reasons may be at odds. Similarly, improper handling of food in leftover bags can compromise food safety. Other trade-offs include effects on income inequality or other distributional effects (see below). Such information is critical for those selecting and adapting interventions for implementation, and remains a priority for future research.

Lack of Attention to Distributional and Equity Considerations

The committee highlights the importance of both assessing the inequity in the impacts of food waste and also accounting for inequities when designing food waste reduction interventions. When designing interventions, it is important to consider the affordability and feasibility of targeted behaviors across diverse income levels, household sizes, languages spoken, and other factors. It is also necessary to assess the effects of interventions on those not directly targeted, including food service staff (some interventions create extra work, such as in washing dishes, which might need to be compensated) and recipients of donated food (the amount and quality of such food may change as businesses shift their practices).

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Food waste prevention interventions need to be designed carefully so they do not exacerbate existing social inequities. For example, interventions promoting the purchase of goods that may be *perceived* as of lesser quality even if they are not (e.g., foods that are near their labeled expiration date, have damaged packaging, or are aesthetically unpleasing) can cause insult, particularly when these foods are promoted at lower prices or distributed in food assistance programs. On the positive side, interventions aimed at decreasing food waste could address inequities in opportunity and ability, such as by supporting the upgrading of the quality of refrigerators or providing more appealing food choices in school food or food assistance programs.

Potential for Generalizability

Only about one-quarter of the intervention studies reviewed by the committee were conducted in the United States. Thus, the research base provides limited evidence useful for targeting interventions to specific U.S. contexts based on such factors as demographics, policy, infrastructure, and geography. As the body of evidence matures, it will be critical to increase the testing of interventions outside of the United States. As explained in this chapter, interventions may affect behavior differently in different contexts: for example, smaller plates may be experienced differently in the home, where norms of taking seconds may be more common, than in a restaurant. Additionally, some of the studied interventions focus on building motivation while relying implicitly on the existence of opportunity and ability. But as noted, opportunity and ability factors are not distributed equally across the population, for reasons including income, geography, and preexisting equipment. Thus it will be important to expand the research base to diverse contexts and scales to identify interventions with the greatest impact and fewest unintended consequences.

REFERENCES

Ahmed, S., C.B. Shanks, M. Lewis, A. Leitch, C. Spencer, E.M. Smith, and D. Hess. 2018. Meeting the food waste challenge in higher education. *International Journal of Sustainability in Higher Education* 19(6):1075-1094.

Andreasen, A.R. 2012. Rethinking the relationship between social/nonprofit marketing and commercial marketing. *Journal of Public Policy & Marketing* 31(1):36-41.

Bel, G., and R. Gradus. 2016. Effects of unit-based pricing on household waste collection demand: A meta-regression analysis. *Resource and Energy Economics* 44:169-182.

Cardwell, N.T., C. Cummings, and M. Kraft. 2019. *Toward cleaner plates: A study of plate waste in food service*. Available: https://www.nrdc.org/resources/toward-cleaner-plates-study-plate-waste-food-service.

Chen, H.S., and T.M.C. Jai. 2018. Waste less, enjoy more: Forming a messaging campaign and reducing food waste in restaurants. *Journal of Quality Assurance in Hospitality and Tourism* 19(4):495-520.

Copyright National Academy of Sciences. All rights reserved.

Chitnis, M., D. Angela, S. Steve, K.F. Steven, and J. Tim. 2014. Who rebounds most? Estimating direct and indirect rebound effects for different UK socioeconomic groups. *Ecological Economics* 106(106):12-32.

Collart, A.J., and M.G. Interis. 2018. Consumer imperfect information in the market for expired and nearly expired foods and implications for reducing food waste. *Sustainability (Switzerland)* 10(11).

Comber, R., and A. Thieme. 2013. Designing beyond habit: Opening space for improved recycling and food waste behaviors through processes of persuasion, social influence and aversive affect. *Personal and Ubiquitous Computing* 17(6):1197-1210.

Cox, J., S. Giorgi, V. Sharp, K. Strange, D.C. Wilson, and N. Blakey. 2010. Household waste prevention: A review of evidence. *Waste Management and Research* 28(3):193-219.

Delmas, M.A., M. Fischlein, and O.I. Asensio. 2013. Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012. *Energy Policy* 61:729-739.

Devaney, L., and A.R. Davies. 2017. Disrupting household food consumption through experimental homelabs: Outcomes, connections, contexts. *Journal of Consumer Culture* 17(3):823-844.

Ellison, B., O. Savchenko, C.J. Nikolaus, and B.R.L. Duff. 2019. Every plate counts: Evaluation of a food waste reduction campaign in a university dining hall. *Resources, Conservation and Recycling* 144:276-284.

Gottfredson, D.C., T.D. Cook, F.E. Gardner, D. Gorman-Smith, G.W. Howe, I.N. Sandler, and K.M. Zafft. 2015. Standards of evidence for efficacy, effectiveness, and scale-up research in prevention science: Next generation. *Prevention Science* 16(7):893-926.

Hamerman, E.J., F. Rudell, and C.M. Martins. 2018. Factors that predict taking restaurant leftovers: Strategies for reducing food waste. *Journal of Consumer Behaviour* 17(1):94-104.

Ilyuk, V. 2018. Like throwing a piece of me away: How online and in-store grocery purchase channels affect consumers' food waste. *Journal of Retailing and Consumer Services* 41:20-30.

Jagau, H.L., and J. Vyrastekova. 2017. Behavioral approach to food waste: An experiment. *British Food Journal* 119(4):882-894.

Kim, K., and S. Morawski. 2013. Quantifying the impact of going trayless in a university dining hall. *Journal of Hunger and Environmental Nutrition* 7(4):482-486.

Koop, S.H.A., A.J. Van Dorssen, and S. Brouwer. 2019. Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics. *Journal of Environmental Management* 247:867-876.

Kuo, C., and Y. Shih. 2016. Gender differences in the effects of education and coercion on reducing buffet plate waste. *Journal of Foodservice Business Research* 19(3):223-235.

Kwasnicka, D., S.U. Dombrowski, M. White, and F. Sniehotta. 2016. Theoretical explanations for maintenance of behaviour change: A systematic review of behaviour theories. *Health Psychology Review* 10(3):277-296.

Lazell, J. 2016. Consumer food waste behaviour in universities: Sharing as a means of prevention. *Journal of Consumer Behaviour* 15(5):430-439.

Le Borgne, G., L. Sirieix, and S. Costa. 2018. Perceived probability of food waste: Influence on consumer attitudes towards and choice of sales promotions. *Journal of Retailing and Consumer Services* 42:11-21.

Lee, S. and K. Jung. 2017. Exploring effective incentive design to reduce food waste: A natural experiment of policy change from community based charge to RFID based weight charge. *Sustainability* 9:1-17.

Liz Martins, M., S.S. Rodrigues, L.M. Cunha, and A. Rocha. 2016. Strategies to reduce plate waste in primary schools—experimental evaluation. *Public Health Nutrition* 19(8):1517-1525.

Copyright National Academy of Sciences. All rights reserved.

Ma, J., and K.W. Hipel. 2016. Exploring social dimensions of municipal solid waste management around the globe: A systematic literature review. *Waste Management* 56:3-12.

Manzocco, L., C. Lagazio, M. Alongi, M.C. Nicoli, and S. Sillani. 2017. Effect of temperature in domestic refrigerators on fresh-cut iceberg salad quality and waste. *Food Research International* 102(102):129-135.

Marteau, T.M. 2017. Towards environmentally sustainable human behaviour: Targeting nonconscious and conscious processes for effective and acceptable policies. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 375(2095).

Meadows, D.H. 1999. Leverage points: Places to intervene in a system. Hartland, VT: Published by the Sustainability Institute.

Meadows, D.H. 2008. *Thinking in systems: A primer.* White River Junction, VT: Chelsea Green Publishing.

Michie, S., M.M. van Stralen, and R. West. 2011. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science* 6:42.

Mourad, M. 2016. Recycling, recovering and preventing "food waste": Competing solutions for food systems sustainability in the United States and France. *Journal of Cleaner Production* 126:461-477.

Niebylski, M.L., K.A. Redburn, T. Duhaney, and N.R. Campbell. 2015. Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence. *Nutrition* 31(6):787-795.

Nisa, C.F., J.J. Belanger, B.M. Schumpe, and D.G. Faller. 2019. Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. *Nature Communications* 10(1):4545.

Parizeau, K., M. von Massow, and R. Martin. 2015. Household-level dynamics of food waste production and related beliefs, attitudes, and behaviours in Guelph, Ontario. *Waste Management* 35:207-217.

Petit, O., R. Lunardo, and B. Rickard. 2019. Small is beautiful: The role of anticipated food waste in consumers' avoidance of large packages. *Journal of Business Research* 113:326-336.

Prescott, M.P., X. Burg, J.J. Metcalfe, A.E. Lipka, C. Herritt, and L. Cunningham-Sabo. 2019. Healthy planet, healthy youth: A food systems education and promotion intervention to improve adolescent diet quality and reduce food waste. *Nutrients* 11(8).

Romani, S., S. Grappi, R.P. Bagozzi, and A.M. Barone. 2018. Domestic food practices: A study of food management behaviors and the role of food preparation planning in reducing waste. *Appetite* 121:215-227.

Samdal, G.B., G.E. Eide, T. Barth, G. Williams, and E. Meland. 2017. Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults: Systematic review and meta-regression analyses. *International Journal of Behavioral Nutrition and Physical Activity* 14(1).

Sandson, K., and E. Broad Lieb. 2019. *Bans and Beyond: Designing and Implementing Organic Waste Bans and Mandatory Organics Recycling Laws*. Harvard Law School Food Law and Policy Clinic; Center for EcoTechnology. Available: https://www.chlpi.org/wp-content/uploads/2013/12/Organic-Waste-Bans_FINAL-compressed.pdf.

Sarjahani, A., E.L. Serrano, and R. Johnson. 2009. Food and non-edible, compostable waste in a university dining facility. *Journal of Hunger and Environmental Nutrition* 4(1):95-102.

Schmidt, K. 2016. Explaining and promoting household food waste-prevention by an environmental psychological based intervention study. *Resources, Conservation, and Recycling* 111(111):53-66.

Shadish, W.R., T.D. Cook, and D.T. Campbell. 2002. *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. Boston: Houghton Mifflin Company.

Copyright National Academy of Sciences. All rights reserved.

Sharp, V., S. Giorgi, and D.C. Wilson. 2010. Delivery and impact of household waste prevention intervention campaigns (at the local level). *Waste Management and Research* 28(3):256-268.

Skumatz, L.A. 2008. Pay as you throw in the US: Implementation, impacts, and experience. *Waste Management* 28(12):2778-2785.

Snyder, L.B. 2007. Health communication campaigns and their impact on behavior. *Journal of Nutrition Education and Behavior* 39(2 SUPPL.):S32-S40.

Soderholm, P. 2010. *Environmental Policy and Household Behavior: Sustainability and Everyday Life*. Abingdon, UK: Earthscan.

Soma, T., B. Li, and V. Maclaren. 2020. Food waste reduction: A test of three consumer awareness interventions. *Sustainability* 12:907-926

Stockli, S., M. Dorn, and S. Liechti. 2018. Normative prompts reduce consumer food waste in restaurants. *Waste Management* 77:532-536.

Strotmann, C., S. Friedrich, J. Kreyenschmidt, P. Teitscheid, and G. Ritter. 2017. Comparing food provided and wasted before and after implementing measures against food waste in three healthcare food service facilities. *Sustainability (Switzerland)* 9(8).

Sweet, S.N., and M.S. Fortier. 2010. Improving physical activity and dietary behaviours with single or multiple health behaviour interventions? A synthesis of meta-analyses and reviews. *International Journal of Environmental Research and Public Health* 7(4):1720-1743.

Thiagarajah, K., and V.M. Getty. 2013. Impact on plate waste of switching from a tray to a trayless delivery system in a university dining hall and employee response to the switch. *Journal of the Academy of Nutrition and Dietetics* 113(1):141-145.

Thomson, C.A., and J. Ravia. 2011. A systematic review of behavioral interventions to promote intake of fruit and vegetables. *Journal of the American Dietetic Association* 111(10):1523-1535.

Varotto, A., and A. Spagnolli. 2017. Psychological strategies to promote household recycling: A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology* 51:168-188.

van der Werf, P., J.A. Seabrook, and J.A. Gilliland. 2019. "Reduce food waste, save money": Testing a novel intervention to reduce household food waste. *Environment and Behavior*. Available: https://doi.org/10.1177/0(0):0013916519875180.

Webb, T.L., and P. Sheeran. 2006. Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychological Bulletin* 132(2):249-268.

Whitehair, K.J., C.W. Shanklin, and L.A. Brannon. 2013. Written messages improve edible food waste behaviors in a university dining facility. *Journal of the Academy of Nutrition and Dietetics* 113(1):63-69.

Whitmarsh, L.E., P. Haggar, and M. Thomas. 2018. Waste reduction behaviors at home, at work, and on holiday: What influences behavioral consistency across contexts? *Frontiers in Psychology* 9:2447.

Williamson, S., L.G. Block, and P.A. Keller. 2016. Of waste and waists: The effect of plate material on food consumption and waste. *Journal of the Association for Consumer Research* 1(1):147-160.

Young, W., S.V. Russell, C.A. Robinson, and R. Barkemeyer. 2017. Can social media be a tool for reducing consumers' food waste? A behaviour change experiment by a UK retailer. *Resources, Conservation and Recycling* 117:195-203.

Young, C.W., S.V. Russell, C.A. Robinson, and P.K. Chintakayala. 2018. Sustainable retailing— influencing consumer behaviour on food waste. *Business Strategy and the Environment* 27(1):1-15.

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5

Strategy for Reducing Food Waste at the Consumer Level

The characteristics of the complex system through which food is produced, marketed, and sold, as well as the many other interconnected influences on consumers' conscious and unconscious choices about purchasing, preparing, consuming, storing, and discarding food, all contribute to significant wasting of food by consumers. The report thus far has identified some primary drivers of consumer behaviors that could be modified so that less food would be wasted, examined the evidence on interventions undertaken to date to modify those behaviors, and explored relevant lessons from six other related domains. Based on this broad exploration, the committee in this chapter proposes a strategy for reducing food waste at the consumer level. We do not propose a measurable target for this reduction, but support the overall goal of reducing food loss and waste in the United States by 50 percent by 2030, which is consistent with Target 12.3 of the United Nations' Sustainable Development Goals.[1]

The committee's proposed strategy targets opportunities to help save valuable food and reduce the profound negative environmental impacts of food waste. This study's objectives took on greater urgency as we carried out our work because of the strains on individual and government budgets and the food supply system resulting from the COVID-19 pandemic. The dramatic shifts in food supply chain operations and changes in consumer behaviors associated with the pandemic may exacerbate many problems associated with food waste, and may also present new opportunities, but the strategy presented here is broad and adaptable to changing circumstances.

[1] See https://sustainabledevelopment.un.org/sdg12.

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FOUNDATION FOR THE STRATEGY

The committee's reasoning about how best to make use of the available evidence began with the motivation-opportunity-ability (MOA) framework, which addresses the importance of the interactions among those three elements in the process of behavior change. This framework provided a basis for considering how the research on drivers of consumer behavior and on interventions designed to modify that behavior can best be exploited to reduce food waste at the consumer level. The MOA framework helped us understand the multiple drivers identified by research and how they interact to result in food waste. It also provided a foundation for identifying categories of behavioral drivers that encompass a range of influences, including context, habit, and other automatic processes, and reflective processes. And the framework helped us integrate the broader lessons from the research on drivers of food waste with lessons from the research on interventions to modify food waste behavior.

Evidence about Drivers of Food Waste

Consumers' conscious and unconscious decisions about food (that is, those based on either conscious or automatic cognitive processes; see Chapter 1) are only the surface manifestations of a complex array of interacting factors, ranging from highly individual, intrapersonal influences through those that operate interpersonally and at the community and societal levels.

At the societal level, decisions made at every stage of the food supply chain, including by large and small farms and businesses, shape consumer-level waste. Decisions made by other industry players, such as food processers and dealers, retailers, governments, international organizations such as the World Trade Organization, and investors, affect markets, prices, and availability, and those decisions are influenced in turn by the marketing and sales strategies of the U.S. food service and retail industries and many other factors. Thus, the U.S. food supply system is embedded in a global system of social and economic cultures, structures, and policies that all affect many outcomes, including the ways in which consumers acquire, consume, store, and dispose of food.

At the same time, individual consumers are influenced by the information they receive about food from myriad sources and the degree of trust they place in those sources. Some may trust government sources, whereas others may look to social media and celebrity influencers. Consumers are also influenced by social and cultural practices and norms within their varying social networks, as well as their own personal values. Although the diversity of the consumer population makes it difficult to generalize about consumer behavior, researchers have identified many drivers that can

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influence behaviors related to food acquisition, consumption, storage, and disposal that affect the amount of food wasted at and away from home. The existing literature has relatively little to say about how various drivers operate across groups or are affected by socioeconomic factors, but the committee found support for 11 summative drivers (or clusters of drivers) that offer promising targets for interventions to reduce food waste:

A. consumers' knowledge, skills, and tools;
B. consumers' capacity to assess risks associated with food waste;
C. consumers' goals with respect to food and nutrition;
D. consumers' recognition and monitoring of their food waste;
E. consumers' psychological distance from food production and disposal;
F. heterogeneity of consumers' food preferences and diets;
G. the convenience or inconvenience of reducing food waste as part of daily activities;
H. marketing practices and tactics that shape consumers' food behaviors;
I. psychosocial and identity-related norms related to food consumption and waste;
J. factors in the built environment (including in household and retail environments) and the food supply chain; and
K. policies and regulations at all levels of government.

All of these summative drivers have the capacity to influence at least one of the three elements of the MOA framework (motivation, opportunity, and ability). Many of them affect more than one, and a few affect all three (see Chapter 3).

Evidence about Interventions to Reduce Food Waste

The evidence about interventions that may be effective in reducing food waste at the consumer level was too limited to support definitive conclusions about the overall merit of any of the various types of interventions. Few of the available studies met the committee's criteria with respect to strength of evidence, and virtually no study assessed how well intervention effects might be sustained across time. The committee therefore urges caution in generalizing from the small existing literature as to the effectiveness of particular intervention approaches. We also emphasize that the effectiveness of any intervention using these approaches or others will depend on its being well designed, tailored to the context and with consideration of the three elements of the MOA framework, and well implemented (see Chapter 6).

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Nevertheless, based on evidence from peer-reviewed analyses, the committee identified a list of interventions that are promising and merit further investigation (see Table 4-2 in Chapter 4; see Appendix D for more detail on the available studies). Given the limitations of the literature, this list does not reflect all of the approaches that merit further assessment. In particular, few studies have examined interventions based on a systems approach, that is, interventions that took into account potential trade-offs, cobenefits, unintended consequences or spillover effects (e.g., effects on income inequality or other distributional issues). Also not well represented among the existing peer-reviewed studies—but possibly very valuable—are interventions involving technological developments (e.g., antimicrobial coatings, improved refrigerators).

More work will be needed to build on this research and integrate findings from across disciplines and contexts. Although the research on drivers and interventions does not point directly to interventions that can be implemented with confidence across contexts and populations, it does offer important lessons. That is, considering how a particular driver of behavior (e.g., consumers' psychological distance from food and its sources) influences food waste (e.g., increasing motivation) and the cognitive processes it activates (e.g., reflective or automatic processing) offers clues about what other drivers may simultaneously be at work in a given setting, and therefore, where intervention efforts might best focus. To identify the relevant drivers for a specific setting or community, designers of interventions could conduct formative research in that community to explore such questions as whether the targeted behavior results from a reflective or automatic cognitive process and which elements of the MOA framework are predominant. This level of analysis can support sound decisions about whether an intervention will be most successful if it focuses on only one driver or if multiple drivers are addressed at once (see detailed examples in Chapter 3).

Taken together, the research on drivers and interventions from both the food waste context and the six related domains highlights the following general points that will be important guides for future efforts to design interventions for reducing food waste at the consumer level. It is important to stress that, as discussed in Chapter 6, intervention design is only the first step; careful attention to evaluation and implementation is also critical.

The value of multifaceted interventions. Research from the six related domains demonstrates that in general, multifaceted interventions—those that take advantage of more than one mechanism—may be more effective than a single intervention alone. Although the food waste–specific research is not yet substantial enough to support a firm conclusion on this point, evidence nonetheless points to the value of integrating multiple intervention types.

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Contextual factors influence, and may override, other drivers. A variety of evidence highlights the important influence of contextual factors on behaviors in some of related domains. This observation has been demonstrated in the domains of water conservation and recycling. In the recycling domain, contextual-factors, such as the availability of convenient recycling, a bin at home, or space to store items for recycling prior to pickup, have been found to be predictors of waste reduction and recycling behavior and possibly to override other drivers. These findings suggest that contextual factors that change opportunity at the food acquisition, consumption, storage, and disposal stages are similarly likely to affect food waste–related behaviors, independently of motivation or ability.

The value of understanding cognitive processes involved in targeted behaviors. Two primary types of cognitive processing—conscious, reflective, and reason-driven processing and automatic processing—play important roles in consumer behavior. These types of processing interact and are best understood not as binary opposites but as anchors of a continuum ranging from reflective to semireflective to automatic. Thus, more than one form of processing may be involved in a particular behavior and shape responses to interventions. For example, once behaviors have become automatic, or habits (e.g., recycling), they are more easily sustained, and are less affected by such drivers as social norms and expectations. Thus, understanding the cognitive processing involved in a particular driver can support careful analysis of how a behavior can be modified and thereby guide the design of interventions.

A STRATEGY FOR REDUCING FOOD WASTE

A broad range of organizations and stakeholders, including farms, nonprofits, innovators (e.g., startups, app developers, incubator hubs), K–12 schools and postsecondary institutions, state and local government entities, and food industry associations and companies, are contributing to efforts to reduce food waste. (Selected efforts to tackle the problem at the national and local levels are described in Chapter 2 and Appendix C.) The Winning on Reducing Food Waste Initiative, a collaboration of the U.S. Department of Agriculture (USDA), the U.S. Environmental Protection Agency (EPA), and the U.S. Food and Drug Administration (FDA), was launched in 2018 to help achieve long-term reductions in food loss and wasted food in the United States by coordinating and leveraging government resources and encouraging nongovernmental efforts, including research, community investments, education and outreach, voluntary programs, public–private partnerships, tool development, technical

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assistance, participation in events, and policy discussion.[2] The priorities for the initiative are shown in Box 5-1.

While all of these efforts are valuable, the need for action remains great. Accordingly, the committee sought ways of leveraging the existing knowledge base on how to influence consumer behavior and to build on the Winning on Reducing Food Waste Initiative. The research on consumer drivers and effective interventions is incomplete, but it nonetheless offers a basis for a variety of approaches to bringing about the widespread changes in consumer behavior needed to significantly reduce food waste, even as researchers continue building the evidence base. Our strategy identifies three primary pathways for reducing food waste, as well as the responsibilities of the multiple partners who will be needed as part of a coordinated effort to pursue those pathways.

Three Pathways to Reducing Food Waste

The following three pathways make up the committee's strategy for reducing consumer food waste:

1. changing the U.S. food environment to discourage waste by consumers;

BOX 5-1
Priorities for the Winning on Reducing Food Waste Initiative

- Enhance interagency coordination
- Increase consumer education and outreach efforts
- Improve coordination and guidance on food loss and waste measurement
- Clarify and communicate information on food safety, food date labels, and food donations
- Collaborate with private industry to reduce food loss and waste across the supply chain
- Encourage food waste reduction by federal agencies in their respective facilities

SOURCE: https://www.usda.gov/foodlossandwaste/winning.

[2] The Winning on Reducing Food Waste Initiative encourages long-term reductions in food loss and wasted food in the United States through a variety of combined and agency-specific actions, including policy discussion, education, community investment, and public–private partnerships. Since its formation, the Winning on Reducing Food Waste Initiative has published a strategic plan and announced partnerships with ReFED, a nonprofit organization, and the Food Waste Reduction Alliance, an industry-led group. See https://www.usda.gov/foodlossandwaste/winning.

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2. strengthening consumers' motivation, opportunity, and ability to reduce food waste; and
3. leveraging and applying research findings and technology to support consumers in food waste reduction.

Pathway 1: Change the U.S. Food Environment to Discourage Waste by Consumers

Implement change and innovation in the food industry.

Marketing practices and tactics intended to promote the acquisition of food that is unlikely to be consumed are an important driver of food waste. Product branding and the practices of retailers and away-from-home food providers influence consumer choice by creating motivation to overacquire or to buy aspirational (i.e., healthy) or novelty products (which may not match preferences) without increasing consumers' ability or motivation to consume those products before they decay. Price promotions and special offers, such as multiple-unit pricing, along with packaging, signage, and displays, and other cues to consumers to seek variety or shop in an exploratory manner, all influence their choices. Such marketing tactics operate at both conscious (e.g., buy-one, get-one-free deals) and nonconscious (e.g., signage that gives consumers the impression that price has been reduced) levels. Other tactics operate at both levels (e.g., larger carts and larger servings).

At the time of this writing, it remained unclear what long-term impact the COVID-19 pandemic would have on food provisioning, but the following trends were observed prior to the pandemic. ReFED estimates that approximately 11 million tons of food are wasted annually at the pre- and postconsumer levels in U.S. restaurants, and another 5 million tons in other food service settings,[3] the majority occurring postconsumer (ReFED, 2018). Food eaten away from home is especially likely to be wasted for several reasons. First, hedonic factors play a greater role in consumers' away-from-home choices than in their choices about food at home. Moreover, eating in public settings also activates "performative" consumption. Buffet dining poses a particular risk for waste, where abundance and variety prompt many consumers to take more food than they are likely to consume.

Although the marketing practices of the food industry prompt overacquisition and waste among consumers, some food businesses have also designed interventions to reduce their preconsumer waste (e.g., regular donations of surplus food to food banks, dining halls that do not provide

[3] See https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=2ahUKEwiRz_O7sM_nAhVUmXIEHSEaCm4QFjABegQIChAB&url=https%3A%2F%2Fwww.refed.com%2Fdownloads%2FRestaurant_Guide_Web.pdf&usg=AOvVaw03jMTkZCRY6yxSxeGS1m75.

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A National Strategy to Reduce Food Waste at the Consumer Level

food trays or encourage sampling and use small plates). Still, although the case for reducing waste in a company's business operations (e.g., preconsumer waste) may be perceived as obvious, business owners do not always recognize the benefits to them of encouraging consumers to waste less food (Messner et al., 2020). For example, a World Resources Institute analysis found that 99 percent of 1,200 food manufacturing, food retail, hospitality, and food service sites earned a positive return when they invested in approaches to reduce food waste in their operations, but that many leaders in the private sector are not aware of this benefit. Industry leaders also may not be aware of other benefits of reducing food waste, such as improving food security, environmental sustainability, and stakeholder relationships, and the satisfaction of taking ethical responsibility (Hanson and Mitchell, 2017). Efforts such as a guide produced by the World Wildlife Fund (WWF)[4] have helped encourage participation in food waste reduction programs in the hospitality sector. An example of another relevant initiative is guidance, developed in the United Kingdom, for retailers on how to create food promotions that will not contribute to increased food waste.[5]

Overall, there is a need to reconcile the tension between the industry's goal of selling food and its role in reducing food waste, not only in its own operations but also at the consumer level. More research is needed to investigate effective interventions at the food industry level and the potential for maintaining profits while increasing food waste reduction efforts and improving consumer loyalty. Food industry trade associations and nonprofit organizations are uniquely positioned to address the needs of the industry and to ensure that industry leaders are informed both of best practices for reducing food waste and of the business and social benefits of implementing those practices not only in their operations but also at the consumer level.

RECOMMENDATION 1: Food trade associations and their joint alliances (e.g., the Food Waste Reduction Alliance, the National Restaurant Association, FMI-The Food Industry Association, the Consumers Brand Association, and smaller food trade associations) and nonprofit organizations should expand their efforts to reduce food waste by convening an ongoing public–private–academic forum with the goal of coordinating industry efforts. Specifically, this forum should

- assist association members in pursuing evidence-based best practices and interventions to reduce food waste at the consumer level,

[4] See https://www.worldwildlife.org/publications/hotel-kitchen-fighting-food-waste-in-hotels.
[5] See https://www.wrap.org.uk/sites/files/wrap/Food%20Promotions-%20Guidance%20for%20Retailers.pdf.

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providing regularly updated written guidance and consultation services;
- encourage association members to evaluate their food waste reduction efforts and publish their findings, and provide tools and assistance for these purposes;
- develop materials to inform members about the impacts of food waste and to characterize the business case, in terms of costs and benefits, of food waste reduction practices;
- support and participate in relevant research;
- create communities of practice in which members can share innovations and lessons learned; and
- work with third-party certifying organizations to include practices that reduce food waste at the consumer level as criteria in their environmental standards, and to encourage members to meet those standards.

RECOMMENDATION 2: With guidance from their food trade associations, manufacturers, retailers, and food service venues should

- develop promotions and other in-store cues that prioritize acquisition of the optimal amount and variety (including frozen, shelf-stable, and perishable) of products rather than prompting overacquisition; and
- implement and evaluate evidence-based strategies that help reduce consumer food waste by combining elements—including presentation of food (amount and variety) to reduce overacquisition and communications targeting consumers—that increase consumers' motivation, opportunity, and ability to alter wasteful behaviors.

Examples of the actions that manufacturers, retailers, and marketers can take to pursue these goals are shown in Box 5-2.

Include food waste reduction in industry certification.

Third-party organizations, governments, and some businesses have developed multiple voluntary environmental certification programs. These programs establish incentives for organizations to achieve such goals as ensuring environmental stewardship in food production and provisioning activities, the safety of products, or other socially beneficial goals (e.g., worker protection). Some programs accord with guidelines established by the International Organization for Standardization (ISO), while others set their own criteria. Organizations that meet such goals and achieve standards are more competitive and attractive to both consumers and business partners, such as purchasers of institutional food, particularly those

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BOX 5-2
Actions that Manufacturers, Retailers, and Food Service Venues Can Take to Reduce Food Waste

- Emphasize food's origins, the natural resources and labor needed to produce and distribute it, and its path and history in product narratives and signage to promote a culture of food valuation and reduce "distancing effects" as a driver.
- Display in-store labeling related to the benefits of frozen foods.
- Combine perishable with nonperishable or well-preserved goods in bundles (e.g., buy one fresh, get one frozen).
- Promote such tools as usage guides and recipes, including practical tools and ingredients that are easily obtained at the point of purchase, to improve food literacy.
- Pair storage tools and containers with appropriate food quantity promotions.
- Design and curate assortments that reduce choice overload.
- Provide in-store nonconscious cues that promote acquisition of foods with long shelf lives as opposed to rapidly perishable goods (e.g., segmented grocery carts with dedicated sections for frozen and fresh products).
- Offset high-quantity anchors (e.g., "buy one, get a second one free") for perishable foods with other acquisition anchors at the point of purchase (e.g., "get the most out of food," "average number eaten in a week," "all the things you can do with one").
- Make smaller baskets and carts available to reduce overacquisition.
- Pair consumer affirmation and food quality messages (e.g., "one of a kind," "buy uncommon") with "ugly food" displays to counteract the inference that "beautiful is good."
- Reformat retail stores to prevent overacquisition and longer stays by consumers.
- Offer smaller plates, plates with guides to portioning, and serveware with a less disposable appearance (e.g. plastic instead of paper).
- Implement trayless dining in cafeterias.
- Redesign menus, such as by reducing the number of varieties offered, which can reduce both pre- and postconsumer waste.
- Include message frames, such as those based on norms and social desirability, that build motivation, supported by other interventions providing opportunity and ability.
- In institutional food settings where consumers typically have few food options and food is often discarded, such as hospitals and schools, offer as much choice as possible to reduce discards due to foods being unwanted.
- Redesign all-you-can-eat buffets to include messages that encourage customers to take only food they will definitely eat, or to sample and return to the buffet if they desire more food.
- Encourage customers to bring their own containers or offer containers for taking leftovers home.
- Use food package labeling and messaging to encourage consumers to store and preserve food (e.g., by freezing).

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that make value-based decisions. Examples of such programs include ISO 14001, the Good Food Purchasing Program, the EPA's 55/30 program, the American Chemistry Council's Responsible Care Program, and the Certified Green Restaurant standard.

The effectiveness of such standards in achieving their goals has been demonstrated, specifically for those standards that include environmental performance, such as ISO 14001 (Boiral et al., 2018). In the realm of food waste, one study tested business social responsibility certification and found that participants would be willing to pay more for products with labels guaranteeing reduced food waste across all firm activities (Del Giudice et al., 2016). However, ISO 14001 and other similar programs do not include in their criteria for certification activities that may decrease the waste created by the companies' consumers.

Certification programs related to environmental performance, such as ISO 14001, are effective tools for encouraging companies to change their behavior, resulting in substantial improvements in environmental stewardship and, in particular, waste reduction. Meeting standards related to industry activities to reduce consumer food waste could improve consumers' views of their operations and increase industry competitiveness. However, the criteria for qualifying for such certifications generally do not include practices that will reduce waste created by the companies' consumers.

> **RECOMMENDATION 3:** The International Organization for Standardization, the Green Restaurant Association, the U.S. Green Building Council, and other organizations in charge of developing environmental standards for businesses should include practices that reduce food waste at the consumer level as criteria in those standards, and encourage food businesses to modify their practices to meet those criteria.

Develop and harmonize sensible date labeling.

Most packaged foods in the United States carry a date label representing the manufacturer's best guess as to how long the product will be at its peak quality (Broad Lieb et al., 2016). Most products are still perfectly edible for days, months, or even years past the date on the label. However, studies have shown that consumers mistakenly believe that the date on the label is an indicator of safety. In addition, many states require the display of dates on all food, including that with an indefinite shelf life, regardless of the safety risk. As a result, food manufacturers serving multiple states include label dates on all products (Broad Lieb, 2013). To add to the confusion, the language of date labels has not been standardized, so the meaning of phrases used on the labels by the food industry, such as "use by," "freshest by," and "best by," is unclear to consumers. Although food trade associations have begun to align date labeling to address this confusion, and

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other efforts have also brought changes that have helped address the problem, usage is still voluntary and not yet standardized. Moreover, because consumers tend to avoid food they understand to be close to expiration, retailers may remove such food from shelves even before the stamped date.

The lack of harmonization of date labels and resulting misinterpretation by consumers likely result in the wasting of edible food. There is a need to apply common, clear language and definitions to the labels on packaged foods sold in the United States, accompanied by relevant information and educational materials. In addition, some nonperishable foods may not need date labels at all. However, only preemptive action at the federal level could override state laws and allow firms the latitude to remove date labels from some nonperishable food packages without fear of violating labeling regulations.

> **RECOMMENDATION 4:** Food industry trade associations, consumer organizations, and other nonprofit organizations should coordinate and advocate for the passage of federal legislation to harmonize the language and standards for use of date labels for packaged food sold in the United States. They should also coordinate efforts to educate the public about the information provided on date labels and how they can use that information to ensure that they neither consume unsafe food nor waste safe food.

Implement state and local policies encouraging behaviors that prevent food waste.

Policies at the state and local levels have a powerful influence on food waste, and state and local agencies have initiated a number of creative and effective programs aimed at food waste prevention (Benson et al., 2018). Traditionally, for example, consumers have paid for trash disposal and recycling in municipalities through a fixed fee, either separately or together with other service fees or through property taxes. A meta-analysis of 25 studies (1970–2013) shows that when households in the United States and other developed countries face unit-based pricing,[6] the amount of waste disposed of declines (Bel and Gradus, 2016). Furthermore, unit-based waste pricing is most effective when programs charge a separate fee based on the amount of compostable waste disposed of or when pricing is based on the weight (versus volume) of discarded items, which suggests the potential impact of this approach on reducing food waste at the household level. About one-fourth of communities in the United States had implemented

[6] Unit-based pricing, also known as pay-as-you-throw or variable-rate pricing, is a system of waste management whereby residents pay for the removal of municipal solid waste per unit of waste collected rather than through a fixed fee or property taxes.

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unit-based pricing policies as of 2006 (EPA, 2016), implying that there may be considerable scope for expanding coverage of this practice.

Another policy approach is to ban the disposal of organic materials in landfills, an approach introduced in six states and seven municipalities as of 2019 (Sandson and Broad Leib, 2019). However, the committee could find no peer-reviewed evaluations of the effectiveness of these bans in the United States or peer-reviewed assessments of their impacts on other segments of the food system and society (e.g., stress on food donation centers, composting facilities, retailers, and local budgets; regressive consumer cost impacts).

Waste management policies such as those that ask residents to pay for the removal of municipal solid waste per unit of waste may be effective in reducing household food waste, although it is important to consider how such policies relate to other aspects of the food system and society (Benson et al., 2018). Both state and local governments can make waste prevention an integral component of their waste management structures. For example, the Oregon Department of Environmental Quality has made reducing the waste of edible food an objective, with targets of 15 percent reduction by 2025 and 40 percent by 2050.

> **RECOMMENDATION 5:** State and local governments should institute policies that reduce the discarding of wasted food. Such policies include (but are not limited to) fees for the removal of municipal solid waste per unit of waste and mandatory organic recycling practices, such as composting. These policies should be integrated with related policies (e.g., on recycling, food recovery), such as those to reduce environmental impact or promote equity-related outcomes.

> **RECOMMENDATION 6:** The Environmental Protection Agency and nongovernmental entities, such as foundations, should support local jurisdictions and states in developing and instituting policies that discourage the discarding of edible food. Actions to this end include providing research, tools, and information and investing in partnerships and forums (e.g., social innovation labs) that bring key stakeholders together to develop feasible interventions that are acceptable to the affected communities.

Pathway 2: Strengthen Consumers' Motivation, Opportunity, and Ability to Reduce Food Waste

The committee recommends three strategies for increasing consumers' motivation, opportunity, and ability to reduce food waste: (1) conducting a national behavior change campaign; (2) taking advantage of the influence of popular food experts (e.g., chefs on cooking shows, food blogs)

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on consumers' attitudes and preferences; and (3) including instruction and experiential learning about food literacy in K–12 and postsecondary education curricula.

Conduct a national behavior change campaign.

An important element of a national behavior change campaign would be to increase consumers' motivation to reduce food waste by providing relevant information about the importance of the problem, appeals that align with their intrinsic motivations to reduce waste, information about the financial benefits to them of reducing waste, and ways to enhance their skills at reducing their own waste at and away from home. To go beyond the objectives of past information campaigns, a behavior change campaign should also address nonconscious factors that affect the propensity to waste food, and be designed so as to have maximum behavioral impact. In addition, the campaign should aim to encourage stakeholders to change relevant political and economic contexts in order to give consumers opportunities to take action once they have been primed to do so (Thomson and Ravia, 2011). Finally, the campaign should be aimed at influencers who can help support change in social norms and pave the way for consumers' behavior change (see below).

Surveys have revealed that the majority of American consumers have not seen information about food waste, are not aware that it contributes to greenhouse gas emissions and environmental degradation, and underestimate both the amount of food they waste and the financial cost of that waste to themselves. As discussed above, consumers also hold many misconceptions about food safety and the meaning of date labels, which are ambiguous and can be misleading, resulting in food waste. However, campaigns focused only on raising awareness may not change actual behavior (Elimelech et al., 2019; Giordano et al., 2019; Grainger et al., 2018; Thomson and Ravia, 2011).

Past information campaigns (e.g., Food: Too Good to Waste, Save The Food) have addressed the problem (see Appendix D) at the national level. For example, WWF organized a national campaign aimed at hotels that addresses consumer food waste. The strategy recommended in this report would build on such prior efforts and should address three main barriers to behavior change.

First, because of the diversity of the consumer population, campaigns targeted at specific audiences are most likely to be effective. For example, consumers already motivated to care about the environment may be especially responsive to a campaign about the environmental costs of wasting food. Other consumers might be driven by the significant monetary savings from reducing food waste, which could range up to $1,800 annually for the average family. Messages should be developed and targeted based on local

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and population segment–related sensitivities. Positive messaging has been shown to be more effective than negative messaging in effecting behavior change.

Second, because of the strong role played by habit and nonconscious behaviors in driving food waste (and other environmentally damaging behaviors, as discussed in Chapters 3 and 4), the mere acquisition of new information may not change behavior. Indeed, in many cases, the issue is not that consumers are or are not motivated to change their behavior, but that the force of habit and consistent habit-related cues make food waste behavior automatic. To address this barrier to change, campaigns should be designed to take advantage of "teachable moments," reaching consumers when routines or environments may be in flux. In such cases, old habits are more easily disrupted and new habits formed. For example, individuals who have recently changed homes, purchased new appliances, or entered new life phases or who are shopping for the first time in a new retail location may be particularly apt to override past automatic tendencies and develop new patterns. The changes due to COVID-19 represent a prime example of a situation among consumers in which the moment is right to reach out to them about the impacts of food waste and how they can alter their food-related habits to reduce it.

Third, the committee's review showed that many factors unrelated to objective information help shape behavior. Examples include social norms, perceived psychological distance from food, and identity. Thus in addition to providing compelling information about the effects of food waste, behavior change campaigns should leverage social science findings related to these drivers of the problem.

Still, a successful behavior change campaign cannot succeed if consumers lack the opportunity or ability to act on the messages provided. Thus, as discussed above, a goal of such a campaign should be to support consumers in modifying their behavior and promote some of the easy ways in which wasting food can be avoided both in and outside of the home, as well as encourage stakeholders to change important political and economic contexts to support consumers' opportunities to take action. To develop sustained behaviors, mechanisms targeting opportunity and ability would ideally also provide feedback and rewards related to the desired behavior changes.

While the federal agencies involved in the Winning on Reducing Food Waste Initiative are in the best position to coordinate a far-reaching campaign that takes advantage of these insights about behavior change, such a campaign will be most effective if it is a collective effort involving state and local governments as well as nongovernmental entities and settings (e.g., schools or workplaces) that can adapt the campaign to local and regional circumstances using culturally appropriate mechanisms and language. In addition, the campaign should benefit from platforms and lessons learned

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from prior efforts, such as the consumer surveys and consumer segmentation research from the Natural Resources Defense Council's Save the Food campaign.

> **RECOMMENDATION 7:** As part of the federal Winning on Reducing Food Waste Initiative, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, and the U.S. Food and Drug Administration should lead the development of a centralized platform for a behavior change campaign. This campaign should be designed both to inform the public about the environmental, economic, and social benefits of reducing food waste and tools and strategies for reducing their own waste, and to address nonconscious drivers of food waste, as well as consumers' ability and opportunity to change wasteful behavior. This platform should be designed to stimulate, guide, and support current efforts at the state and local levels and those led by nongovernmental entities. The platform should incorporate the following elements
>
> - provide resources and easy, everyday tips for reducing food waste;
> - make use of a variety of traditional (e.g., books, website, apps) and new (e.g., short media content bursts, short sound bites, multimedia, gamification, refrigerator magnets) tools and tactics;
> - use positive messaging;
> - provide multiple cues at the food acquisition, consumption, and disposal stages;
> - focus on reaching consumers during "teachable moments";
> - use social science research, particularly as related to norms and consumers' psychological distance from food and food production;
> - deliver short, intense, and frequent action ideas and nudges;
> - include components and mechanisms that are culturally relevant to various settings and populations, such as food service employees, retail food establishments, students, workplaces, grocery shoppers, and general consumers;
> - include provisions for rigorous evaluation of effectiveness and reward for behavior change;
> - urge stakeholders to alter social and economic contexts to provide opportunities for behavior change; and
> - spur influencers to help alter norms and amplify messages.

Spread and amplify messages about food waste through influencers

Influencers within the food domain include chefs, social media personalities, recipe providers, and food and culture journalists. They can drive consumer choices by helping to establish and reinforce social norms; providing information on broad topics related to food and the environmental

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impacts of its production; and offering guidance for the acquisition, cooking, storage, and consumption of food through recipes and through the behaviors and attitudes they model. This guidance could reinforce behaviors and values that have the potential to reduce food waste. In addition, influencers could help spread accurate, evidence-based information about the social, environmental, and economic benefits of reducing food waste.

Consumers are also influenced by interactions with dietitians; state extension specialists; community health champions; and other health, food, and nutrition professionals. Thus, professional and community organizations through which these experts exchange knowledge are ideal venues for augmenting evidence-based information about specific aspects of food literacy, such as food safety and quality, how to understand food labels, and practical food preparation and storage skills that can optimize the utilization of food.

> **RECOMMENDATION 8:** Professional (e.g., the Culinary Institute of America, the Institute of Food Technologists, the Academy of Nutrition and Dietetics) and community organizations should work with their memberships and with influencers, such as dietitians, state extension specialists, recipe providers, cooking show hosts, chefs, and social media personalities, to promote the use of their platforms to advance consistent food literacy information, provide evidence-based guidance about optimizing the consumption of food and minimizing waste, and help shift social norms by providing information about the positive effects of supporting consumers in reducing waste.

To leverage this source of influence, experts and influencing organizations, including foundations, chefs, dietitians, professional organizations, and environmental nonprofits, could collaborate in updating the information they offer to consumers with evidence-based guidance on food waste and relevant information related to food literacy, food safety, and nutrition; promoting consistency in messaging; and targeting messages appropriately for the populations they reach. Influencers are in position to

- shift social norms related to edibility, abundance, freshness, and seasonality;
- incorporate easy solutions into existing guidance (e.g., recipes, food and lifestyle blogs, cooking shows) related to optimizing acquisition, storage, and consumption that will result in less wasted food (e.g., tools integrated into recipes that allow users to easily alter the number of portions; suggestions for repurposing leftovers or unused food items);

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- when writing recipes, consider how the ingredients are packaged and sold to avoid waste, or provide suggestions for alternative ingredients or uses of the leftovers;
- incorporate messages and guidance about the benefits of avoiding waste into their exiting guidance; and
- help influence other stakeholders to provide more opportunities for consumers to take action.

Include instruction and experiential learning about food literacy in education curricula

Schools and academic institutions (preschool/K–12, trade schools, universities and colleges) are a substantial source of food waste (e.g., Schupp et al., 2018). They are in a position to impart and support foundational skills and knowledge pertaining to food provisioning practices and habits, and to foster social norms and food literacy to support positive decisions about food (Koch, 2016). Further, these institutions interact with students at teachable points (e.g., when they move to a new geographic area), which could provide opportunities for the development of waste-avoiding habits. Lessons learned in the cafeteria can encourage students to become better environmental stewards in the future (Devine and Pearson, 2019). K–12 and postsecondary institutions can make a lasting contribution and can influence students' food literacy and motivation to reduce food waste by

- including programming related to the effects, prevention, and management of food waste, as well as how to prevent it, in the curricula for math, science, social studies, language, arts, family/food/consumer sciences, financial literacy, economics, vocational classes, and others;
- altering their own practices to prevent food waste in their operations and assist their students and staff in preventing food from being discarded;
- providing other educational resources, including relevant spaces such as teaching kitchens, food gardens, campus orchards, and campus farmers' markets, for experiential learning related to sound food practices and for meetings with food producers; and
- providing incentives (e.g., credits, certificates, awards, internships) for student-led innovations in food waste reduction (e.g., through university hackathons, design jams, business-pitching competitions).

Schools, colleges, and universities are already doing many of these things, and many are collaborating with other stakeholders in the food

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supply chain (food service entities, culinary schools) to develop curriculum and educational opportunities, as well as policies and interventions, aimed at reducing food waste in their institutions. In other cases, however, institutions may have the impetus but lack the resources to devote to such programs. Leadership at the national level could help diffuse best practices and innovative ideas, support their adaptation to new circumstances, provide resources, and avoid reinvention of good ideas.

Existing collaborations provide a valuable foundation on which to build. One example is the Menus of Change: University Research Collaborative,[7] which among its activities is conducting studies of food waste in university cafeterias. Some groups are providing guidance for specific curriculum activities, such as food waste audits, measurement of environmental impact, food budgeting, analysis of recipe books, food safety training, and cooking (e.g., the WWF Food Waste Warrior toolkit,[8] the Commission for Environmental Cooperation's Food Matters Action Kit,[9] and the Johns Hopkins FoodSpan[10]). Others are providing guidance for school administrators and teachers on strategies for reducing food waste by both the institutions and by the students (e.g., NRDC,[11] USDA's Food and Nutrition Service[12]). These ideas could be incorporated into USDA's Farm to School program as well. There is a need for rigorous evaluation to explore which interventions are most effective, and in which settings, and to communicate findings widely to reduce unnecessary duplication of effort.

RECOMMENDATION 9: Nongovernment organizations (e.g., the World Wildlife Fund) should engage with other appropriate entities (e.g., state departments of education, U.S. Department of Agriculture's Food and Nutrition Service, foundations) in concerted, coordinated efforts to provide K–12, postsecondary, and secondary institutions with appropriate tools and resources and promote their use in instruction and hands-on learning about the social, environmental, and economic impacts of food waste and ways to reduce it.

[7] The Menus of Change: University Research Collaborative is a collaboration of forward-thinking scholars, food service leaders, executive chefs, and administrators for colleges and universities who are accelerating efforts to move people toward healthier, more sustainable, and delicious foods using evidence-based research, education, and innovation. See https://www.moccollaborative.org/about.

[8] See https://www.worldwildlife.org/teaching-resources/toolkits/food-waste-warrior-toolkit.

[9] See http://www3.cec.org/flwy.

[10] See http://www.foodspanlearning.org.

[11] See https://www.nrdc.org/sites/default/files/k-12-food-waste-best-practices-ib.pdf.

[12] See https://www.fns.usda.gov/tn/what-you-can-do-help-prevent-wasted-food.

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Pathway 3: Leverage and Apply Research Findings and Technology to Support Consumers in Food Waste Reduction

Support research and technology

Many technological developments, such as packaging and processing to extend shelf life, refrigeration approaches, and food preservation technology, can play a role in reducing food waste. Important drivers of food waste at the consumer level, such as unpredictable and busy lifestyles; lack of time, energy, and the cognitive demands of everyday life; and consumers' limited ability to assess food safety, can be addressed by technology. Progress in this sphere is rapidly developing, and promising recent developments include

- improvements in the built environment, such as sophisticated temperature controls in refrigerators that preserve perishable foods longer and provide consumers with information about the freshness and safety of their food;
- technologies supporting behavior that limits waste in the acquisition, preparation, and storage of food (e.g., online food acquisitions,[13] apps, online gamification tools,[14] smart grocery carts[15]);
- technology advances in food products and packaging, including food coatings, food product development, preservatives developed for consumer acceptability and safety, and packaging that meets consumer and environmental goals for reduced packaging while preserving food longer;
- smart bins that measure wasted food and help with managing food scraps (inedible parts); and
- apps and other devices to help consumers with awareness, planning, and other behaviors related to food.

Technology may help support consumers in overcoming some of the conscious and unconscious drivers that lead to food waste, particularly those related to lack of knowledge, the complexity of everyday life, and the ability to assess food safety. Food and food storage manufacturers, food retailers, food service providers, and innovators can contribute significantly to reductions in food waste by continuing to improve existing technologies and creating new ones to help consumers with reducing food waste. At the same time, there are many unknowns regarding the effects of deploying

[13] See Chapter 2 for a discussion of the possibilities that online shopping offers for reducing food waste.

[14] See https://www.mdpi.com/2071-1050/12/3/907.

[15] See https://www.cnn.com/2019/12/23/tech/smart-shopping-cart/index.html.

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technologies, including how easily consumers may accept them; their feasibility; their costs and benefits; their effects on reducing food waste; and their unintended effects, including those related to equity. Academic researchers can contribute by conducting studies that go beyond effectiveness to consider such issues as acceptability to consumers and unintended effects, including those related to equity.

Beyond technology, researchers from a number of disciplines are studying other aspects of the challenge of reducing food waste at the consumer level, and they have already provided the foundation for meeting this urgent challenge. However, the ongoing success of the strategy laid out in this report will depend on ongoing work to address significant gaps in the knowledge base (see details in Chapter 6). Dedicated investments are needed to support this research.

RECOMMENDATION 10: Government agencies at all levels and relevant foundations concerned with the problem of food waste should support the proposed food waste reduction strategy by investing in

- research to develop methods for measuring food waste at the consumer level, including the collection of data on food waste, both aggregated and by type of food and reasons for wasting food in the United States, as part of an overall effort to measure food waste at the national level;
- research and pilot studies that are adequately designed to evaluate interventions for reducing consumer-level food waste and both the intended and unintended outcomes of those interventions and are integrated with implementation plans;
- training in intervention evaluation and implementation planning for appropriate staff of community-based organizations and graduate students through, for example, an evaluation institute; and
- dissemination of information about the efficacy and effectiveness of interventions, including detailed descriptions of the intervention design and implementation.

Coordination and Partnership

The overarching goal of the committee's proposed strategy is to create and sustain a broad societal commitment to reducing food waste. Achieving this goal will require the participation of government entities at the federal, state, and local levels as well as the food industry and retailers; influencers and the media; nongovernmental organizations; and those who provide food through a number of different channels, such as cafeterias in schools and universities. Leadership and financial support from the federal

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level will be necessary to stimulate and coordinate the efforts of multiple stakeholders. It is only through a multistakeholder commitment that the United States can make the transition from a society in which attitudes and habits facilitate the wasting of food to one in which attitudes and habits are consistent with appreciating the value of food and its utilization.

Federal agencies (USDA, EPA, and FDA) have the capacity to engage multiple stakeholders, including state and local governments, the food industry and its representative trade associations, the community of nongovernmental organizations, and private foundations in a comprehensive initiative to reduce food waste. The improved coordination and cross-sectoral discussions fostered by this new initiative, if conducted in an inclusive and equitable manner, could have multiplier effects and advance solutions and innovations rapidly and for all populations. Partnerships focused on reducing food waste, such as the Pacific Coast Collaborative, which includes the West Coast of the United States and Canada and industry and local government partners, provide examples on which to build.

RECOMMENDATION 11: The U.S. Department of Agriculture, the U.S. Environmental Protection Agency, and the U.S. Food and Drug Administration should expand the Winning on Reducing Food Waste Initiative by coordinating with key stakeholders at multiple levels and across societal sectors, including state and local governments, nonprofit organizations, foundations, industry leaders, food producers, and others, in efforts to reduce food waste at the consumer level. The federally sponsored initiative should

- be the locus of practical information for the consumer and guidance on the evaluation and implementation of interventions, to be disseminated by initiative partners;
- support the development and management of a public clearinghouse for sharing information on current research and evaluation data and on funding opportunities relevant to researchers, funders, policy makers, social marketers, and other stakeholders;
- support research-based interventions that take into account consumers' motivation, opportunity, and ability to reduce food waste and apply lessons from behavioral change disciplines; and
- work with others in resolving technical challenges, including by developing and publishing standard terminology for research and practice related to food waste.

Table 5-1 provides an overview of the contributions that the essential partners would make to the committee's proposed coordinated food waste reduction strategy.

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TABLE 5-1 Potential Contributions of Partners in the Committee's Strategy

Partner	Example Contributions
Federal agencies	• Coordinate efforts encompassed by the Winning on Reducing Food Waste Initiative • Provide resources for collaboration and coordination with a broad group of stakeholders (e.g., state and local governments, corporations, academic institutions, foundations) • Develop evaluation and implementation guidelines • Coordinate and fund a national behavior change campaign, and provide relevant stakeholders and the public with tools and strategies for reducing food waste • Provide research, adaptable tools, and information to state and local entities • Coordinate and provide support for research and for a clearinghouse for sharing information and resources • Where federal agencies have jurisdiction over institutional procurement, support initiatives aimed at reducing consumer food waste
State and local governments	• Coordinate efforts with respect to food waste among agencies • Provide funding to support food waste reduction efforts • Adapt and disseminate the national behavior change campaign • Provide the public, businesses, and institutions with resources and easy everyday tips for reducing food waste • Encourage and support changes to the built environment and to food marketing that help reduce food waste • Establish and evaluate policies that encourage reduction of food waste behaviors, such as pay-as-you-throw disposal fees, and integrate them with other relevant policies • Coordinate efforts to provide schools, universities, and other educational institutions with appropriate tools and to promote the inclusion of food literacy and associated practical opportunities in curricula • Where state governments have jurisdiction over schools or institutional procurement, support initiatives aimed at reducing consumer food waste

continued

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TABLE 5-1 Continued

Partner	Example Contributions
Manufacturers, retailers, and marketers	• Provide evidence-based food safety and other information to help consumers reduce food waste • Use evidence-based guidance to develop and offer promotions that may reduce food waste, including prioritizing acquisition of the optimal amount and variety (including frozen, shelf-stable, and perishable) of foods rather than stimulating overacquisition, with the goal of helping consumers improve their decision making in ways that are likely to reduce food waste • Develop and offer in-store cues that activate unconscious behaviors that prioritize acquisition of the right amount and variety (frozen, shelf-stable, and perishable) of foods rather than large quantities • Work with researchers to evaluate impacts and potential unintended consequences of interventions to reduce consumer food waste
Food producers and the agriculture sector	• Inform consumers about the impacts of food waste, and provide tips to help them reduce such waste • Reach out to consumers with the goal of reducing their physical and psychological distance from food and food production
Restaurants and other food service providers (e.g., cafeterias at workplaces)	• Use evidence-based guidance to design, implement, and tailor interventions to reduce consumer food waste—for example, optimize portions and number of options offered; redesign menus and food presentation, such as buffets; stop using trays; encourage taking a sample helping and returning for more if desired; provide containers for leftovers; and provide tips for consumers on how to reduce food waste • Work with researchers to evaluate impacts and potential unintended consequences of interventions to reduce consumer food waste
Food industry organizations (e.g., National Restaurant Association, FMI-The Food Industry Association, Food Waste Reduction Alliance, Consumers Brand Association)	• Engage with the Winning on Reducing Food Waste Initiative to coordinate efforts and use consistent methods, approaches, and terminology, and support evidence-based best practices for reducing food waste at the consumer level by providing regularly updated written guidance, consultation services, and tools to the relevant industries • Encourage businesses to evaluate their efforts and provide tools, funds, and connections to researchers for this purpose • Develop materials for campaigns aimed at specific sectors to educate the business community about costs and benefits of these activities • Create communities of practice to support sharing of innovations and lessons learned
International Organization for Standardization and other standards organizations	• Include practices that reduce food waste at the consumer level as criteria in environmental management systems or other standards for food businesses

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TABLE 5-1 Continued

Partner	Example Contributions
Nongovernmental organizations	• Develop/support the development of guidelines, toolkits, and best practices • Support and conduct relevant research • Continue to support with guidelines and information innovators, industries, and institutions that provide food through such channels as cafeterias in schools, universities, and workplaces • Engage with the Winning on Reducing Food Waste Initiative and others to develop consistent measures, methods, interventions, and terminology
Professional associations (e.g., the Culinary Institute of America Institute of Food Technologists, the Academy of Nutrition and Dietetics)	• Work with their memberships to promote the use of their platforms to advance consistent food literacy information, including evidence-based guidance to help people optimize the consumption of food and minimize its discarding, and help shift social norms by providing information about the effects of wasting food
Influencers (e.g., recipe providers, cooking show hosts, chefs, social media personalities), extension specialists, consumer organizations, community leaders, and other educators	• Assist in disseminating guidance about food waste prevention from the Winning on Reducing Food Waste Initiative, advancing consistent food literacy information, including evidence-based guidance to help people optimize the consumption of food and minimize its discarding • Help shift social norms by providing information about the effects of wasting food
Schools, colleges, and universities	• Implement interventions that can help students and staff reduce food waste
Innovators (e.g., developers of software and apps)	• Improve existing technologies and create new ones (e.g., features of the built environment, appliances, apps) to help consumers with reducing food waste
Foundations	• Invest in research to advance measurement of food waste at the consumer level and study of the drivers of food waste behavior and mechanisms for changing that behavior • Support food waste reduction programs/resources • Require and provide resources for evaluations in funded projects, and ensure that funded interventions are building on best practices and evidence rather than reinventing approaches
Researchers and academic institutions	• Produce research to support future innovations and build the knowledge base on drivers of consumer behavior and on best practices for interventions to change that behavior

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Finally, as new approaches to reducing food waste are tested, adapted, and implemented it will be critical to collect and analyze data on their operation and effects. As discussed in Chapter 6, effective implementation of research-based interventions is an ongoing process that requires evaluation, adaptation to local conditions, and often design modification. The government partners and others who contribute funding for elements of the committee's proposed strategy can ensure that systematic evaluation is built into the effort.

RECOMMENDATION 12: Government agencies and others who fund interventions pursued as part of the proposed strategy to reduce food waste at the consumer level, as well as developers of state and local policies and regulations, should require that the effects of an intervention, policy, or regulation on reducing food waste and increasing consumer capacity to reduce food waste, as well as on other elements of the food system and issues beyond food waste, be evaluated. The results of this evaluation should be peer-reviewed and made available to researchers and the public.

To sustain the strategy laid out in this report, ongoing work will be needed to address significant gaps in the knowledge base on food waste. The following chapter describes the primary gaps and provides suggestions for research priorities.

REFERENCES

Bel, G., and R. Gradus. 2016. Effects of unit-based pricing on household waste collection demand: A meta-regression analysis. *Resource and Energy Economics* 44:169-182.

Benson, C., W. Daniell, and J.A. Otten. 2018. A qualitative study of United States food waste programs and activities at the state and local level. *Journal of Hunger and Environmental Nutrition* 13(4):553-572.

Boiral, O., L. Guillaumie, I. Heras-Saizarbitoria, and C.V. Tayo Tene. 2018. Adoption and outcomes of ISO 14001: A systematic review. *International Journal of Management Reviews* 20(2):411-432.

Broad Leib, E. 2013. *The Dating Game: How Confusing Date Labels Lead to Food Waste in America*. Available: http://www.chlpi.org/wp-content/uploads/2013/12/dating-game-report.pdf.

Broad Leib, E., C. Rice, R. Neff, M. Spiker, A. Schklair, and S. Greenberg. 2016. Consumer perceptions of date labels: National survey. Available: http://www.chlpi.org/wp-content/uploads/2013/12/Consumer-Perceptions-on-Date-Labels_May-2016.pdf.

Del Giudice, T., F. La Barbera, R. Vecchio, and F. Verneau. 2016. Anti-waste labeling and consumer willingness to pay. *Journal of International Food and Agribusiness Marketing* 28(2):149-163.

Devine, K., and P. Pearson. 2019. *Reducing Food Waste in Schools: The Business Case*. Available: https://www.worldwildlife.org/publications/reducing-food-waste-in-schools-the-business-case.

Copyright National Academy of Sciences. All rights reserved.

Elimelech, E., E. Ert, and O. Ayalon. 2019. Exploring the drivers behind self-reported and measured food wastage. *Sustainability (Switzerland)* 11(20):5677.

EPA (U.S. Environmental Protection Agency). 2016. *Communities: 2006 PAYT Programs*. Available: https://archive.epa.gov/wastes/conserve/tools/payt/web/html/06comm.html.

Giordano, C., F. Alboni, and L. Falasconi. 2019. Quantities, determinants, and awareness of households' food waste in Italy: A comparison between diary and questionnaires quantities. *Sustainability (Switzerland)* 11(12):3381.

Grainger, M.J., L. Aramyan, S. Piras, T.E. Quested, S. Righi, M. Setti, M. Vittuari, and G.B. Stewart. 2018. Model selection and averaging in the assessment of the drivers of household food waste to reduce the probability of false positives. *PLoS ONE* 13(2):e0192075.

Hanson, C., and P. Mitchell. 2017. *The Business Case for Reducing Food Loss and Waste*. Washington, DC: Champions 12.3.

Koch, P.A. 2016. Learning, food, and sustainability in the school curriculum. In *Learning, Food, and Sustainability: Sites for Resistance and Change*, edited by J. Sumner. New York: Palgrave Macmillan US. Pp. 55-73.

Messner, R., C. Richards, and H. Johnson. 2020. The "prevention paradox": Food waste prevention and the quandary of systemic surplus production. *Agriculture and Human Values*. Available: https://doi.org/10.1007/s10460-019-10014-7.

ReFED (Rethink Food Waste Through Economics and Data). 2018. *Restaurant Food Waste Action Guide*. Available: https://www.refed.com/downloads/Restaurant_Guide_Web.pdf.

Sandson, K., and E. Broad Lieb. 2019. *Bans and Beyond: Designing and Implementing Organic Waste Bans and Mandatory Organics Recycling Laws*. Harvard Law School Food Law and Policy Clinic; Center for EcoTechnology. Available: https://wastedfood.cetonline.org/wp-content/uploads/2019/07/Harvard-Law-School-FLPC-Center-for-EcoTechnology-CET-Organic-Waste-Bans-Toolkit.pdf.

Schupp, C.L., K.M. Getts, and J.J. Otten. 2018. An evaluation of current lunchroom food waste and food rescue programs in a Washington state school district. *Journal of Agriculture, Food Systems and Community Development* 8(1), 167-186. Available: https://doi.org/10.5304/jafscd.2018.081.013.

Thomson, C.A., and J. Ravia. 2011. A systematic review of behavioral interventions to promote intake of fruit and vegetables. *Journal of the American Dietetic Association* 111(10):1523-1535.

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6

A Research Agenda for Improving Interventions to Reduce Food Waste and Their Implementation

Much remains to be learned about how food waste at the consumer level can be reduced. Researchers from a number of disciplines are studying many aspects of this challenge, and they have already provided the foundation for meeting this urgent challenge, as described in this report. To sustain the strategy laid out in Chapter 5, however, ongoing work is needed to address significant gaps in the knowledge base. This concluding chapter summarizes the gaps identified throughout the report, and offers the committee's suggestions for research priorities. The research gaps relate to two distinct but interconnected areas:

- understanding drivers of consumer behavior and designing interventions to change that behavior, and
- understanding how promising interventions can be implemented effectively.

UNDERSTANDING DRIVERS OF CONSUMER BEHAVIOR AND DESIGNING INTERVENTIONS TO CHANGE THAT BEHAVIOR

Although research in the area of food waste, particularly at the consumer level, is expanding rapidly, there remains a need for research to better understand the drivers of consumer waste within the food system and how that understanding can be translated into effective interventions. The current momentum to make rapid progress in preventing consumer-level food waste is hampered by a lack of well-designed and -executed studies of the effectiveness of interventions that can contribute to that progress. Further,

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to support decisions about selecting and prioritizing such interventions, it will be necessary to evaluate outcomes that include not only effects on food waste but also other effects (positive or negative) that may be unintended. The effects of the COVID-19 pandemic on the food system and consumer behavior will also need to be factored into future studies and will likely generate new research questions as well.

Needed Research on Drivers of Consumers' Food Waste Behavior

As in the research on behavior change, the committee did not conduct an in-depth literature review, but relied mainly on systematic reviews to examine the literature related to drivers of food waste at the consumer level. We synthesized information on drivers related to away-from-home discards from the peer-reviewed academic literature since we could find no systematic review in this area. The topics suggested below are meant to address the limitations of existing research and inspire future research on the drivers of food waste. Advances in this area are important because they will help in improving current interventions and designing novel interventions to reduce food waste at the consumer level.

Understanding Consumers and the Food Environment in the United States

Further understanding of consumers and the U.S. food environment is needed in the following areas:

- Explore consumer segmentation regarding food waste behaviors and attitudes so that interventions can be targeted. Particular attention is needed to research investigating such behaviors and attitudes among consumers with low income because of the lack of current data and the need for research methodologies, such as ethnographic methods, that would reach these consumers.
- Assess the benefits of reducing food waste for the different sectors of the food industry so they can be communicated to industry leaders and relevant staff. In addition, examine the upstream factors that encourage consumers' overconsumption and identify ways to counteract these pressures.
- Identify gaps in food literacy by population groups and settings so communication and education approaches related to food waste can be tailored and designed to be more effective.
- Continue to understand the rapidly changing environment of the food industry (e.g., pandemic-induced supply chain disruptions); emerging marketing models (e.g., meal kits); and the contribution

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to food literacy of social media, influencers, and other modern forms of communication and their potential effect on food waste, consumer behaviors, and other outcomes.

Focusing Beyond the Individual

The effects of many correlates of food waste, such as those rooted in sociodemographic factors, likely affect food waste behaviors through the activation of other drivers, such as social norms, tool availability, or the built environment. This realization points to the importance of a systems approach, particularly the need to study interactions between drivers and socioeconomic factors. However, the literature on drivers tends to focus on the individual instead of on drivers across other contexts outside the household. Additionally, very little research has examined how behaviors and attitudes related to food waste translate across different contexts (e.g., home vs. restaurant vs. work). These contexts may activate a host of consumer goals, attitudes, and norms. For example, if it is possible to shape food waste behaviors away from home, it may be possible to design interventions that are universally useful, building new habits that consumers from many different populations and communities incorporate into their practices at home. Further, policies, such as those related to international trade and pricing mechanisms, affect the cost of food, what food is produced, how much is produced, and where. The effects of these and other policies on food waste need to be explored.

Designing Studies to Understand Causal, Correlational, and Intervening Drivers

Qualitative studies are important tools for understanding the interplay among the drivers of consumer behavior and how their interrelationships result in food waste at the consumer level. However, it is also important to understand the size of the effects of the various drivers. These two types of research complement each other. As with the literature on interventions described in Chapter 4, a shortcoming related to quantitative methods is that a large proportion of studies do not use directly measured data on the generation of wasted food. Additionally, most quantitative studies are correlational, and thus do not represent causal pathways or clarify what type of relationship a driver has with the generation or magnitude of wasted food, if any (e.g., Koivupuro et al., 2012; Setti et al., 2018). Further, to develop effective interventions, it is important to understand more precisely the relative contribution of different drivers of food waste behaviors in different populations.

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Needed Research on Interventions to Reduce Consumer-Level Food Waste

The committee's review of the intervention literature revealed multiple examples of interventions with promising results; those promising interventions can be tested further across contexts and scale, with rigorous methods, to identify best practices. Our identification of evidence gaps and limitations serves as a roadmap for the research needed to advance a set of interventions with the power to help bring widespread change. These research needs fall into two areas: methods and intervention types.

Methods

The committee identified five methodological priorities for strengthening the literature on interventions:

- Long-term follow-up evaluation of interventions, particularly for some small studies, is warranted to ensure that behavioral change is sustained beyond the initial intervention, to identify unintended consequences before scale-up, to improve tailoring to context and implementation, and to ensure that the most efficacious and cost-effective approaches are selected for continued support and scaling. The need for such follow-up is reinforced by the fact that research in the six related domains explored by the committee yielded few insights about how intervention effects persist over time (Abrahamse and Steg, 2013; Koop et al., 2019; Nisa et al., 2019; Snyder, 2007; Varotto and Spagnolli, 2017) or about to undo old and create new habits, how to prolong and reinforce newly formed habits, and how interventions may differ between those that target one-off and infrequent behaviors and those that target habits (Koop et al., 2019).
- Well-designed nonexperimental field studies (e.g., with measures of food waste, accounting for confounding factors) are helpful because they have better external validity relative to experimental studies and can be conducted for longer periods. Nonetheless, there is a need for more tier 1 studies that include appropriate control groups and other design elements to support robust causal inferences and to ensure that what is measured is actual waste reduction, rather than intentions to reduce waste. These studies would ideally leverage appropriate theory to better shape intervention design and implementation.

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- Research is needed that integrates the development of interventions and implementation strategies.[1] Implementation research is essential to refine interventions—in particular, translational research that applies findings from implementation science to food waste initiatives. Also needed, however, is development of a method that pairs intervention development with implementation research. Systematic reviews in the six related domains corroborate the need to use formative research, monitoring research, and evaluative research to design interventions, monitor their implementation, and evaluate how implementation affects an intervention's impacts (Snyder, 2007).
- As data sources and methods develop, further modeling research and other systems-oriented studies will be important. Methods for understanding multifaceted interventions are also needed. Outcomes beyond efficacy to be assessed include trade-offs, spillovers, and equity and distributional implications. In addition, more qualitative studies on interventions would allow for better understanding of the complexity of and underlying practices influencing change. The committee's review of the six related domains revealed the lack of studies exploring underlying mechanisms, such as social norms, attitudes, and knowledge, and thus most studies cannot explain why an intervention worked or what it changed (Abrahamse and Steg, 2013; Abrahamse et al., 2005).
- The research base needs to be expanded to address diverse population groups, particularly communities with lower incomes and their contexts, and different scales.

Intervention Types

In addition to research to further evaluate the efficacy and effectiveness of interventions shown to be promising by existing studies (including those with suggestive evidence; see Table 4-2 in Chapter 4), the following types of intervention are priorities for additional study:

- interventions targeting drivers that have rarely been studied (e.g., those related to consumers' assessment of risk, everyday complexity, influences across the supply chain) (see Chapter 4), and "strong" prevention interventions that address root-cause factors and work to shift patterns of unsustainable production and consumption; and

[1] Implementation outcomes to be considered are acceptability, appropriateness, adoption, cost, feasibility, fidelity, and penetration.

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- multifaceted interventions, implemented so as to enable segmentation of component effects in analysis.

THE SCIENCE OF IMPLEMENTING INTERVENTIONS

Implementation is an aspect of successful transformation that is frequently neglected by researchers, decision makers, and practitioners, but is essential in achieving desired outcomes. A systematic approach to implementation requires an investment of both financial and human resources. The field of implementation science is well established in such areas as education and health. As the committee's assessment of systematic reviews in environmental and health-related behavior revealed, however, the field of implementation in these areas is still underresearched. In the realm of food waste, a few implementation guides exist for specific interventions (e.g., for reducing food waste in schools or for community education campaigns), but more attention is needed to the development of strategies and tools to support stakeholders as they implement food waste interventions. Given that implementation strategies are context dependent, providing strategies for each of the recommendations in this report would not be feasible. However, the following sections explain the importance of stakeholders' systematic engagement in implementation and of their considering it essential to realizing the desired outcomes of interventions.

The Importance of Considering the Dissemination and Implementation of Interventions

A number of interventions designed to reduce food waste at the consumer level have shown positive results, and this report calls for new interventions to be developed and researched. Broadly speaking, interventions fall into a number of categories, such as programs (e.g., food waste curricula in schools), practices (e.g., reducing plate sizes), products (e.g., smart refrigerators), and policies (e.g., pay-as-you-throw) (Brown et al., 2017). As emphasized throughout the report, robust empirical evidence supporting the efficacy of food waste interventions is limited, and in the absence of such evidence, decision makers might choose to adopt a given intervention because it appears to be the best available solution to an identified problem or because the intervention has been mandated by an external party. Furthermore, even an intervention with empirical evidence of efficacy within a controlled experimental environment or in a given setting may not be effective in other settings. Regardless of the strength of evidence supporting an intervention, the approach used to disseminate information about the intervention and the strategies used to implement it will affect its rate of diffusion and the effectiveness of its implementation.

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Given that the evidence for most interventions targeting food waste is not well developed, it is likely that new interventions will continue to be developed, and existing interventions may be redesigned. Considering dissemination and implementation issues when designing interventions can help prevent the development and testing of interventions that are unlikely to be disseminated and adopted in practice. The importance of doing so has been highlighted by implementation researchers in other fields. For example, the concept of "designing for dissemination"—defined as "an active process that helps to ensure that public health interventions, often evaluated by researchers, are developed in ways that match well with adopters' needs, assets, and time frames"—responds to evidence about the ineffectiveness of passive dissemination approaches, the importance of engaging stakeholders in the design process, and the need to tailor dissemination activities to specific audiences (Brownson et al., 2013, p. 1695). Similarly, principles of "user-centered design"—such as active user participation throughout the project, early prototyping, and multidisciplinary design teams—have been applied to guide the development of information systems and technologies, as well as various types of interventions (Gulliksen et al., 2003). Applying similar design principles to interventions aimed at reducing food waste could be particularly important for achieving desired benefits across population subgroups.

Deciding Which Interventions to Disseminate or Implement

A community, organization, or individual may face multiple problems that could be addressed by interventions. In most cases, food waste would be one of many competing priorities, and reducing consumer food waste in one area could affect operations in another area. In addition, for any given problem, multiple possible solutions (interventions) likely exist. In some cases, there is insufficient evidence (or knowledge) to determine the optimal way to address a problem. Alternatively, evidence may exist that supports multiple solutions (interventions), leaving decision makers to select which is the best fit for addressing the identified problem. In all cases, simply selecting an intervention is not enough. In fact, as highlighted throughout this report, interventions commonly need to be adapted because some of their components or features are not applicable to the local context (Strauss et al., 2013). For example, educational content may need to be added, removed, or altered to account for the needs of different populations and to ensure cultural appropriateness (Escoffery et al., 2018). Guidance exists for planning and documenting such modifications to support research and evaluation efforts for modified interventions (Wiltsey Stirman et al., 2019).

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Barriers to and Facilitators of Implementation

Once an intervention has been selected, additional work is needed to help ensure that it will lead to the desired results, such as a reduction in food waste. Just as multiple factors (i.e., drivers) contribute to food waste, various factors can influence whether an intervention aimed at reducing food waste is adopted and ultimately implemented effectively. These factors can serve as either barriers or facilitators and may occur at multiple levels, such as the intervention, the individual, the organization, and the external environment. For example, the evidence supporting the intervention, the complexity of the intervention, and its cost all may influence whether decision makers adopt it. Furthermore, perceptions of the intervention may be influenced by how information about such characteristics is communicated—by whom, by which methods, and with what content (Damschroder et al., 2009; Rogers, 2003).

At the individual level, such characteristics as the person's role, prior experience, and knowledge about the intervention can shape perceptions of its appropriateness and, ultimately, whether decision makers choose it (Damschroder et al., 2009). Within organizations, various factors may contribute to (or hinder) the adoption of an intervention and the effectiveness of its implementation once it has been selected for adoption. For example, an organization's readiness for change—its collective willingness and ability to implement an intervention—can be expected to influence the extent to which the members cooperate with each other during the implementation process and persist despite implementation challenges (Weiner, 2009). Similarly, a strong "implementation climate" within an organization—the extent to which use of an intervention is expected, supported, and rewarded by leadership—is expected to promote more consistent, high-quality use of the intervention (Weiner et al., 2011). Finally, in the external environment, such factors as policies, incentives, and interorganizational relationships may affect the adoption of an intervention and the effectiveness of its implementation (Damschroder et al., 2009).

Selecting and Tailoring Dissemination and Implementation Strategies

Widespread adoption of an intervention may not occur absent dissemination strategies designed to communicate information about the intervention and promote its adoption (Bero et al., 1998). These dissemination strategies can be categorized as (1) developing messages and materials and (2) distributing those messages and materials for specific audiences (Leeman et al., 2017). Once the decision has been made to adopt an intervention, its intended users typically need support to promote effective implementation.

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Implementation strategies provide this support and are "the 'how to' of implementation efforts" (Waltz et al., 2019).

More specifically, implementation strategies can be seen as "methods or techniques used to enhance the adoption, implementation, and sustainability" of an intervention (Proctor et al., 2013, p. 140). They are intended to address barriers to adopting and/or using an intervention and may be carried out by actors other than those targeted by the intervention (Powell et al., 2015). If used effectively, these strategies help ensure that well designed interventions yield the expected benefits. Examples of such strategies include (1) holding meetings for specific stakeholder groups to teach them about the intervention; (2) forming a learning collaborative consisting of groups of organizations attempting to implement the same intervention; and (3) auditing and providing feedback about performance data so users can better monitor, evaluate, and modify their use of the intervention (Powell et al., 2015).

In the food waste context, organizations might pay attention, for example, to the many waste-producing behaviors of their members and how they are embedded in routine practices and habits. As a result, they might intervene to break the habit cycle and support the development of new food use routines during "teachable moments" when new practices are being formed. For example, higher education institutions might provide storage tools, refrigerator and freezer access, and information as part of move-in kits and establish norms via visible waste reduction campaigns in university food service facilities. Hospitals and postnatal care organizations might offer tools and incentives to help new mothers maximize the value from food as they establish new routines. Neighborhood organizations might introduce new residents to food stewardship when new residents move in, along with cues placed close to points of consumption and disposal regarding the neighborhood's shared commitment to waste reduction. Employers might welcome new employees with storage containers and information about in-workplace storage tools and options. Agencies, nongovernmental organizations, and educators might initiate campaigns on holidays, at the beginning of the week or month, or on "special days" to capitalize on "fresh start effects." And parent-teacher organizations might provide food use toolkits to incoming students and their families.

Just as interventions effective in one context need to be adapted to a different local context or setting (e.g., hospitals vs. schools), barriers to using an intervention may vary across different groups and settings (Mittman, 2012). This variability may necessitate the use of different combinations of implementation strategies to address those different barriers and/or tailoring of a specific implementation strategy (Powell et al., 2019). For example, communities may vary in terms of the presence of supportive policy, infrastructure, and citizen awareness related to food waste. Some

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communities may need strategies targeting barriers within each of these domains, whereas others may need to focus strategies on a subset of the domains. Examples of specific strategies that may need to be tailored include the method for distributing educational materials (e.g., in person, by mail, or online) or the particular indicators monitored when auditing and providing feedback on behaviors or practices. Guidance for selecting and tailoring implementation strategies is available, and the knowledge base in this area continues to grow (Powell et al., 2017). The need to select and tailor interventions and implementation strategies illustrates some of the principles underlying the recommendations in this report, for example, that not all consumers are already highly motivated to reduce food waste and that underlying differences in household characteristics influence the amount of waste generated.

Identifying Implementation Outcomes

Given that the effectiveness of implementation influences the extent to which desired outcomes (e.g., a reduction in wasted food) are realized, it is important to select implementation strategies that address barriers to and therefore promote more effective implementation. The effectiveness of implementation can be evaluated based on implementation outcomes, which are distinct from the desired outcomes of the intervention. Implementation outcomes are "the effects of deliberate and purposive actions to implement new treatments, practices, and services" and serve as indicators of the success of implementation and as key intermediate outcomes (Proctor et al., 2011, p. 65). A commonly used framework identifies eight implementation outcomes: acceptability, appropriateness, adoption, cost, feasibility, fidelity, penetration, and sustainability (see Table 6-1).

Given the limited evidence for food waste interventions and their implementation, future research in the field could benefit from using hybrid effectiveness–implementation designs to assess both intervention outcomes and implementation barriers, strategies, and outcomes. Such a hybrid design allows for assessment that is appropriate given the current state of evidence for the interventions and their implementation. More specifically, a hybrid design follows one of three paths: (1) testing effects of an intervention while secondarily collecting information about implementation (e.g., barriers to implementation), (2) dual testing of the intervention and an implementation strategy (or strategies) for the intervention, or (3) testing of a discrete or multifaceted implementation strategy while also assessing the intervention's effect to determine whether intervention outcomes differ relative to prior evidence (e.g., from efficacy trials) (Curran et al., 2012).

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TABLE 6-1 Implementation Outcomes

Outcome	Indicators of Success
Acceptability	Perception among stakeholders that a given intervention is agreeable (e.g., not overly complex)
Appropriateness	Perceived fit of the intervention for a given setting or consumer
Adoption	Initial decision or action to try to employ an intervention
Cost	Financial impact of an implementation effort, which may vary depending on the complexity of the intervention, the implementation strategy, and the setting in which implementation occurs
Feasibility	Extent to which an intervention can be used in a given setting
Fidelity	Degree to which an intervention is implemented as intended by its designers
Penetration	Extent to which the intervention is integrated within a setting and its subsystems (e.g., departments or other groups of intended users)
Sustainability	Extent to which use of an intervention is institutionalized within a setting's operations and/or maintained over time

General versus Intervention-Specific Capacities

Although the issues discussed above relate to the implementation of a specific intervention, it is important to consider that communities, organizations, and even individuals may have both a general and an intervention-specific capacity for change (Wandersman et al., 2008, 2015). In other words, potential adopters of interventions (e.g., communities, organizations, individuals) can vary both in their ability to make changes in general and in their willingness and ability to make a specific change (i.e., to implement a particular intervention). For example, an organization with a culture supportive of innovation, engaged leadership, robust information and communication systems, effective planning processes, and systematic quality monitoring and improvement processes may be viewed as having a high level of general capacity for change. Examples of strategies for increasing general capacity within an organization include training, technical assistance, and peer networks (Leeman et al., 2015). Although a high level of general capacity provides a supportive environment for the implementation of any specific intervention, it does not guarantee the success of its implementation (Leeman et al., 2017). Thus implementation strategies (as discussed above) are likely needed to facilitate effective implementation of any specific intervention. At the same time, however, having a general capacity for change may be foundational for selecting and tailoring the implementation strategies needed to promote successful implementation of an intervention. Therefore, it is important to consider (and increase as needed) both the general and the intervention-specific capacity for change.

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SUMMARY AND CONCLUSIONS

Research evidence is vital for identifying promising interventions, but implementing them on a broad scale requires attention to other factors as well. There is a rapidly developing body of research on the implementation of interventions designed to meet public policy objectives. However, relatively little of that research has addressed food waste specifically. Efforts are needed to align the development of food waste interventions with activities to disseminate and implement them.

CONCLUSION 6-1: Implementation of interventions identified as promising requires careful attention not only to unexpected outcomes but also to such factors as feasibility, capacity, fidelity to the intervention design, cost, and appropriateness to the settings in which an intervention will be used. Translational research is needed to apply frameworks, methods, and existing evidence from implementation research to food waste initiatives.

CONCLUSION 6-2: Many interventions that have been studied have demonstrated significant efficacy in reducing food waste at the consumer level in experimental settings. However, few of these promising interventions have been systematically evaluated for effectiveness in real-world and large-scale applications. Interventions that demonstrate high levels of efficacy and effectiveness are needed to significantly reduce consumer-level food waste. Research integrating intervention development with implementation research is needed to identify and refine the most promising interventions so they can be put into practice at a broad enough scale to have meaningful effects.

REFERENCES

Abrahamse, W., and L. Steg. 2013. Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change* 23(6):1773-1785.

Abrahamse, W., L. Steg, C. Vlek, and T. Rothengatter. 2005. A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* 25(3):273-291.

Bero, L.A., R. Grilli, J.M. Grimshaw, E. Harvey, A.D. Oxman, and M.A. Thomson. 1998. Closing the gap between research and practice: An overview of systematic reviews of interventions to promote the implementation of research findings. The Cochrane effective practice and organization of care review group. *BMJ (Clinical Research Ed.)* 317(7156):465-468.

Brown, C.H., G. Curran, L.A. Palinkas, G.A. Aarons, K.B. Wells, L. Jones, L.M. Collins, N. Duan, B.S. Mittman, A. Wallace, R.G. Tabak, L. Ducharme, D.A. Chambers, G. Neta, T. Wiley, J. Landsverk, K. Cheung, and G. Cruden. 2017. An overview of research and evaluation designs for dissemination and implementation. *Annual Review of Public Health* 38:1-22.

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Brownson, R.C., J.A. Jacobs, R.G. Tabak, C.M. Hoehner, and K.A. Stamatakis. 2013. Designing for dissemination among public health researchers: Findings from a national survey in the United States. *American Journal of Public Health* 103(9):1693-1699.

Curran, G.M., M. Bauer, B. Mittman, J.M. Pyne, and C. Stetler. 2012. Effectiveness-implementation hybrid designs: Combining elements of clinical effectiveness and implementation research to enhance public health impact. *Medical Care* 50(3):217-226.

Damschroder, L.J., D.C. Aron, R.E. Keith, S.R. Kirsh, J.A. Alexander, and J.C. Lowery. 2009. Fostering implementation of health services research findings into practice: A consolidated framework for advancing implementation science. *Implementation Science* 4:50-65.

Escoffery, C., E. Lebow-Skelley, R. Haardoerfer, E. Boing, H. Udelson, R. Wood, M. Hartman, M.E. Fernandez, and P.D. Mullen. 2018. A systematic review of adaptations of evidence-based public health interventions globally. *Implementation Science* 13(1):125.

Gulliksen, J., B. Göransson, I. Boivie, S. Blomkvist, J. Persson, and Å. Cajander. 2003. Key principles for user-centred systems design. *Behaviour and Information Technology* 22(6):397-409.

Koivupuro, H.K., H. Hartikainen, K. Silvennoinen, J.M. Katajajuuri, N. Heikintalo, A. Reinikainen, and L. Jalkanen. 2012. Influence of socio-demographical, behavioural and attitudinal factors on the amount of avoidable food waste generated in Finnish households. *International Journal of Consumer Studies* 36(2):183-191.

Koop, S.H.A., A.J. Van Dorssen, and S. Brouwer. 2019. Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics. *Journal of Environmental Management* 247:867-876.

Leeman, J., L. Calancie, M.A. Hartman, C.T. Escoffery, A.K. Herrmann, L.E. Tague, A.A. Moore, K.M. Wilson, M. Schreiner, and C. Samuel-Hodge. 2015. What strategies are used to build practitioners' capacity to implement community-based interventions and are they effective?: A systematic review. *Implementation Science* 10(1):80-95.

Leeman, J., S.A. Birken, B.J. Powell, C. Rohweder, and C.M. Shea. 2017. Beyond "implementation strategies": Classifying the full range of strategies used in implementation science and practice. *Implementation Science* 12(1):125.

Mittman, B.S. 2012. Implementation science in health care. In *Dissemination and Implementation Research in Health: Translating Science to Practice*, edited by R.C. Brownson, G.A. Colditz and E.K. Proctor. New York: Oxford University Press. Pp. 400-418.

Nisa, C.F., J.J. Bélanger, B.M. Schumpe, and D.G. Faller. 2019. Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. *Nature Communications* 10:4545-4558.

Powell, B.J., T.J. Waltz, M.J. Chinman, L.J. Damschroder, J.L. Smith, M.M. Matthieu, E.K. Proctor, and J.E. Kirchner. 2015. A refined compilation of implementation strategies: Results from the expert recommendations for implementing change (ERIC) project. *Implementation Science* 10:21-35.

Powell, B.J., R.S. Beidas, C.C. Lewis, G.A. Aarons, J.C. McMillen, E.K. Proctor, and D.S. Mandell. 2017. Methods to improve the selection and tailoring of implementation strategies. *Journal of Behavioral Health Services and Research* 44(2):177-194.

Powell, B.J., M.E. Fernandez, N.J. Williams, G.A. Aarons, R.S. Beidas, C.C. Lewis, S.M. McHugh, and B.J. Weiner. 2019. Enhancing the impact of implementation strategies in healthcare: A research agenda. *Frontiers in Public Health* 7:3.

Proctor, E., H. Silmere, R. Raghavan, P. Hovmand, G. Aarons, A. Bunger, R. Griffey, and M. Hensley. 2011. Outcomes for implementation research: Conceptual distinctions, measurement challenges, and research agenda. *Administrative Policy in Mental Health and Mental Health Services Research* 38(2):65-76.

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A National Strategy to Reduce Food Waste at the Consumer Level

Proctor, E.K., B.J. Powell, and J.C. McMillen. 2013. Implementation strategies: Recommendations for specifying and reporting. *Implementation Science* 8:139.

Rogers, E.M. 2003. *Diffusion of Innovations, 5th Edition*. New York: Free Press.

Setti, M., S. Andrea, B. Federico, F. Luca, and V. Matteo. 2018. Consumers' food cycle and household waste: When behaviors matter. *Journal of Cleaner Production* 185(185):694-706.

Snyder, L.B. 2007. Health communication campaigns and their impact on behavior. *Journal of Nutrition Education and Behavior* 39(2 SUPPL.):S32-S40.

Strauss, S.E., J. Tetroe, and I.D. Graham. 2013. *Knowledge Translation in Health Care: Moving from Evidence to Practice*. West Sussex, UK: John Wiley & Sons, Ltd.

Varotto, A., and A. Spagnolli. 2017. Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology* 51:168-188.

Waltz, T.J., B.J. Powell, M.E. Fernandez, B. Abadie, and L.J. Damschroder. 2019. Choosing implementation strategies to address contextual barriers: Diversity in recommendations and future directions. *Implementation Science* 14(1):42.

Wandersman, A., J. Duffy, P. Flaspohler, R. Noonan, K. Lubell, L. Stillman, M. Blachman, R. Dunville, and J. Saul. 2008. Bridging the gap between prevention research and practice: The interactive systems framework for dissemination and implementation. *American Journal of Community Psychology* 41(3-4):171-181.

Wandersman, A., K.A. Alia, B. Cook, and R. Ramaswamy. 2015. Integrating empowerment evaluation and quality improvement to achieve healthcare improvement outcomes. *BMJ Quality and Safety* 24(10):645-652.

Weiner, B.J. 2009. A theory of organizational readiness for change. *Implementation Science* 4(1):67.

Weiner, B.J., C.M. Belden, D.M. Bergmire, and M. Johnston. 2011. The meaning and measurement of implementation climate. *Implementation Science* 6(1):78.

Wiltsey Stirman, S., A.A. Baumann, and C.J. Miller. 2019. The frame: An expanded framework for reporting adaptations and modifications to evidence-based interventions. *Implementation Science* 14(1):58.

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Appendix A

Public Session Agendas

The committee held two meetings that were open to the public. The first took place on August 16, 2019, in Washington, D.C. The second took place on October 7–8, 2019; it was held as an online conference on October 7 and in Washington, D.C, on October 8.

Committee on A Systems Approach to Reducing Consumer Food Waste
Open Meeting 1
Friday, August 16, 2019
8:00 AM–12:30 PM ET

PERSPECTIVES FROM THE SPONSORS
Moderator: *Barbara Schneeman, Committee Chair*

8:00 Welcome
Barbara Schneeman, Committee Chair

8:05 Perspectives from the Foundation of Food and Agriculture Research
Sally Rockey, Executive Director

8:25 Perspectives from The Walmart Foundation
Eileen Hyde, Director of Hunger and Healthy Eating (by Zoom)

8:40 Q&A

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PERSPECTIVES FROM RESEARCHERS
Moderator: *Barbara Schneeman, Committee Chair*

8:50 Household Food Waste: Lessons from around the Globe
Tom Quested, Waste and Resources Action Programme (WRAP) Global (by Zoom)

9:10 Reducing Consumer Food Waste: Insights from the Guelph Food Waste Research Group
Kate Parizeau, University of Guelph

9:30 Consumer-level Wasted Food: Insights, Ideas and Lessons Learned
Ashley Zanolli, Emerging Possibility LLC

9:50 Q&A

10:15 Break

10:30 Wasted Food in Oregon: Recent Research Findings and Next Steps
Elaine Blaitt, Oregon Department of Environmental Quality (by Zoom)

10:50 Peeling Back Layers of the Wasted Onion: Root Causes of Consumer Food Waste and Shifting the Environment around Them
Dana Gunders, Next Course, LLC (by Zoom)

11:10 Experiences from the Hospitality and Food Service Industries
Pete Pearson, World Wildlife Fund

11:30 Wise Psychological Interventions
Greg Walton, Stanford University (by Zoom)

11:50 Q&A

12:30 Open session adjourns

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Committee on A Systems Approach to Reducing Consumer Food Waste
Open Meeting 2

Monday, October 7, 2019
4:30–5:15 PM ET

Moderator: *Barbara Schneeman, Committee Chair*

4:15 Welcome
Barbara Schneeman, Committee Chair

4:20 The Value of Packaging as a Strategy to Prevent Food Waste in America
Martin Gooch, VCM-International (by Zoom)

4:40 Q&A

5:00 Open Session Adjourns

Tuesday, October 8, 2019
8:30 AM–1:40 PM ET

8:30 Registration

Moderator: Barbara Schneeman, Committee Chair

9:00 Welcome
Barbara Schneeman, Committee Chair

Session 1: Trends in Food Distribution and Purchasing

9:05 Understanding Consumption Habits to Influence Food Waste
Darren Seifer, The NDP Group

9:25 Q&A

Session 2: Learning from Other Disciplines

9:40 Lessons from Psychological Research on Recycling, Energy Use, and Composting
Alex Maki, American Association for the Advancement of Science

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10:00 A Community-Based Environmental Change Intervention to Sustain Weight Reduction
Christina Economos, Tufts University (by Zoom)

10:20 Q&A

Session 3: Potential Technological and Policy Interventions

10:40 Save the Food Campaign
Erik Olson, Natural Resources Defense Council
Andrea Spacht Collins, Natural Resources Defense Council
(by Zoom)

11:00 The Science of Behavior Change: How to Maximize Reductions in Food Waste at the Consumer Level
Corby Martin, Pennington Biomedical Research Center

11:20 Food Waste and Food Security Policies in Washington State
Katie Rains, Washington State Department of Agriculture
(by Zoom)

11:40 Q&A

12:00 Lunch

1:00 The Power of Social Movements and Civic Activism to Bring About Social Change
Dana Fisher, University of Maryland

1:25 Q&A

1:45 Open Session Adjourns

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Appendix B

Literature Search Approach

Two sets of literature searches were conducted (in 2019) to inform the committee's work. The first was conducted to identify implementation strategies to reduce food waste at the consumer level. The second was done to identify reviews, systematic reviews, and meta-analyses of drivers and strategies to intervene for consumer or household behaviors related to energy saving, recycling, water conservation, waste prevention, and diet change.

In order to obtain a more rounded set of results that accounted for differences in indexing practices and use of vocabulary in titles and abstracts, the first set was split into two groups. The first iteration explicitly included behavior-related terms and avoided prevention-related terms. The second iteration left out behavior-related terms and targeted prevention-related terms. Searches were conducted in six online databases: Agricola, Embase, Medline, ProQuest Research Library, PubMed, and Scopus. Articles were included if they were published within the last 15 years, available in English, peer-reviewed, and conducted in Europe or English-speaking countries. The search terms for both iterations are shown in Table B-1. The searches yielded 548 unduplicated articles from the first group and 234 unduplicated articles from the second group.

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TABLE B-1 Search Terms Used to Identify Relevant Literature on Food Waste

Topic	Search Terms
Food Waste	Domestic food waste
	Food
	Food discard
	Food loss
	Food scraps
	Food shrink
	Food wastage
	Food waste
	Household food waste
	Leftovers
	Meals
	Plate waste
	Restaurant food waste
	School food waste
	Surplus food
	Wasted food
Consumer Behavior	Consumer
	Customer
	Diner
	End user
	Final consumer
	Food purchaser
	Household
	Shopper
	Attitude
	Behavioral change
	Behavioral modification
	Intervention
Food Waste Reduction	Avoid
	Avoidance
	Compost
	Control
	Decrease
	Doggy bag
	Lower
	Minimization
	Minimize
	Prevent
	Prevention
	Reduce
	Reduction

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The second set of searches, which targeted other efforts to change consumer or household behaviors, was also conducted in two parts. The first focused on strategies to promote energy saving and recycling behaviors. The second was directed at strategies to promote energy saving, recycling, water use conservation, waste prevention behaviors, and diet change, but it was limited to systematic reviews and meta-analyses. Both sets of searches were conducted in ProQuest Research Library, PubMed, and Scopus. The first search on energy-saving behaviors included papers that were published within the last 15 years, and it was limited to reviews, including, but not limited to, systematic reviews from Europe and English-speaking countries. The second search used the same terms, but it was restricted to systematic reviews and meta-analyses that had been published in English since 2000. Search terms are presented in Table B-2. The first search yielded 380 unduplicated studies; the second search yielded 406 unduplicated studies.

TABLE B-2 Search Terms Used to Identify Relevant Literature on Energy-Saving and Recycling Behaviors

Topic	Search Terms
Energy-Saving Behaviors	Attitudes
	Behavior modification
	Behavioral change
	Behavioral modification
	Choice behavior
	Consumer
	Consumer attitudes
	Consumer behavior
	Customer
	Decision making
	Demand side management
	Domestic
	Efficient energy use
	End user
	Energy conservation
	Energy efficiency
	Energy saving
	Final consumer
	Food purchaser
	Home
	Household
	Imitative behavior
	Intention
	Shopper
	User behavior

continued

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TABLE B-2 Continued

Topic	Search Terms
Recycling Behaviors	Attitude
	Behavior modification
	Behavioral change
	Behavioral modification
	Choice behavior
	Consumer
	Consumer attitudes
	Consumer behavior
	Customer
	Decision making
	Domestic
	Efficient energy use
	End users
	Energy conservation
	Energy efficiency
	Energy saving
	Final consumer
	Food purchaser
	Home
	Home recycling
	Household
	Household recycling
	Imitative behavior
	Intention
	Recycling
	Shopper
	User behavior

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TABLE B-2 Continued

Topic	Search Terms
Water Consumption and Water Use Conservation Behaviors	Attitudes
	Behavior modification
	Behavioral change
	Behavioral modification
	Choice behavior
	Consumer
	Consumer attitudes
	Consumer behavior
	Customers
	Decision making
	Domestic
	End users
	Final consumer
	Food purchaser
	Home
	Household
	Imitative behavior
	Intention
	Residential water conservation
	Residential water use
	Shopper
	User behavior
	Wasting water
	Water conservation
	Water consumption
	Water use conservation
	Water wasting

continued

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TABLE B-2 Continued

Topic	Search Terms
Waste Prevention Behaviors	Attitude
	Behavior modification
	Behavioral change
	Behavioral modification
	Choice behavior
	Consumer
	Consumer attitudes
	Consumer behavior
	Customer
	Decision making
	Domestic
	End users
	Final consumer
	Food purchaser
	Home
	Households
	Imitative behavior
	Intention
	Preventing waste
	Reduce waste
	Reducing waste
	Shopper
	User behavior
	Waste minimization
	Waste prevention
	Waste reduction

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TABLE B-2 Continued

Topic	Search Terms
Diet Change Behaviors	Attitude
	Behavior modification
	Behavioral change
	Behavioral modification
	Changing diet
	Choice behavior
	Consumer
	Consumer attitudes
	Consumer behavior
	Customer
	Decision making
	Diet change
	Diet habits
	Dietary habits
	Domestic
	Eating behavior
	Eating habits
	End user
	Final consumer
	Food habits
	Food policy
	Food purchaser
	Home
	Household
	Imitative behavior
	Intention
	Nutrition policy
	Shopper
	User behavior

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Appendix C

Additional Information on Food Waste

This appendix focuses on the defining and estimating food loss and food waste. After laying out the basics of the various definitions and the challenges and efforts to standardize those terms, the rest of the appendix presents an overview of methods to estimate food loss and food waste and examples of programs to reduce food loss and food waste. In addition, the appendix includes selected resources and efforst by stakeholders in the United States. The appendix focuses primarily on consumer-level food waste.

ESTIMATING FOOD LOSS AND FOOD WASTE

Defining Food

The definition of "food" is key to most definitions of food loss and food waste. It is common for "food intended for human consumption" to be used to differentiate between food materials included and excluded. Food materials grown for nonfood uses (e.g., ethanol production or animal feed) and inedible parts of plants (e.g., corn stalks) are excluded. There is a differentiation between "associated inedible parts," which tend to be harvested alongside the edible parts (e.g., corn husks), and "inedible parts," which are unlikely to be harvested (e.g., corn stalks). Other unintended or unmarketable parts of plants (e.g., small ears of corn) or loss from natural causes are sometimes included (Spang et al., 2019).

After the definition of food is determined, there are three major differences that delineate the definition of food loss and food waste: (1) stages

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of the supply chain included (e.g., on-farm losses are sometimes excluded); (2) inclusion or exclusion of associated edible parts (e.g., the U.S. Department of Agriculture [USDA] excludes associated inedible parts while the U.S. Environmental Protection Agency [EPA] includes them); and (3) end-of-life/discard destinations included (e.g., sometimes only landfill/incineration is considered food waste) (Spang et al., 2019). The many definitions and terms for food loss and food waste (Roodhuyzen et al., 2017) make comparisons between studies difficult (Bellemare et al., 2017; Östergren et al., 2014; Spang et al., 2019). To reduce this difficulty, an international accounting and reporting standard was created to standardize reporting, and it requires a clear description of the boundaries of quantification (Hanson et al., 2016). Additionally, FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies), a project of the European Union, released a definitional framework, clearly defining suggested boundaries for food loss and food waste (Östergren et al., 2014).

Sometimes "food loss" and "food waste" are distinguished from each other, although there are multiple ways in which they have been defined: (1) food loss as occurring upstream in the food supply chain and food waste as occurring at retail and consumer levels; (2) food waste as a subset of food loss; or (3) food loss as involuntary and food waste as voluntary. There are also other less common differentiations, such as wasted food (edible) and food scraps (inedible) or edible and inedible. Edibility (and avoidability), however, is not a fixed characteristic of food, but is based on biological/physical, social, cultural, and technological factors. Another term that is found in the literature, ingestibility (or digestibility), is not appropriate because many things are ingestible, for example lemon rind, but have unpleasant taste or texture or can become ingestible with enough processing (Gillick and Quested, 2018; Nicholes et al., 2019). Distinguishing between edible and associated inedible parts is important because it is generally acknowledged that these parts have different underlying reasons for being discarded; food waste prevention programs tend to focus on the avoidable or edible fraction of food waste while the inedible parts are targeted for composting or other valuable disposal streams. Another term, rescuable, refers to whether a food was safe to eat at the time of discard (e.g., moldy lasagna is considered edible but not rescuable).

Overview of Methods to Estimate Food Loss and Food Waste

Measurement and quantification are used to establish baselines, estimate impacts, identify areas for intervention or "hot spots," and track progress over time. Quantification and measurement of food loss and waste has greatly increased in the last decade (Xue et al., 2017).

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The different purposes of measurement may require different levels of granularity or accuracy. The most common metric, expressed in total volume or as proportion, is mass (weight) although volume, monetary value, or cost and nutritional value (e.g., calories) are also used. The impacts of food loss and waste that are commonly explored are water use, energy use, influence on nutrient cycling, pollution and toxic material production, biodiversity loss, and land use change.

Given the recent proliferation of food waste estimates, there has been a call for standardization in quantification to enable comparison and track progress toward global, national, and regional goals (Xue et al., 2017), and multiple organizations have published guidances (Hanson et al., 2016; Quested, 2019; Tostivint et al., 2016). Notably, the Food Loss and Waste Accounting and Reporting Standard was developed by an international group of experts and provides guidance on quantification, including a template to clearly define the boundaries of quantification (Hanson et al., 2016).

Despite the proliferation of estimates of food loss and waste at national and subnational levels, as well as for various stages along the food supply chain, there are major limitations in the current data. According to Xue et al. (2017) over half of the studies they reviewed were based on secondary data, signaling high uncertainties. In addition to the lack of primary data, outdated data are also frequently used. As mentioned above on definitions, significant variation in system boundaries and methodologies for quantification make comparisons and verification difficult (Hanson et al., 2016; Spang et al., 2019; Xue et al., 2017). Xue et al. (2017) suggest addressing this issue by creating a database that uses a common reporting framework to improve consistency and comparison.

Broadly, quantification methods at the consumer level are categorized into those that directly measure discarded food and those that quantify other metrics (e.g., total food production or food consumption) to estimate the amount of food waste (see Table C-1). Common direct methods are waste composition analyses, weighing studies, diaries, surveys (e.g., Stefan et al., 2013; Visschers et al., 2016), and records (e.g., waste bills). Common indirect methods are food balance models and use of proxy data as commonly used methods (Moreno et al., 2020; Roodhuyzen et al., 2017; Xue et al., 2017).

Many of these methods have differences in the information they provide (e.g., ability to provide granular data, drivers), representativeness of the data (e.g., communities, states, households), or whether they are self-reported data. Self-reported data from diaries, surveys, and some records (e.g., waste bills) are often subject to more bias associated with gaining a representative sample (e.g., bias in participation), accurate reporting (e.g., lapses in memory or intentional omissions), and changes in behavior as a result of

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TABLE C-1 Most Common Methods for Estimating Wasted Food at the Consumer Level

Method	Description	Information	Consumer Level	Accuracy, Objectivity, and Reliability
Direct Measurements				
Weighing	Scales; used in food service settings	Less able to provide granular data; objective	Populations	High
Diaries	Daily records; used for households and commercial kitchens	Better able to provide granular data, with added information about drivers; self-reported but likely more accurate than surveys	Individuals	Medium
Surveys	Questionnaires; used for households	Better able to provide granular data, with added information about drivers; self-reported	Individuals	Medium
Records (e.g., waste bills)	Nonfood waste-related data; used for households as well as retail and manufacturing businesses	Less able to provide granular data; self-reported when measuring it at household level	Individuals and populations	Medium
Observation	Visual estimation or counting the number of items wasted	Less able to provide granular data; estimaed	Populations	Low
Indirect Measurements				
Modeling	Using mathematical models	Less able to provide granular data	Populations	Low accuracy and reliability; medium objectivity

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TABLE C-1 Continued

Method	Description	Information	Consumer Level	Accuracy, Objectivity, and Reliability
Food Balance Models	Using a food balance sheet or human metabolism based on inputs, outputs, and stocks along the food supply chain	Less able to provide granular data	Populations	Medium accuracy and reliability; high objectivity
Proxy Data	Using data from companies or statistical agencies; for scaling data to produce aggregated estimates	Less able to provide granular data	Populations	Medium accuracy and reliability; high objectivity

reporting the data. However, some data are hard to obtain without self-reporting (e.g., information on drain disposal of food waste). Certain types of self-reported data (e.g., weighing or a kitchen diary) are considered more accurate than others, such as surveys, which ask people to recall how much food they wasted in the previous day or week or estimate how much they waste "on average." Diaries and photo journals have been found to underestimate household-level food waste (van Herpen et al., 2019), but surveys and recalls are less accurate than diaries (Thompson and Subar, 2001).

The review by Xue et al. (2017) found that less than 20 percent of the studies used first-hand data. Although direct measurements have problems with achieving a representative sample, indirect measurements lack granularity. The authors argue that that no single measurement methodology is good enough and suggest the use of a statistics-based estimation of food loss and waste coupled with first-hand measured data to corroborate findings (Xue et al., 2017).

SAMPLES OF U.S. GUIDELINES AND INITIATIVES TO REDUCE FOOD WASTE AT THE CONSUMER LEVEL

Despite the challenges in measuring food waste, there is a general consensus that food waste is a growing concern, and many efforts have been undertaken by a wide variety of stakeholder groups to reduce it at the consumer level. Table C-2 provides a sampling of guidelines and toolkits

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TABLE C-2 Sample Guidelines and Toolkits for How to Reduce Food Waste

Title	Author	Target Audience	Description
Food Waste Reduction Guidelines at Home	FUSIONS	School children and their families; preschool educators; kindergarten food service employees	Practical information about food waste, ways to maintain and store food, leftover recipes, and tips for efficient food purchases
Refresh Community of Experts	Refresh, European Union	All stakeholders	Website that shares and collects information and best practices on food waste prevention
What You Can Do To Help Prevent Wasted Food	USDA	School staff; parents; Students	Tips with links to related resources on how to reduce, recover, and recycle food
Tackling Food Waste in Cities: A Policy and Program Toolkit	NRDC	City policy makers and agency staff	Strategies with detailed actions for what cities can do to rethink, reduce, rescue, and recycle food waste
Guide to Conducting Student Food Waste Audits	USDA, EPA, and University of Arkansas	Students; school staff	Information and why and how to conduct a food waste audit. Ideas for preventing food waste in schools
Fighting Food Waste in Hotels	WWF and the American Hotel and Lodging Association	Hospitality industry	Toolkit with information, tools, and resources to help hotel industry prevent, donate, and divert wasted food at their properties
Food Waste Warrior Toolkit	WWF	Students; Teachers	Website with lesson plans, resources, and activities
Wasting Less Food in K–12 Settings: Best Practices for Success	NRDC	K–12 schools	Practical steps to reduce wasted foods in school cafeterias and kitchens
Food: Too Good to Waste (FTGTW). Implementation Guide and Toolkit	EPA	Local governments; community organizations	The implementation guide shows how to implement FTGTW using the toolkit the toolkit covers behavior change and outreach for individuals and households using community-based social marketing principles

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TABLE C-2 Continued

Title	Author	Target Audience	Description
Food Promotions Guidance for Manufacturers and Food Promotions Guidance for Retailers	WRAP	Food manufacturers and retailers	Guidance for developing food promotions that do not contribute to increased food waste in the grocery sector
Your Business Is Food, Don't Throw it Away	WRAP	Hospitality and food service	Toolkit for creating a food waste reduction action plan
Toolkit. Reducing the Food Wastage Footprint	FAO	Households; producers; government; food industry	Provides examples of good practices for reducing food waste; also identifies food waste information sources and guidelines
Best Practices and Emerging Solutions Toolkit	FWRA	Retailers and food manufacturers	Provides basic steps to reducing food waste while also raising the profile of the issue of food waste to a broader audience.
Keeping Food Out of the Landfill: Policy Ideas for States and Localities	Harvard Food Law and Policy Clinic	State and local governments	Toolkit describes policy areas that governments can examine as methods to reduce food waste and details the relevant federal laws
Bans and Beyond: Designing and Implementing Organic Waste Bans and Mandatory Organics Recycling Laws	Harvard Food Law and Policy Clinic	State and local governments; regulators; advocates	Toolkit is a resource for policy solutions to reduce food waste; examines policies and programs to incentivize waste reduction
Toolkit for Food Waste-Free Events	The Rockefeller Foundation	Businesses; hospitality industry; food service industry; community organizations; educators; consumers; governments	Toolkit of best practices and strategies for reducing food waste at events (festivals, fairs, conferences, sports events, etc.)

NOTES: EPA, U.S. Environmental Protection Agency; FAO, U.N. Food and Agriculture Organization; FUSIONS, Food Use for Social Innovation by Optimising Waste Prevention Strategies; FWRA, Food Waste Reduction Alliance; NRDC, Natural Resources Defense Council; WRAP, Waste and Resources Action Programme; WWF, World Wildlife Fund.

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that have been developed worldwide. The different products are tailored to the target many audiences, including households, policy makers, educators, hospitality industry, retailers, and community organizers.

In the United States, governments at all levels have initiatied a number of programs to help reduce food waste. Box C-1 provides examples of federal programs. The committee did not carry out a systematic identification of state and local initiatives, but received briefings on them; examples are shown in Box C-2.

BOX C-1
Selected Federal Initiatives to Reduce Food Waste

In 2015, USDA and EPA announced two new efforts. One is the 2030 Food Loss and Waste Reduction Goal to reduce food loss and waste in the United States by 50 percent by 2030, aligning with the United Nations Sustainable Development Goals. To meet this goal, the federal government will work within and across agencies and partner with communities, organizations, businesses, and local governments.

The second is the U.S. Food Loss and Waste 2030 Champions program by which businesses and organizations can make a public commitment to reduce food loss and waste in their operations by 50 percent by 2030. To date, 25 corporations have made commitments, such as eliminating postharvest losses on farms, training hotel kitchen staff on wasted food reduction techniques, and donating excess food at the retail level. These are all voluntary efforts with no formal monitoring, reporting, or evaluation.

In 2018, USDA, EPA, and the U.S. Food and Drug Administration jointly launched the Winning on Reducing Food Waste Initiative to encourage long-term reductions in food loss and wasted food in the United States through a variety of combined and agency-specific actions, including policy discussions, education, community investment, and public–private partnerships. Since its formation, the Initiative has announced partnerships with ReFED, a nonprofit organization, and the Food Waste Reduction Alliance, an industry-led group.

The Food Date Labeling Act* would establish a uniform national date labeling system on food products to clarify the meaning of date labels for quality and safety. This bipartisan bill proposes to give food manufacturers a choice between two labels: "best if used by," which would indicate the food's quality, and "use by," which sets a date to throw it out. Those terms are already being embraced by the food industry as part of a voluntary effort to streamline its labeling system.

School Food Recovery Act** would provide funding for educational programs, some of which have already been created (see Table C-2). Under this bipartisan bill, schools that participate in the federal assisted meal programs, National School Lunch Program, or the School Breakfast Program would be eligible to apply for grants to measure food waste, educate students, provide training, purchase equipment, and other projects.

*See https://www.congress.gov/bill/116th-congress/house-bill/3981/text.
**See https://www.congress.gov/bill/116th-congress/house-bill/5607.

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BOX C-2
Selected State and Local Initiatives to Reduce Food Waste

The Washington State 2019 Food Waste Reduction Act

Washington State has committed to create a plan that will recommend actions to achieve a 50 percent reduction in wasted food by 2030 in the state. The plan is currently being written with stakeholder input by the Washington State Department of Ecology. A report from the Johns Hopkins Center for a Livable Future used an online tool developed by ReFED and identified 74 wasted food reduction plans in the United States, 36 at the municipal level, 18 at the county level, and 20 at the state level; the number of new plans in the United States and worldwide has markedly increased each year since 2000 (Gorski et al., 2017). Most plans in this analysis did not include an evaluation component or did not have data on the types, quantities, and sources of wasted food. Plans varied greatly, with most focused on diversion of wasted food from landfills or increasing the rate of recycling, primarily in the form of composting; few targeted prevention.

Oregon's Commitment to Reduce Wasted Food by 50 Percent by 2030

The Oregon Department of Environmental Quality (DEQ) conducted the Oregon Wasted Food Measurement Study to track and identify the drivers of wasted food. In this multiphase study, the DEQ surveyed residents about food habits, including planning, shopping, preparing, eating, and discarding food. Additionally, they estimated wasted food by waste sorts of curbside trash bins and kitchen diaries. They also measured the impact on wasted food pre- and post-survey. After the survey, a slightly larger proportion (63.6 percent) thought they could avoid throwing out "a little" of their food, as compared to pre-survey respondents (56.9 percent) (McDermott et al., 2018).

Pay-as-you-Throw (PAYT) Program in Sandwich, Massachusetts

Beginning in 2011, Sandwich charges residents for trash bags and for access to the waste transfer stations. All trash must be in approved bags, which can be purchased at local stores, and brought to the transfer station for disposal. The town does not charge for recycling. Before the implementation of PAYT, residents were charged only to dispose of trash at the transfer station. The desired outcome is that residents will be encouraged to reduce, re-use, and recycle to avoid excess costs of trash disposal. During the first 6 months of implementaton, the town found that recycling increased and solid waste decreased. More recent data have not been publicly reported.

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BOX C-2 Continued

Massachusetts Commercial Food Materials Disposal Ban

As part of its initiative to divert at least 35 percent of all wasted food from disposal by the year 2020, the state has put in place a regulation that prohibits businesses, universities, hospitals, and other large organizations from disposing of 1 ton or more of wasted food per week in the trash. The Massachusetts Department of Environmental Protection provides guidance on compliance and encourages companies to investigate options, such as food donation, composting, or anaerobic digestion. Since taking effect in 2014, the ban has created jobs, stimulated growth in the state's organics diversion and reuse industry, and has generated millions of dollars in state and local tax revenue (ICF, 2016).

Specific examples of food waste reduction activites that are currently in use by various stakeholder groups are shown in Table C-3. For example, some food service operators have switched to trayless dining or smaller portion sizes. Food retailers are trying to reduce food waste by removing "buy one get one free offers" and technology companies are testing apps with reminders to eat purchased food before it expires.

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TABLE C-3 Examples of Ongoing Activities Targeted at Reducing Food Waste by Consumers

Organization Type	Reduction Activity
Food Service Company	• Reusable to-go food and beverage containers and trayless dining programs • Trayless dining • Sample tastes to reduce waste • Educational and scholarship programs • Menus developed with student involvement and wellness committee meetings • Video campaign in store checkout lanes explaining ways to save money by reducing wasted food at home • Trayless dining in all dining halls since 2009 reduced post-consumer food waste by 30 percent • Smaller portion sizes • More meals made to order
Food Manufacturer	• New technology (e.g., "easy-out" technology to decrease the amount of mayonnaise that sticks in the bottle) • Development of different doughs that can be filled with leftover food
Food Retailer	• Requests to suppliers to start converting to a "best if used by" date label terminology. As of February 2016, 92 percent of Walmart qualifying private brand products have adopted this new label, or have started to transition to its use • Removal of multi-buy offers • Stopped "buy one get one free" promotions on all fruit and vegetables • Removed "best before" dates on fruit and vegetable lines
Innovator in Food Packaging and Technology	• Temperature sensitive, bioreactive food labels, which decay to show when a product is past its shelf life; used in stores and homes • Smart kitchen app with reminders to eat purchased food before it expires, creates shopping lists, and keeps track of what is in the refrigerator • Web-based advice on food perishability • Smart refrigerator that helps manage groceries • Foodkeeper app • Self-adhesive food calendar labels that show at a glance when food was first opened, stored, or frozen
Nonprofit Organizations	• "Save the Food" public service campaign targeting moms and millennials; scalable to other consumer segments, regions, and time frames • Love Food Hate Waste national consumer awareness campaign; online and print. • Meal Prep Mate website to help consumers avoid over-purchasing and over-prepping food

continued

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TABLE C-3 Continued

Organization Type	Reduction Activity
Federal, State, and Local Government Agencies	• Funding LeanPath software for businesses and institutions • Wasted food education in schools • Residential wasted food pilot programs • Websites, media campaigns, and toolkits • Waste audits • Cookbook and smart food tips developed by partnerships among local governments, the U.S. Environmental Protection Agency and local restaurants and grocers

SOURCES: Data from U.S. Department of Agiculture Food Loss and Waste 2030 Champions; ReFED; Further with Food.

REFERENCES

Bellemare, M.F., M. Cakir, H.H. Peterson, L. Novak, and J. Rudi. 2017. On the measurement of food waste. *American Journal of Agricultural Economics* 99(5):1148-1158.

Gillick, S., and T.E. Quested. 2018. *Household Food Waste: Restated Data for 2007-2015*. WRAP.

Gorski, I., S. Siddiqi, and R. Neff. 2017. *Governmental Plans to Address Waste of Food*. Available: https://clf.jhsph.edu/sites/default/files/2019-01/governmental-plans-to-address-waste-of-food.pdf.

Hanson, C., B. Lipinski, K. Robertson, D. Dias, I. Gavilan, P. Greverath, S. Ritter, J. Fonseca, R. VanOtterdijk, T. Timmermans, J. Lomax, A. Dawe, V. Berger, M. Reddy, D. Somogyi, B. Tran, B. Leach, and T.E. Quested. 2016. *Food Loss and Waste Accounting and Reporting Standard*. Available: https://flwprotocol.org.

ICF. 2016. *Massachusetts Commercial Food Waste Ban. Economic Impact Analysis*. Available: https://www.mass.gov/doc/massachusetts-commercial-food-waste-ban-economic-impact-analysis/download.

McDermott, C., D. Elliott, A. Johnson, K. Hunter, and C. de Venecia. 2018. *2017 Oregon Wasted Food Study: Residential Sector Waste Sort, Diary, and Survey Study*. Available: https://www.oregon.gov/deq/mm/Documents/ResKitchenDiarySurvey.pdf.

Moreno, L.C., T. Tran, and M.D. Potts. 2020. Consider a broccoli stalk: How the concept of edibility influences quantification of household food waste. *Journal of Environmental Management* 256:109977.

Nicholes, M.J., T.E. Quested, C. Reynolds, S. Gillick, and A.D. Parry. 2019. Surely you don't eat parsnip skins? Categorising the edibility of food waste. *Resources, Conservation & Recycling* 147:179-188.

Östergren, K., J. Gustavsson, H. Bos-Brouwers, T. Timmermans, O.-J. Hansen, H. Møller, G. Anderson, C. O'Connor, H. Soethoudt, T. Netherlands, T. Quested, S. Easteal, A. Politano, C. Bellettato, M. Canali, L. Falasconi, S. Gaiani, M. Vittuari, F. Schneider, and B. Redlingshöfer. 2014. *FUSIONS Definitional Framework for Food Waste. Full Report*. Available: https://www.eu-fusions.org/phocadownload/Publications/FUSIONS%20Definitional%20Framework%20for%20Food%20Waste%202014.pdf.

Quested, T.E. 2019. *Guidance for Evaluating Interventions Preventing Household Food Waste. Refresh Report*. Available: https://eu-refresh.org/guidance-evaluating-interventions-preventing-household-food-waste.

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Roodhuyzen, D.M.A., P.A. Luning, V. Fogliano, and L.P.A. Steenbekkers. 2017. Putting together the puzzle of consumer food waste: Towards an integral perspective. *Trends in Food Science & Technology* 68:37-50.

Spang, E.S., L.C. Moreno, S.A. Pace, Y. Achmon, I. Donis-Gonzalez, W.A. Gosliner, M.P. Jablonski-Sheffield, M.A. Momin, T.E. Quested, K.S. Winans, and T.P. Tomich. 2019. Food loss and waste: Measurement, drivers, and solutions. *Annual Review of Environment and Resources* 44(1):117-156.

Stefan, V., A.A. Tudoran, E. van Herpen, and L. Lahteenmaki. 2013. Avoiding food waste by Romanian consumers: The importance of planning and shopping routines. *Food Quality and Preference* 28(1):375-381.

Thompson, F.E., and A.F. Subar. 2001. Dietary assessment methodology. In *Nutrition in the Prevention and Treatment of Disease*, C.L. Rock and E.R. Monsen, Eds. San Diego, CA: Academic Press. Pp. 3-30.

Tostivint, C., K. Östergren, T.E. Quested, H. Soethoudt, A. Stenmarck, E. Svanes, and C. O'Connor. 2016. *Food Waste Quantification Manual to Monitor Food Waste Amounts and Progression*. Available: http://www.eu-fusions.org/phocadownload/Publications/Food%20waste%20quantification%20manual%20to%20monitor%20food%20waste%20amounts%20and%20progression.pdf.

van Herpen, E., I.A. van der Lans, N. Holthuysen, M. Nijenhuis-de Vries, and T.E. Quested. 2019. Comparing wasted apples and oranges: An assessment of methods to measure household food waste. *Waste Management* 88(88):71-84.

Visschers, V.H.M., N. Wickli, and M. Siegrist. 2016. Sorting out food waste behaviour: A survey on the motivators and barriers of self-reported amounts of food waste in households. *Journal of Environmental Psychology* 45:66-78.

Xue, L., G. Liu, J. Parfitt, X. Liu, E. Van Herpen, A. Stenmarck, C. O'Connor, K. Östergren, and S. Cheng. 2017. Missing food, missing data? A critical review of global food losses and food waste data. *Environmental Science & Technology* 51(12):6618-6633.

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Appendix D

Interventions to Reduce Food Waste at the Consumer Level: Examples from the Literature

This appendix presents examples of selected studies that the committee reviewed to assess the effectiveness of interventions to reduce food waste at the consumer level. To provide context for the examples, which are presented in boxes D-1 through D-13, the text from Chapter 4 that summarizes each intervention type is repeated here. At the end of the examples, Table D-1 summarizes all of the intervention studies, grouped by one of two tier levels and setting. Tier 1 studies met four criteria: an intervention was implemented; wasted food was measured; causal effect can be attributed; statistical analysis was adequate; tier 2 studies failed to meet at least one of the four criteria. The settings in the studies were universities, schools, restaurants, retail establishments, and households.

The studies in this appendix are organized by type of intervention, paralleling the structure in Chapter 4. Interventions were selected for description in the boxes based on their ability to inform understanding of the intervention type or to provide ideas for future research and interventions. Most studies include more than one intervention type, and in a few cases the committee opted to discuss a study twice, highlighting different aspects of it in separate examples.

Table D-1 provides a comprehensive overview of the studies meeting our inclusion criteria, though not all of them are covered in the boxes; the table also includes a handful of modeling studies. Although they are based on assumptions and less on empirical data, modeling studies are useful in that they explore not only the effect of interventions on wasted food, but

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also effects on other variables of interest. Therefore, they can be particularly well designed to explore potential systems-level effects. Description of the literature search process can be found in Appendix B.

The summary and conclusions from the committee's review is presented in Chapter 4, which also presents the criteria that the committee used to assess the quality of the studies and to group by tier levels.

APPEALS

Appeal interventions encourage consumers to change their behavior to achieve a social benefit. Explicit appeals, which request action directly, are distinct from implicit appeals, which do not make a request. Implicit appeals may be based on a presumption that the facts will tap into existing attitudes or values, or may serve as prompts to action by raising awareness. Explicit appeals build on those mechanisms, and also activate the human tendency to respond to requests, particularly when they align with values, when the requestor is valued, or when something is owed to the requestor (reciprocity). Twenty-five of the 64 studies reviewed by the committee included appeal interventions, including 13 which used explicit appeals (Box D-1), 3 which used implicit appeals (Box D-2), and 9 that used both and other intervention types (Box D-3). The largest number of interventions presented signage or other messaging in food service venues, often in universities. Other interventions provided messages directly to study participants, or engaged participants in creating messages; one pair of studies involved delivering messages to the general public.

One tier 1 study (Ellison et al., 2019; United States) found a null effect for the appeal component, and one found an overall null intervention effect (Liz Martins et al., 2016; Portugal), but it was not possible to isolate the appeal component. All but three of the tier 2 studies found statistically significant impacts, with the magnitude of effect varying. A few tier 2 studies involved comparing appeal interventions with other types, such as providing information (Collart and Interis, 2018, United States), and feedback (Whitehair et al., 2013, United States) with results favorable to appeal interventions. In at least a quarter of the studies it was not possible to disentangle the results of the appeal intervention from those of other interventions included in the study. Few studies looked at maintenance of impact across time.

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BOX D-1
Explicit Appeals

No tier 1 study relied solely on explicit appeals, but they were a frequent ingredient in studies using multiple communication approaches jointly, including in Ellison et al. (2019; United States), a tier 1 study in which posters at dining hall entrances and in serving areas urged students to reduce plate waste in the one of the university's all-you-care-to-eat buffets. Although this study involves an intervention that includes information about the social implications of wasted food that might be expected to engender feelings of guilt or shame and therefore a reduction in food waste, no effect size was reported. A question remains about whether other elements of the intervention, including information that wasted food is used to create energy, could induce licensing* by patrons, countering any feelings of guilt and resulting in no significant food waste reduction.

Whitehair et al. (2013, tier 2, United States) compared a direct appeal to avoid wasting food with one that was supplemented with feedback (e.g., waste statistics tailored to the campus). These appeals were communicated via posters near ordering points and eating areas in a university cafeteria featuring an all-you-care-to-eat buffet. They found that the appeal alone was associated with a 15 percent reduction in waste and that the feedback intervention did not increase the effect.

Another set of explicit appeals requested diners to reduce portions or take less food. Such interventions need to provide sufficient motivation to overcome any negative feelings triggered by a sense of scarcity, and accordingly, many of the studied interventions supplemented the calls for action with other motivational strategies. Two tier 2 interventions had contrasting effects. Kuo and Shih (2016) presented information in a Taiwanese campus restaurant encouraging diners to avoid overeating and avoid wasting food, which resulted in only a 1 percent reduction in plate waste. In contrast, in a Portugal university canteen, using a similar strategy, Pinto et al. (2018) observed a significant 15 percent reduction in their waste consumption index. Kallbekken and Saelen (2013, tier 1, Norway) went further, testing an intervention explicitly designed to override the potential scarcity associations of portion reduction by posting a sign encouraging patrons to take multiple trips to a buffet rather than taking a large amount at once. They found a 20 percent reduction in waste compared to control locations, suggesting the potential benefit of such an approach.

While most appeals targeted pre-identified values, Graham-Rowe et al. (2019, tier 2, United Kingdom) tapped into the values subjects identified as most important to them personally. The authors asked subjects to identify these values ("self-affirmation" treatment), and to both identify these values and indicate how they had previously demonstrated them ("integrated self-affirmation" intervention). They also provided subjects with information about the negative effects of wasting food and tips for waste reduction. This self-affirmation intervention was associated with a significant reduction in self-reported discards, potentially driven by reminding consumers of themselves as ethical actors, though the integrated self-affirmation intervention yielded no significant reduction.

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BOX D-1 Continued

Another explicit appeal type involved mobilizing guilt and shame. Jagau and Vyrastekova (2017, The Netherlands, tier 2) used prospect theory to design an intervention in which waste would be associated with guilt and shame, and thus a sense of loss. Specifically, they compared a poster asking patrons to take smaller portions at the buffet if less hungry in order to reduce waste (a call to action intervention) against a poster with a red sad face linked to a picture of wasted food. While the impact was small, they found that about twice as many consumers accepted smaller portions during the intervention period, despite paying the same price. They did not assess whether these smaller portions affected waste levels.

*A licensing effect occurs when a prior normatively desirable behavior boosts people's self-concepts, thus reducing negative self-attributions associated with subsequent behaviors that may not align with norms (Khan and Dhar, 2006).

BOX D-2
Implicit Appeals

Multiple implicit appeals used presentation of facts regarding negative impacts of wasted food to advance motivation to avoid waste. For example, when Qi and Roe (2017, tier 1, United States) provided diners with information about the social impacts of wasted food prior to ordering their meals (e.g., environmental damages and reductions in food security), diners wasted 77 percent less food in their subsequent meals compared with diners who received information about financial literacy. Longer term impacts were not assessed. One potential unintentional effect of one of the elements of this intervention was noted in the form of licensing (see footnote in Box D-1). Although after receiving information about the social implications of wasted food the amount of waste declined significantly, the waste reduction was significantly less (only 28 percent) for those patrons who also received information that wasted food would be composted. This suggests that in this context the introduction of composting services may evoke licensing on the part of patrons, creating justification for discarding food.

Other interventions skip the negative frame and simply seek to motivate change based on awareness of waste or quantities wasted; these are based on a presumption that consumers implicitly dislike waste and will want to reduce it when they know about it. For example, Stockli et al. (2018, tier 2, Switzerland) invoked preexisting consumer attitudes toward waste by presenting table placards in a pizza parlor highlighting the quantity of waste in restaurants. The cards asked patrons to request boxes for leftovers, resulting in more than a doubling of box requests compared to the control condition (55 percent vs. 25 percent). There was no measurement of how much of the pizza was then wasted at home.

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BOX D-3
Appeals (and Other Approaches) to Motivate Purchase of Suboptimal Products

Five tier 2 studies in the committee's review tested approaches to convincing consumers to purchase products that might not otherwise be sold, such as so-called "ugly fruits and vegetables" or items close to expiration dates. These interventions mobilize consumers to prevent waste earlier in the food chain, rather than reducing waste at the consumption level. Consumer barriers to such purchases include perceptions of quality and questions regarding likelihood of consuming them at home before spoilage. The reviewed studies commonly combined explicit and implicit appeals with other intervention approaches in order to address these barriers, including financial interventions, information, and nudges, such as conveying credence values (e.g., authenticity) to the foods.

The findings were mixed. Results within studies varied by food type and demographics. Two studies found that altruistic messages framed around sustainability or food waste were more effective in increasing purchasing than those framed around price (and, in one case, taste) (Aschemann-Witzell et al., 2018, Uruguay; Rohm et al., 2017, Norway), while one of them found that altruistic messages were equally as effective as communicating about price and organic production (Aschemann-Witzell, 2018, Denmark). A third study, Collart and Interis (2018, United States), found that providing information about the waste of food and its environmental implications increased consumer willingness to pay for food past its "best before" date, while clarification of the label meaning alone did not. The last study in this group (van Giesen and de Hooge, 2019) found that while the sustainability frame was effective, even more impactful among Dutch and Italian consumers was framing suboptimal appearance as a sign of "authenticity" (e.g., a sign stating, "Directly from the tree: apples with natural shapes!").

ENGAGEMENT

Engagement interventions change psychological processes by engaging the consumer in, for example, setting goals, establishing implementation intentions, making a commitment, or increasing mindfulness toward the target behavior. Some examples of interventions are in Box D-4. Twelve studies (six in tier 1) feature such interventions, which are often multifaceted, operating through multiple drivers. Thus, the results of this type of intervention may be manifested in a variety of ways. These interventions have a mixed record in delivering significant reductions in food waste, which makes it difficult to provide a summary evaluation. For example, engagement interventions delivered in the home included diverse mechanisms: systematic engaging individuals to reconsider household food routines (Devaney and Davies 2017, tier 2, Ireland); providing tools to support changes in meal planning or preparation (Romani et al., 2018, tier 1, Italy);

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and using gamification to accelerate and deepen learning about wasted food (Soma et al., 2020, tier 1, Canada). Several food service interventions were also comprehensive, involving both food service personnel and patrons (Strotmann et al., 2017, tier 2, Germany) or both food service personnel and student customers (Prescott et al., 2019, tier 1, United States).

The results of these studies suggest that interventions aimed at reprogramming base processes that drive food waste hold promise, but the lack of consistent reductions implies that formulating the multiple elements common to this approach may be difficult. Furthermore, the complex and multifaceted nature of these interventions impedes assessment of which individual strategy or subset of strategies drives efficacy.

SOCIAL COMPARISON

Social comparison interventions operate on principles of social influence. Some examples of interventions are in Box D-5. Twelve studies, all tier 2, included such interventions. The interventions studied were diverse, focusing on social desirability, public commitment, social media communications, communication of social norms, food sharing, and such situations as workshops in which a peer group might influence behavior. The authors of only three of these studies provide quantitative results that make it possible to distinguish the effects of the social comparison intervention from those of other interventions in the study. Two of these three focused on restaurant leftovers. Stockli and colleagues (2018, Switzerland) and Hamerman and colleagues (2018, United States) found that messages designed to invoke social norms (i.e., saying a majority of patrons request to take food home) were not more effective than informative messages. Hamerman and colleagues (2018) found that study participants were significantly more likely to request to take home leftovers when they envisioned dining with friends versus dining with someone they wanted to impress. Five of the studies used qualitative or mixed methods approaches, with all but one suggesting that social comparison was beneficial in preventing waste. Findings from Lazell (2016, United Kingdom) echo those from Hamerman et al. (2018 United States) suggesting that the effectiveness of social comparison interventions can depend on participants' views about what behavior is normative, and about the social groups with which they are comparing themselves.

Overall, the evidence regarding social comparison interventions is inconclusive, and the research suggests a need for nuanced intervention development and careful selection of social groups for comparison and messaging.

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BOX D-4
Engagement

Liz Martins et al. (2016, tier 1, Portugal) engaged students in one elementary school and teachers at a matched elementary school. For the students, the intervention included engagement in menu planning and creating posters, in addition to an informational educational intervention and rewards (stickers) for students who did not waste food on a designated day. For teachers, the engagement occurred through a discussion session on causes and encouragement to model behavior, in addition to building motivation through social comparison (providing the school's waste statistics) and providing informational flyers to the teachers. The interventions overall had mixed results, with reductions in discards ranging from 0 to 40 percent, and with some reaching statistical significance. While it is not possible to disentangle the effects of engagement from the other approaches included, the study does suggest an approach meriting further research and highlights the importance of partnering with schools to introduce interventions.

Prescott et al. (2019, tier 1, United States), used social interactions and shared values to promote waste reduction as part of a community-based research approach that engaged multiple partners, including the participating school district. Specifically, the multifaceted intervention included sixth-grade curriculum that leveraged student interactions through group projects and voting on student-developed project posters designed to nurture shared values, including the reduction of wasted food. The intervention, which also included personalized and group feedback (students estimating their own waste during school lunches and their classrooms' aggregate waste), led to a significant reduction in salad bar waste compared with the control group.

Soma et al. (2020, tier 1, Canada) implemented a multiarm randomized control trial in which each arm takes a different approach to providing information to respondents about the importance of reducing waste and how to reduce wasted food. One arm featured a relatively passive provision of information, including a booklet on enrollment, refrigerator magnets prompting participants to follow the waste-minimizing storage advice printed on the magnet, and regular informational emails to participants. Participants in another arm received all this information and were also invited to participate in a sequence of community-based workshops on reducing wasted food. A third arm, involving gamification, featured all the information from the first arm but engaged participants in learning the information with online quizzes where correct responses were rewarded with points and prizes. Waste audits revealed a marginally significant improvement among households in the gamification arm compared with a control group after the intervention, but no significant differences among the other two arms. Analyses found that few participants attended the community workshops and that participants in the gamification arm who engaged in the online quizzes reduced waste the most.

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BOX D-5
Social Comparisons

Stockli et al. (2018, tier 2, Switzerland) designed a controlled study at a pizza parlor to explore the circumstances that would encourage customers to request a leftover bag. This study found that messages designed to invoke social norms (i.e., saying a majority of patrons request a leftover bag) did not increase the requests for leftover bags over informative appeal messages. (Note, this study is also described in the Appeals section, above). In Hamerman et al. (2018, tier 2, United States), customers were asked to envision dining in a restaurant with others and consider taking leftover food home. This study found that participants were significantly more likely to request to take home leftovers when envisioning dining with friends versus dining with someone they wanted to impress.

Schmidt (2016, tier 2, Germany) leveraged goal setting with a public commitment. In this study, participants were randomly assigned to food waste prevention behaviors based on self-reported actions or assigned to a control group. The treatment group was asked to set goals and commit publicly to performing the assigned actions. All participants self-reported adherence about 4 weeks later: the experimental group reported a significant improvement in target behaviors versus the control group. However, attrition was high; only 43 of 108 experimental participants took the follow-up test

Several other tier 2 studies explored technology-enabled tools that linked small groups of people in order to reduce wasted food. Comber and Thieme (2013, United Kingdom) deployed web-linked cameras in study participants' waste bins (bin cams), which provided feedback to the participant and to linked groups of individuals on the amount of waste generated. The technology operates on behavioral drivers, including enhanced feedback about waste and group norms and accountability concerning waste. The authors concluded that the technology provided social pressure that induced participant shame when food was wasted, which could yield an effective internal motivation for change. Sintov et al. (2017, tier 2, United States) found no change in self-reported food waste reduction behaviors among households randomly assigned to part of an in-home composting intervention undertaken in cooperation with the local sanitary district, where they also received weekly messages about the level of food waste separation in their community. These results suggest that promotion of food composting does not necessarily result in greater waste of food.

FEEDBACK

Feedback interventions shape targeted behaviors by providing information that reinforces or corrects those behaviors. Some examples of interventions are in Box D-6. Seven of the studies reviewed (three tier 1) featured feedback interventions, largely as part of multifaceted interventions implemented in food service settings. Thus, it was difficult to identify the independent impact of the feedback strategies. A common strategy was to offer cafeteria patrons feedback concerning the average waste created by other

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BOX D-6
Feedback

The feedback interventions we reviewed all combined this approach with other strategies, and thus it was not possible to identify the distinct effects from the feedback. Feedback interventions are featured in the textboxes as part of other intervention types (see e.g., Comber and Thieme, 2013 under social comparisons; Ellison et al., 2019 under appeals; Liz-Martins et al., 2016 under engagement; Prescott et al., 2019 under engagement; Whitehair et al., 2013 under appeals).

patrons, although studies using such strategies as part of a multifaceted intervention revealed little success. Personalized feedback, often generated for elementary and middle school students in cafeteria settings as part of a multifaceted intervention, showed some statistically significant effects (e.g., Liz Martins et al., 2016, tier 1, Portugal; Prescott et al., 2019, tier 1, United States). Feedback delivered among different food service worker stations within a large hospital facility showed promise as part of a multifaceted intervention that significantly reduced waste (Strotmann et al., 2017, tier 2, Germany). And a qualitative assessment of the use of home cameras to track waste suggests that such approaches could stimulate waste reduction by invoking feelings of shame (Comber and Thieme, 2013, tier 2, United States). Overall, feedback interventions have a mixed record, with weaker effects when feedback is not individualized.

FINANCIAL INCENTIVES

Interventions providing financial incentives alter the monetary consequences of behaviors that can influence the amount of food consumers waste. One tier 1 study in South Korea found that financial penalties that increase with amount of wasted food generated at the household level are more effective at reducing the amount of wasted food than financial penalties tied to community level waste amounts (Lee and Jung, 2017). It has been well documented that overall household waste disposal (food plus nonfood waste) declines when households are forced to pay more for additional amounts of waste (Bel and Gradus, 2016). Nine studies (all tier 2) featured financial interventions. Some examples are in Box D-7. Most involved comparing the effects of retail price reductions with those of other approaches used to encourage consumers to purchase suboptimal (ugly or expired) food that might otherwise be wasted. These studies yielded statistically significant evidence that price reductions can increase purchase intentions. However, alternative motivational approaches, such as highlighting

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BOX D-7
Financial Incentives

Discard Penalties

Two tier 2 studies assessed impacts of assigning financial penalties for discarding food in buffet restaurants, and they showed differing results. In the United States, Chen and Jai (2018) used an online survey featuring a hypothetical buffet setting to compare the impact of messages in which consumers were threatened with a penalty for leaving excess food with altruistic messages themed around environment. They found that neither message influenced behavioral intentions, though the environmentally focused message was associated with greater positive attitudes toward preventing waste. By contrast, Kuo and Shih (2016), using table tent messages stating that a fine would be imposed on patrons who discarded too much food, induced a sizable reduction in waste in a university canteen in Taiwan, though a message simply encouraging less waste had little effect.

Retail Marketing Schemes

Retail marketing schemes, such as "buy one, get one free," nudge consumers toward excess purchasing, due to the desire to get a good deal. LeBorgne et al. (2018, tier 2, France) sought to understand consumer responses to alternate promotion schemes that spread out the benefit so that perishable food (cheese, bread) might be less likely to be wasted. In this online survey of French consumers, consumers perceived that discounts giving multiple units of a perishable good (e.g., buy two, get one for free), would lead them to waste more than otherwise. An alternative discount approach in which they could get the additional items a week later avoided the consumer concerns about increased waste. In open-ended responses, most participants were skeptical about retailers' and their own follow-through on the "free next week" scheme. Promotions perceived to increase waste were significantly less attractive to participants. Future studies could include components to provide reassurance and to compensate for the delay in benefit. A similar finding comes from another survey where participants were asked about purchasing preferences at a hypothetical retailer (Petit et al., 2019, tier 2, United States). The study found that package size affected the anticipated food waste for perishable products among consumers, which was found to mediate purchasing intentions. The study also found that priming individuals with information about the consequences of food waste reduced their preferences for bonus packs.

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the environmental consequences of food waste, often yielded changes similar to those seen in purchase intentions or enhanced the effectiveness of price discounts.

Two studies focused on quantity (e.g., large pack or multipack) (Le Borgne et al., 2018, tier 2, France; Petit et al., 2019, tier 2, United States). These studies showed that giving consumers information about how such deals can translate to greater waste had less effect on purchase intentions relative to simply lowering unit costs for certain foods. Two studies in food service settings showed mixed results when comparing the efficacy of imposing fines for excessive plate waste with that of emphasizing environmental benefits to reduce plate waste (Chen and Jai, 2018, tier 2, United States; Kuo and Shih, 2016, tier 2, Taiwan).

Overall, financial incentives are a promising way to discourage behaviors that are precursors to food waste and to increase motivation for overall home waste reduction. However, linking financial incentives to decision points specific to wasting food may prove difficult, and establishing efficacy and implementation feasibility will require considerable additional research.

NUDGES

Nudge interventions alter the choice architecture faced by consumers in a manner designed to encourage targeted behaviors without engaging conscious (reflective) decision making (see Chapter 1). The committee reviewed 24 studies (four tier 1) that involved such interventions, most of which addressed food service settings. The nudge interventions studied operated by means of diverse mechanisms, including shifting perceived quantity, altering appeal, or changing the default/easiest action. The interventions assessed in about 40 percent of the studies focused on shifting consumers' perceptions of quantity through changes to portion size, package size, plate size, or tray availability (see examples in Box D-8). Most of the studies found significant reductions in waste attributable to quantity manipulations, although only two such studies were tier 1. Three studies in the United States (Kim and Morawski, 2013, tier 1; Sarjahani et al., 2009, tier 2; Thiagarajah and Getty, 2013, tier 2) focused on removal of cafeteria trays, which limits quantity by making it more difficult for patrons in buffet settings to carry multiple plates. All three of these studies (plus several non-peer-reviewed) found significant reductions in plate waste. In contrast, one recent non-peer-reviewed literature study (Cardwell et al., 2019) found no effect.

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BOX D-8
Nudges that Shift the amounts of food served

The behavioral economics literature suggests that regardless of serving size, consumers may anchor their consumption to particular percentages of the amount served (Wansink and van Ittersum, 2013).

Portion Size

Three tier 2 studies of portion size are notable both because of confirmatory findings regarding the effect of portion sizes and because of further exploration of the acceptability of such interventions. Berkowitz et al. (2016, United States) examined the effects of offering reduced portion sizes in both a worksite cafeteria and an upscale restaurant. While they found relatively low frequency of selecting the reduced portion sizes (10-26 percent), plate waste was reduced by 41 percent per plate on average during the intervention, while food intake was reduced, and establishments saved money. Two other studies collaborated with university dining facilities to change portion sizes of French fries. Freedman and Brochado (2010, United States) engineered a sequential weekly decrease in portion size, up to a 50 percent reduction. They found a dose–response reduction in both waste and consumption, with waste dropping by 30 percent from the largest to smallest portion size and with 70 percent of diners not noticing a change. Vermote et al. (2018, Belgium) reduced French fries portions by 20 percent and served portions in small paper bags instead of porcelain bowls. They observed a 66 percent reduction in plate waste and a 9 percent reduction in consumption. Most students noticed the reduction and said the new portion size was adequate; however, only a third said they were open to a permanent shift.

Package Size and Promotions

A related type of nudge strategy to shift consumer opportunities to address the waste of food is changing the amount of food purchased at once in retail settings, via package size and promotional approaches. Two studies suggest that when consumers perceived a higher likelihood that a purchased product would be wasted, they were less willing to purchase it.

Petit et al. (2019, United States) assessed the impact of package size on the waste of food through three studies. The findings suggest that dislike of wasting food may create willingness to avoid larger packages and related promotional offers. The authors found, first, that with larger package sizes, consumers anticipated greater waste of products (described as near their expiration dates), and this anticipated waste played a mediating role in intention to purchase. They further found that when consumers were asked to read information about food waste, the effect was increased, leading to reduced interest in buying a larger package, even at half price. Lastly, their work suggests that estimation of food quantity is improved when food is partitioned into portions. This finding suggests that con-

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sumers fearing they may waste excess food might be less likely to purchase a multipack than a large package with the same amount of food in it—despite the fact that packaging the items separately might extend shelf life and prevent waste. Further research is needed to add depth to understanding of ways to shift mental imagery in packaging for waste reduction.

Plate Size

Plate size studies are premised on the idea that the size of a plate both communicates a social norm and affects perceptions of food quantity; this environmental cue would thus shift the opportunity to reduce waste. For example, Kallbekken and Saelen (2013, tier 1) collaborated with a hotel chain to experimentally reduce plate size in seven Norwegian hotel breakfast buffets and compared the amount of waste to buffets in 38 control hotels. This difference-in-difference study found about a 20 percent reduction in plate waste based on plate size reductions. Supporting evidence for the effect of plate size on wasted food comes from tier 2 studies, including Wansink and van Ittersum (2013, United States) who reported several linked studies exploring different aspects of the relationship between plate size and food waste.

Tray Removal

Two studies explored a related concept aimed at changing environmental opportunity factors, specifically, collaborating with cafeterias to remove serving trays. Tray removal studies rely on the idea that when consumers are forced to select only what they can carry, they will take less food. In a sample of 360 diners in one cafeteria, Kim and Morawski (2013, tier 1, United States) found a significant 32 percent reduction in plate waste for both lunch and dinner. Another study (Thiagarajah and Getty, 2013, tier 2, United States) yielded less dramatic findings: an 18 percent reduction in solid waste and a nonsignificant reduction in liquid waste. One non-peer-reviewed study conducted by a large food service provider (ARAMARK, 2008, United States) measured plate waste from more than 186,000 meals at 25 academic institutions during periods before and after trays were removed: the study found a 25 percent to 30 percent reduction in per-person waste on trayless days.

Importantly, however, a different study (non-peer-reviewed) by another large food service provider (Cardwell et al., 2019, United States) assessed the correlation between plate waste and tray availability at 11 different all-you-care-to-eat food service entities in the United States and found no statistically significant correlation. However, unlike the other tray availability studies discussed, this study did not assess interventions, but rather identified patterns across different entities with differences in tray availability. The lack of an intervention frustrates a clear causal interpretation and could imply several possible diverse interpretations. One possible interpretation is reverse causality: for example, locations where smaller meals and less waste are generated were more willing to remove trays. Another possible interpretation is acclimation: for example, patrons at locations where trays were removed acclimated to the absence of trays and improvised methods to acquire traditionally sized meals that led to waste amounts similar to locations with trays. The latter interpretation highlights the critical need for longitudinal research.

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Another 40 percent of studies involved altering the appeal of food with the intent of decreasing waste by encouraging increased consumption. Several tier 2 studies enhanced appeal directly by improving meal quality or better matching meal components to patron preferences. Box D-9 provides examples of those studies, the majority of which showed a significant reduction in waste for these interventions.

BOX D-9
Nudges that Shift Food Quality

Several interventions, all tier 2, altered food environments and provisioning with the aim of making food higher quality or more appealing. Their purpose was commonly to change quality (e.g., nutrition or taste) rather than reduce waste; however, because they used plate waste as an indicator of amount consumed, they can shed light on how such "food quality" interventions might alter discarding. In institutional settings, such as K–12 schools and hospitals, food quality is often criticized, choices are often few, and consumers often do not directly experience the cost of their food.

In the only nonschool study in this group, Kuperberg et al. (2008, Canada) performed a pilot study in collaboration with a pediatric hospital aimed at better aligning food options with patient preferences. They found that improving food quality and selection and reducing lag time from order to delivery were associated with an approximate halving of waste. Satisfaction, nutritional intake, and costs also improved, though staffing changes would be needed for full implementation, which would increase program costs.

Cohen et al. (2012, United States) collaborated with local schools to evaluate the effects of chef-provided training for school cafeteria staff to increase lunch healthfulness and palatability. In this study, post-intervention plate waste in two participating middle schools was compared against plate waste in matched controls, finding a significant difference in the percent wasted for carbohydrate-based side dishes, but no significant percentage difference in the plate waste of entrées. Students in intervention schools did eat more healthfully, increasing consumption of vegetables and acceptance of whole grains. Because intervention participants were not randomly selected and because no pre-intervention data were collected, the committee has less confidence in assigning the observed differences as a causal outcome of the intervention.

Two studies explored effects of the Healthy, Hunger-Free Kids Act of 2010. Cohen et al. (2014, United States) worked in four urban elementary and middle schools in a lower-income district. The study found a 17.7 percent reduction in amount of entrée wasted and 39.4 percent reduction in amount of vegetable wasted, with no significant change in fruit consumption. The study had a large sample size, but, as might be expected with a national policy, only pre- and post-intervention assessment without a control group was possible. The authors did

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not explore any theory regarding why waste decreased, making it difficult to draw conclusions regarding implications for future interventions. The second study (Schwartz et al., 2015, United States) focused on a single cohort of students from 5th to 7th grade in 12 randomly selected middle schools in an urban, low-income district. The authors found the same pattern of reduced percentages of vegetables and entrées wasted over time. Due to study design, the possibilities that changed consumption was due to aging, social desirability, or biased participation in later years could not be excluded.

Other studies, including two tier 1 studies (Ilyuk, 2018, United States; Williamson et al., 2016, United States) involved nudges to increase appeal less directly, including by altering the quality of the material of the plate used; providing priming messages to subtly enhance the self-esteem of customers considering the purchase of suboptimal foods; making purchasing require more effort to enhance the consumer's psychological ownership of food; and providing cafeteria meals after recess, when student appetite would be greater. Box D-10 provides examples of four of these studies, all of which found significant effects.

BOX D-10
Nudges that Indirectly Alter Appeals

Altered Plate Material Qualities

Williamson et al. (2016, tier 1, United States) explored how serving food on disposable or permanent plates might affect waste. This research tested and found significant support for the idea that subjects subconsciously associated a food's level of disposability with that of the plate material (automatic categorization). The theory was supported in both laboratory and field settings, for snack and meal foods, and with both professionals and high school students. In future research, the costs vs. benefits of less-disposable-seeming serving plates needs to be considered, including the environmental, social, and logistical (dishwashing), and financial costs and their intersection with materials with varying levels of compostability. There is also a need for deeper understanding of how serving plates might affect perceived satiety and for approaches to shaping nudge manipulations to meet both consumption and waste goals.

Self-Esteem Linkage

In another indirect nudge intervention aimed at shifting appeal, Grewal et al. (2019, tier 2, Sweden) explored a novel and potentially promising behavioral

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BOX D-10 Continued

intervention linking produce aesthetics and self-perception. They first performed experiments that convincingly supported their theory that confronting so-called "ugly produce" calls up subconscious negative self-perceptions; thinking of buying or eating it may cause us to link its suboptimality to oneself. They explored the potential of interventions that alter this dynamic through message intended to improve self-perception for those who purchase the produce. Through collaboration with a Swedish grocery retailer, they posted an in-store messages stating either "You are Fantastic! Pick Ugly Produce!" or "Pick Ugly Produce!": the first message was associated with a 93 percent increase in selection of unattractive apples and a 22 percent increase in willingness to pay over the second message. The research ruled out multiple alternative explanations, and it used retail and online samples. Further study of self-perception interventions seems warranted, including longer term follow-up. The committee notes that it is unfortunately easy to imagine such a simple manipulation becoming overused, which could lead to cynicism and reduced impact.

Increased Effort to Obtain Food

Ilyuk (2018, tier 1, United States) explored the idea that increased mental and physical effort invested in obtaining food could lead to a stronger sense of ownership and thus to reduced likelihood of waste. The author used scenario-based laboratory studies comparing onsite and online grocery shopping for the same items. She found that investing greater practical or psychological effort in obtaining a product led to a greater sense of psychological ownership of the product, which in turn was connected to reduced waste. It would be useful to further elaborate the types of tasks that shape the sense of ownership of food, the level and type of inconvenience needed to reduce waste, and how consumers might offset induced inconvenience (e.g., change to more convenient shopping modes). The costs and benefits of such inconvenience could then be considered to create optimized approaches.

Recess before Lunch

Bergman et al. (2004, tier 2, United States) examined whether scheduling recess before lunch could reduce waste and improve nutrient consumption, on the theory that when lunch happens first, children are eager to socialize and get outside and so may eat less and waste more. The research examined differences between schools with differences in practice and followed several similar studies starting in 1977. Focusing on grades 3-5 in two schools with a high percentage of students receiving free and reduced lunch, this study found 32 percent less wasted food in the school with lunch served after recess, in addition to improved consumption of multiple nutrients. As the study did not assess an intervention, it is not possible to know whether the difference reflects the order of meal and recess or other differences between the schools in the study.

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The remaining studies (all tier 2) involved forcing changes to consumers' default behaviors (see examples in Box D-11). Two studies focused on date labels, with one altering descriptive phrases (e.g., changing "sell by" to "use by") to stimulate different processing of date information (no effect) and the other removing dates to force different evaluation approaches for product freshness (significant reduction).

One study (Manzocco et al. (2017, tier 2, Italy) considered how lowering ambient refrigerator temperatures might help consumers discard less produce and elicited consumer-intended discard of salad packages that were maintained under different refrigeration conditions (see also below for modeling studies that highlight the potential benefits of improving refrigeration technology). Extending the time period at which food remains at peak quality is among the most promising approaches to preventing waste at all levels of the food supply chain, and such approaches have particular utility for helping consumers navigate scheduling shifts that prevent using purchased food when planned. Although considerable technological design effort exists in that space, such as packaging, including modeling studies assessing potential impacts, they are seldom tested in interventions that

BOX D-11
Nudges that Change Food Date Labels

Food expiration date labels (such as "best before") are frequently misconstrued as providing information about food safety, although this is true only for a small number of foods (labeled with "use by" under the voluntary food industry standard). Much attention has focused on the language used on labels, including the role of misunderstanding in promoting unnecessary discards. Wilson et al. (2017, tier 2, United States) found null effects of changing the date label phrase on intended discard of a variety of foods evaluated by laboratory respondents. Roe et al. (2018, tier 2, United States) explored the possibility of removing date labels altogether, finding that intended discard of milk lacking a date label by study participants declined by 28 percent.

A second line of research explored the potential to reduce discards by extending the window of time on the label. Yu and Jaenicke (2020) find a 10 percent reduction in milk purchases following the change in New York City milk date labeling regulations that resulted in printed package dates expanding from 9 days post pasteurization to about 15 days. Subsequent modeling suggested a commensurate 10 percent reduction in household waste of fluid milk. WRAP (Waste and Resources Action Programme) (2013, United Kingdom) developed a model calibrated from its unpublished work to explore how extension of the shelf-life date on milk would affect milk discards. Their model predicts that milk discard would decrease from about 8 percent to less than 1 percent if shelf-life dates were extended from 7 to 13 days.

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specifically assess the impact on consumer discards; and thus other studies did not qualify for this review.

Policies that ban organic waste from landfills can also change default behaviors (Sandson and Broad Leib, 2019) although none of the studies reviewed examined such interventions.

Overall, the empirical support of nudge interventions focused on shifting food quantity and appeal is the stronger than that for any of the other intervention types with statistically significant effect sizes being documented in multiple studies of this intervention type. However, the evidence is mixed, dominated by tier 2 studies, and limited in context (studies of nudges were primarily short-run evaluations carried out in buffet settings). Further, the potential for these interventions to be feasible needs to be considered in light of effects of the COVID-19 pandemic, such as how the closing of food service venues during the pandemic will affect other practices related to food.

INFORMATION

One of the most common and seemingly intuitive approaches to addressing food waste is providing participants with concrete advice aimed at helping them reduce their waste: a tool for action, such as knowledge or skills regarding how to reduce waste. This category is distinct from appeal and feedback interventions, which also provide forms of information; information interventions entail providing only "how-to" information. Intervention designs of this type are often rooted in the theory of planned behavior (see Chapter 1).

The committees' literature search identified 22 studies that included information interventions, three of which are tier 1 studies (see examples in Box D-12). The interventions studied were fairly evenly divided between household and food service settings. In most cases, the guidance provided included multiple how-to tips targeting different strategies for reducing food waste or preserving food longer. The information and tools provided were often designed to be proximate to the point of decision making (e.g., refrigerator magnets and food containers for storage decisions, spreadsheets for use when planning meals). Advice was provided in a variety of modalities, from pamphlets and information packets to films, signage, and social media.

In most cases, the information interventions paired advice with other interventions, such as calls to action, tracking, or communication of social norms. Thus in many of the studies (8 of the 22, including 2 of the 3 tier 1 studies (Liz Martins et al., 2016; Portugal; van der Werf et al., 2019, Canada), it was not possible to distinguish the effects of the information component itself. The third tier 1 study (Soma et al., 2020, Canada) showed

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a small effect for the information component when the intervention encouraged participants to engage actively with the information through quizzes with rewards, while passive participation or modes that required more coordination to achieve engagement (attending group workshops) failed to produce significant waste reduction.

Six of the tier 2 studies found significant positive effects that could be attributed directly to the information provision. One involved tailoring the information provided based on pretest results, a procedure that significantly improved outcomes (Schmidt, 2016, Germany). Two studies found null effects of the information provision (Ahmed et al., 2018, United States; Jagau and Vvrastekova, 2017, The Netherlands). In some cases, the effects measured reflected intermediate outcomes, such as knowledge. Qualitative studies generally found positive effects for providing information through such means as intensive small group sessions. The committee also reviewed two studies (tier 2) where a U.K. retailer implemented multiple informational and social approaches using communication techniques, with positive effects on food waste (Young et al., 2017, 2018). Several other reports of large-scale information interventions that had not been peer reviewed also suggested potential positive impacts for information interventions.

In summary, while some studies suggest significant effects may be achieved with simple informational interventions alone, other studies suggest null effects, and long-term impacts must be assessed. Additionally, as the public grows more knowledgeable about wasted food, the impact of informational approaches may be reduced.

BOX D-12
Information Interventions

One tier 1 study in Italy found striking impacts from a simple and low-cost intervention. Romani et al. (2018) simply asked participants to read an article communicating the importance of meal planning and then provided advice and a planning tool for doing so. The result was a significant 24 percent reduction 1 week following the intervention, with reduced waste mediated by planning behaviors. Longer term effects were not assessed. Kowalewska and Kollajtis-Dolowy (2018, tier 2) collaborated with Polish schools to implement an educational intervention with middle school students and their households. They reported that showing students four brief educational videos about food waste and its prevention, plus providing a leaflet to parents, led to a knowledge effect nearly twice that seen in households receiving only the leaflet. Some knowledge improvements persisted at 3 months follow-up. However, wasted food levels were not measured in this study.

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BOX D-12 Continued

An additional and more labor-intensive tier 1 informational intervention was carried out by van der Werf et al. (2019) in Canada at the household level. They presented a 2-week benefits-framed (saving money) multicomponent intervention aimed at building waste prevention literacy, rooted in the theory of planned behavior. Components included a mailed packet containing visual reminders (magnets) to post on refrigerators or freezers, a link to a website with details, five emails reinforcing campaign messages over 2 weeks, and a container to extend food shelf life. The intervention was associated with a 30 percent reduction in avoidable food waste—measured directly through waste collection. It was not possible to segment the separate roles of the different intervention components. It is possible that these strong effects from information studies will attenuate as public knowledge grows. Furthermore, as noted in the main text, other information studies have found null or weaker effects, and research on long-term effects is needed.

National Campaigns

Large-scale campaigns commonly focus on distributing materials and tools that can then be used by a variety of actors to inform consumers and organizations about wasted food and provide positive, easy-to-implement behavior solutions. For example, the "Love Food, Hate Waste" campaign, developed in the United Kingdom by WRAP, launched in 2007, includes an extensive suite of tools, including communication kits (i.e., social media assets, posters, leaflet, blogs, videos) that can be adapted by influencers, industry, and organizations related to promoting the value of food, the cost of food waste, and the positive behaviors to reduce wasted food. The campaign has engaged actors and has published lessons learned related to how to develop, conduct outreach activities, monitor, and research a successful campaign to reduce wasted food.

In the United States, the Natural Resources Defense Council (NRDC) and the Ad Council launched a national campaign in 2016, "Save the Food," with a multimodal approach (i.e., video, print, and digital messaging). While primarily based in information and appeal elements, the campaign also includes nudges, social comparisons, and other elements. Ongoing consumer surveys revealed that awareness about the campaign and about wasted food was higher after the campaign as was the percentage of people reporting reducing the amount of wasted food in the last 6 months.

It is important to note that large informational campaigns have only minimally been evaluated in the peer-reviewed literature, although their effectiveness has been reported in non-peer-reviewed assessments. One example is the 2012-2013 West London "Love Food Hate Waste" campaign, which estimated for 2007-2012, a 14 percent food waste reduction and a 1-to-8 return on investment.* However, those results were challenging to untangle from the concurrent economic recession. The success of such campaigns depends on many factors, including the ability to engage influential actors, the characteristics of the tools themselves, and the availability of human and financial resources for the campaign to be active and adapted to changes.

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Young et al. (2017, 2018, both tier 2, United Kingdom) presented a rare peer-reviewed study of a large informational campaign implemented at scale. The multicomponent project, implemented via intensive collaboration with a U.K. food retailer, combined multiple informational and social influence approaches reaching users of store social media and other communications, as well as on-site customers. Informational aspects of the intervention included a feature article in the store's magazine with expert tips, an e-newsletter feature on using leftovers, tips shared by social media users, and information about correct food storage. Across the study period, both exposed individuals and controls reported reduced discards, and no differential change was detected. While measurement and secular changes may have been a factor, it is also possible that the indirectness of contact, or the many factors competing for participant attention, also reduced impact.

*See: https://www.wrap.org.uk/sites/files/wrap/West%20London%20LFHW%20Impact%20case%20study_0.pdf.

MODELING STUDIES

While high-quality empirical evaluations are critical for providing robust recommendations concerning the effectiveness of interventions to reduce wasted food at the consumer level, studies that develop, calibrate, and simulate models of consumer behavior (modeling studies) can also provide important insights concerning the potential effectiveness of individual interventions or suites of interventions. Given the burden of implementation and tracking, most intervention studies focus on a single stage in the consumer process (e.g., purchase, home meal preparation, consumption, discard) rather than systems-level interventions. Modeling studies can provide insights into systems-level spillovers that might occur in response to interventions, including predictions concerning behavioral and organizational responses that occur at other points in the food supply chain and the associated costs and benefits. Modeling studies generally rely on empirical work for calibration, and hence the insights generated are circumscribed by the validity of those empirical efforts. Still, they are often critical in order to connect narrow and potentially fragmented empirical efforts into a systems vision that permits broader assessment and evaluation of interventions. Box D-13 describes the modeling studies the committee reviewed: unless otherwise mentioned, these studies did not feature primary data collection.

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BOX D-13
Modeling Studies

Belavina et al. (2017) simulated the revenue and environmental implications of two online grocery delivery business models: the subscription model, in which patrons pay an annual fee for unlimited grocery deliveries, and a per-order model, in which patrons pay a fee for each grocery delivery. Their simulations, which were calibrated for a variety of business and delivery requirement parameters, suggest that the subscription model will lead to less wasted food, as patrons will order more frequently and avoid stockpiling that often leads to waste, and that the accompanying environmental benefits from reduced food waste are greater than the additional environmental burdens triggered from additional vehicle trips.

Duret et al. (2019) simulated multiple interventions in the cooked ham supply chain that promote reduced food spoilage, including changes to home refrigerator temperature settings and insulation levels, to identify trade-offs between the amount of ham wasted, consumer exposure to elevated pathogen levels, and energy use. Their simulation suggests that reducing home refrigerator thermostat settings from 6° C to 4° C could reduce ham waste by about one-half and reduce exposure to high doses of foodborne pathogens by 68 percent while increasing energy use by only 9 percent. As noted above, a related effort by Manzocco et al. (2017) collected original data on consumer food discard intentions, which was used to simulate the consumer waste reduction potential from reductions in home refrigerator temperatures for iceberg lettuce.

Van Holsteijn and Kemna (2018) simulated the potential extension of food shelf life that would be possible from redesigning home refrigerators to feature multiple compartments with different ambient temperatures. They showed that average shelf life for a bundle of foods commonly found in homes could be extended by a factor of two to three from such a redesign that was then appropriately used by consumers in their homes.

Two studies used life-cycle assessment approaches to assess the tradeoff between reductions in wasted food due to delivered meal-kit options against other possible sources of environmental damage (e.g., increased packaging waste and transportation). Heard et al. (2019) found that for most of the meals considered, the meal-kit option provided less life-cycle impact per meal than meals prepared at home by consumers sourcing ingredients through in-person grocery purchases. Gee et al. (2019) assessed this same trade-off through a broader lens: considering a weekly rather than per-meal basis and considering upstream transportation required by meal-kit fulfillment centers. They found the waste reduction from meal kits did not offset the additional environmental impact from the additional packaging in their base scenarios. However, they suggested that if meal kits can induce fewer trips to the grocery store per week or rely on lower-impact packaging, then meal kits could yield fewer life-cycle damages than home-produced meals made with ingredients from traditional grocery store shopping. Life-cycle assessment is also evoked by Wikström et al. (2016) in their comparison of packaging alternatives for minced meat, where they calibrate trade-offs between the tendency for different packaging materials to reduce food waste and to be recycled.

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Hamilton and Richards (2019) deduced qualitative results from a stylized model of home meal production and food utilization, finding that commonly held beliefs (e.g., lower food prices lead to more wasted food, reductions in the cost of food utilization lead to less wasted food) need not hold and may have alternative relationships under certain consumer demand conditions (e.g., food demand is highly sensitive to prices).

WRAP (2013, non-peer-reviewed) constructed a discrete event simulation model focused on home milk waste, calibrated with previous empirical evidence collected by WRAP. This model replicates several findings from independent empirical studies (e.g., reductions in wasted milk as household size increases) and generates insights that are plausible but not independently validated from empirical studies (reductions in wasted milk for extensions in milk shelf life and increased refrigerator monitoring). Kandemir et al. (2019) extended these modeling efforts to include additional elements of the consumer experience (e.g., shopping module), additional food items (e.g., hard cheeses and yogurt), and additional interventions (e.g., introduction of smaller multipack products). Manzocco et al. (2017) conducted a similar modeling effort, where the authors leverage their original consumer data collection; they concluded that reducing home storage temperatures of lettuce from 12 degrees Celsius to 8 or 4 degrees could yield a 13 percentage point reduction in home lettuce waste.

Somkun (2017) develops a model that links in-home behavioral responses to package size to in-store inventory management to provide a rare look at the relationship between in-home and in-store waste generation. To be tractable, the model requires several strong assumptions (e.g., there is a single product with a one-day shelf life), but such assumptions permit an analyst to track how product size alters wasted food that occurs both in homes and at retailers, that is, how a particular package size could increase waste at home but decrease waste at the store (or vice versa).

Perhaps the broadest modeling study in this literature is offered by Chitnis et al. (2014), a study exploring system-wide rebound effects of food waste reduction efforts alongside other proenvironmental behaviors that households might undertake. The authors assessed the implications for greenhouse gas emissions from food waste reduction efforts by estimating from secondary data how the cost savings generated from food waste reduction efforts would be spent by households. They then compared the projected reductions in emissions from reduced food waste to the change in emissions created by the projected expenditure pattern facilitated by the household food budget savings. They concluded that savings in the food budget are very likely to be spent on items that provide little reduction (a large rebound) to a household's total contribution to greenhouse gas emission creation, particularly among the lowest-income households. Similar findings were observed in WRAP's econometric study (non-peer-reviewed) aimed at understanding impacts of their campaign (WRAP, 2013). Together, these two studies raise a concerning counterpoint to the intervention literature and potentially suggest a need for an even wider lens in constructing intervention approaches in order to prevent such rebound effects.

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TABLE D-1 Studies on Interventions to Reduce Food Waste at the Consumer Level, by Tier and Setting

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Setting: University				
Tier 1[b]				
Ellison et al., 2019 (United States)	Campaign had no significant effect on food waste but changed beliefs related to food waste	Multifaceted with four elements (5 weeks): • food waste's economic, environmental, and social consequences • how much food was wasted last week compared with a goal • ask each student to change behavior • list positive efforts (donation, digestion of uneaten food) undertaken by dining hall	Intervention Types • Appeals • Engagement • Feedback Drivers A-Knowledge C-Waste vs. other goals D-Lack of awareness/ monitoring E-Psychological distance	Unable to unpack individual effects of each intervention element

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Kim and Morawski, 2013 (United States)	Tray removal had a *significant* effect size on food waste	Removal of trays from the cafeteria (6 days)	Intervention Types • Nudges Drivers A-Knowledge	Exclusion of breakfast, which often features less waste, and could bias effect size upward; excludes patrons who did not use a tray even though one was available, which could bias effect size upward; does not measure long-run acclimation to trayless dining
Qi and Roe, 2017 (United States)	Both information interventions with buffet diners yield *significant reductions* in plate waste	2 x 2 (several sessions) intervention design: • information sheet about food waste and its impacts • information that the food waste from the meal would be composted rather than discarded	Intervention Types • Appeals Drivers C-Waste vs. other goals E-Psychological distance	Short-run assessment only; limited food menu items
Williamson et al., 2016 (United States)	More food served on disposable (i.e., paper) plates is wasted than when the same food is served on permanent (i.e., hard plastic) plates. This effect persists when instead of being served a fixed quantity of food, participants select the amount and type of food	Replacing paper with plastic plates in free buffet settings in five experimental conditions, two laboratory and three field studies: (1) classroom (2) online survey (3A) university dining hall (3B) university dining hall (3C) high school cafeteria	Intervention Types • Nudges Drivers A- Knowledge E-Psychological distance	Study at universities (3A and 3B) had different limitations: study 3A plate material was confounded with food options served; study 3B captured amount wasted but not amount taken; both featured small samples (n ~ 40); no study featured the same limitation and all converged to similar magnitude of effect size

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Tier 2[b]				
Chen and Jai, 2018 (United States)	Environmentally focused messages had a greater favorable influence on consumer attitudes toward food waste prevention than a threat-focused message; a higher level of perceived social corporate responsibility increased intentions to reduce food waste; perceived social corporate responsibility moderated the relationship between attitudes toward food waste messaging and the intention to reduce food waste	Information (3 months) in hypothetical buffet dining scenario (student and faculty survey) in a 2 x 2 intervention design: • message focus (help the environment vs. the threat of a fine) • source attribution (none vs. EPA)	Intervention Types • Appeals • Financial incentives Drivers A-Knowledge D-Lack of awareness/ monitoring E-Psychological distance I- Psychosocial factors	Criteria not met: wasted food not measured; other limitations: sample limited to university students and staff
Freedman and Brochado, 2010 (United States)	Portion size was positively correlated with consumption per diner and plate waste; total amount produced in the kitchen was positively correlated with plate waste	Intervention decreased the portion size of French fries (plate size was 88g and decreased through weeks 2-5)	Intervention Types • Nudges Drivers: A-Knowledge F-Dietary differences	Criteria not met: no control group

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Jagau and Vyrastekova, 2017 (The Netherlands)	Consumers were willing to pay the same price for less food more often during the campaign than before the campaign, but the approximated impact on food waste was not significant	Information campaign (3 weeks) with banners, posters, and a recommendation to ask for a smaller portion if consumers expect not to finish the meal portion; designed to avoid consumers' insufficient planning problem	Intervention Types • Appeals • Information Drivers A-Knowledge	Criteria not met: no control group
Kuo and Shih, 2016 (Taiwan)	Overall average plate waste was slightly reduced with the information intervention and reduced dramatically with the coercion intervention	3-week longitudinal design: • Baseline: first week, no intervention • Intervention 1 (week 2): information strategy (information encouraging patrons not to overeat and waste food) • Intervention 2 (week 3): coercion strategy (threat of a fine if too much food was left on table)	Intervention Types • Appeals • Financial incentives Drivers A-Knowledge D-Lack of awareness/ monitoring	Criteria not met: no control group; statistical significance not assessed

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Lazell, 2016 (United Kingdom)	The effects of the intervention were null due to insufficient usage of the intervention tool due to situational barriers	Mixed method study with surveys, semistructured interviews, focus groups, and an intervention (4 months): • a social media tool on Twitter that interrupted the linear process of consumers' consuming and throwing away food by allowing participants to send messages to inform others of food that would have otherwise been wasted within the study setting	Intervention Types • Social comparisons Drivers A-Knowledge I-Psychosocial factors	Criteria not met: no control group; wasted food not measured, statistical significance not assessed

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Manomaivibool et al., 2016 (Thailand)	The proportion of clean containers (no food waste) rose significantly; a bigger increase was seen among female students than among male students	Multifaceted design (5 days): • stickers with food ordering tips by food vendors • information cards on dining tables about resource use and environmental impacts in food production • other materials from FAO "save food" campaign, such as posters and banners with messages and images eliciting a proenvironmental norm • encouragement to increase the visibility of the actions via social media to students that took a course with practical tasks to prevent food waste	Intervention Types • Appeals • Social comparisons • Information Drivers D-Lack of awareness/ monitoring E-Psychological distance	Criteria not met: no control group; other limitations: cannot unpack individual effects of each intervention element

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Pinto et al., 2018 (Portugal)	A significant mean reduction in the waste consumption index and a significant reduction in unserved food in the kitchen	Multifaceted design (16 days): • display of informative posters in canteen reminding patrons to choose smaller portions if desired and not to accept food they knew they would not eat • students approaching their colleagues to inform them about social impact of food waste and how they could make a difference • parallel actions encouraging separation of organic and inorganic waste in the kitchen	Intervention Types • Appeals • Information Drivers D-Lack of awareness/ monitoring F-Dietary differences	Criteria not met: no control group; other limitations: cannot unpack individual effects of each intervention element
Sarjahani et al., 2009 (United States)	Removing trays in an all-you-can-eat cafeteria setting had a significant effect on food waste	Removal of trays from the cafeteria (3 days)	Intervention Types • Nudges Drivers A-Knowledge	Criteria not met: no control group; other limitations: data collected was limited to 3 days of the week

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Thiagarajah and Getty, 2013 (United States)	Removing trays in an all-you-can-eat cafeteria setting had a significant effect on solid food waste; it had a nonsignificant effect on liquid waste	Removal of trays from the cafeteria (2 weeks)	Intervention Types • Nudges Drivers A-Knowledge	Criteria not met: no control group
Vermote et al., 2018 (Belgium)	Smaller portion sizes resulted in a decrease in the total intake of French fries and the total plate waste.	Longitudinal design (2 weeks): Baseline: usual porcelain bowl of French fries served (+/-200 g) Intervention: replaced bowl with smaller volume paper bags (+/-159 g)	Intervention Types • Nudges Drivers A-Knowledge F-Dietary differences	Criteria not met: no control group
Whitehair et al., 2013 (United States)	The point prompt-type message resulted in a reduction in food waste; addition of a more personalized feedback-based message did not stimulate an additional change beyond that of the prompt message	Longitudinal design (6 weeks): Baseline: 2 weeks, no intervention Intervention 1: 1 week, posters and table tents displayed with the following text: "*Eat what you take. Don't waste food.*" Intervention 2: 1 week, same posters and table tents with detailed general waste statistics (feedback-based intervention)	Intervention Types • Appeals • Feedback Drivers A-Knowledge	Criteria not met: no control group

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Setting: School				
Tier 1[b]				
Liz Martins et al., 2016 (Portugal)	Two education interventions on soup and main dish waste in an elementary school showed mixed results: significant effects were observed in the short term for students and in the medium term for teachers	Multifaceted design (3 months) educational intervention for students and teachers: A. For children: • noted the social, economic, and nutritional consequences of food waste • identified most wasted items • helped plan menu to reduce food waste • created posters on food waste • gold stickers for students who did not wasted food on 'No Plate Waste Day'	Intervention Types • Appeals • Engagement • Feedback • Information Drivers D-Lack of awareness/ monitoring E-Psychological distance	Other limitations: cannot unpack individual effects of each intervention element

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B. For teachers:

- teacher discussion session on causes of food waste
- showed food waste statistics for the school and highlighted it was higher than average
- told of their role in influencing children's food waste behavior
- encouraged to model behavior at lunch
- given flyer about importance of food waste and strategies to reduce it

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Prescott et al., 2019 (United States)	Educational intervention for 6th graders with significant reductions of fruit and vegetable plate waste 5 months post-intervention; the extent of the reduction depended on food and point in time	Mixed methods with multifaceted design: • five lesson plans (~ 2 weeks) integrated into existing curriculum that met 6th- grade science standards, including units on food waste and school cafeteria waste • tasking students with estimating their personal lunch waste for 1 week and then aggregate and post class-wide results • created a poster about lessons from unit, selected best posters to hang in cafeteria during last month of intervention	Intervention Types • Appeals • Engagement • Feedback Drivers A-Knowledge D-Lack of awareness/ monitoring E-Psychosocial distance	Plate waste measurements over time not taken from identical menus; control group (7th and 8th graders) was older than treatment group (6th graders); treated classrooms required teacher to be willing to participate; cannot unpack individual effects of each intervention element .
Williamson et al., 2016 (United States)	More food served on disposable (i.e., paper) plates was wasted than when the same food was served on permanent (i.e., hard plastic) plates; the effect persisted when instead of being served a fixed quantity of food, participants selected the amount and type of food	Replacing paper with plastic plates in free buffet settings in five different experiments (two laboratory and three field studies): (1) classroom (2) online survey (3A) university dining hall (3B) university dining hall (3C) high school cafeteria	Intervention Types • Nudges Drivers A- Knowledge E-Psychological distance	Study 3C treatment occurred 1 month later than control measures though for the same menu items, but cannot rule out seasonal trend; no study featured the same limitation, and all converged to similar magnitude of effect size

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Tier 2[b]

Barnes and Warren, 2017 (United States)	After *MyPlate Food Group* books were read once a day for 2 weeks by teachers, changes in food consumption behaviors measured by food waste were not observed, but teachers indicated changes in the preschoolers' attitudes toward trying new foods	Preschool classroom reading (2 weeks) of *MyPlate Food Group* books concerning origins and benefits of certain food groups (grains, fruits, and vegetables)	Intervention Types • Engagement Drivers E-Psychological distance	Limited to 2- to 5-year-olds; insufficient power to detect differences; intervention was not geared toward reducing food waste
Bergman et al., 2004 (United States)	Plate waste was compared between two elementary schools: plate waste in the school where recess was scheduled before lunch was significantly less than when recess was scheduled after lunch	Intervention: change in practice (10 days) with recess after school lunch Control: recess before school lunch	Intervention Types • Nudges Drivers A-Knowledge F-Dietary differences	Criteria not met: no new intervention tested; rather, schools with preexisting differences in scheduling recess and lunch were compared; other limitations: no pre- and post-measurement as the scheduling of recess times had always differed between these two schools; no randomization of school to treatment
Cohen et al., 2014 (United States)	No overall significant difference in plate waste between intervention and control; significantly less plate waste for side items for intervention schools	Training of staff for 2 years and introduction of a healthier lunch in two Boston schools	Intervention Types • Nudges Drivers A-Knowledge	No measurement of plate waste pre-intervention

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Schwartz et al., 2015 (United States)	Increased consumption (less food waste) of entrée meals and vegetables; no significant changes in consumption of milk or fruit	Implementation (36 days) of the 2010 Healthy, Hunger-Free Kids Act required by USDA to update the nutrition standards of the National School Lunch Program; new policies were implemented in the 2012-2013 school year	Intervention Types • Nudges Drivers A-Knowledge_	Criteria not met: no control group
Chan et al., 2008 (United States)	There was no difference in consumption for the 50:50 blend or the refined wheat pizza crusts	Partially substitute white whole wheat flour for refined-wheat flour in pizza crust	Intervention Types • Nudges Drivers F-Dietary differences	Criteria not met: no control group; other limitations: study goal was not reducing food waste
Setting: Restaurant				
Tier 1[b]				
Kallbekken and Saelen, 2013 (Norway)	Each intervention resulted in a *significant* reduction in food waste	Two different interventions (6 weeks) • sign encouraging multiple trips to buffet • reduction of plate size	Intervention Types • Appeals • Nudges Drivers A-Knowledge I-Psychosocial factors	Other limitations: long-term effects not assessed

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Tier 2[b]

Berkowitz et al., 2016 (United States)	Food waste was significantly reduced in intervention compared with the baseline period; energy intake and intakes of total fat, saturated fat, cholesterol, sodium, fiber, calcium, potassium, and iron were significantly lower when both full- and reduced-size entrées were served in the worksite setting and in the restaurant setting compared with when only full-size entrées were served	Intervention (7 weeks): reduce and full size serving of food items at a noncommercial worksite cafeteria and a commercial upscale restaurant Control: only full-size entrées were offered for each entrée of the day	Intervention Types • Nudges Drivers A-Knowledge F-Dietary differences	Criteria not met: no control group

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Stockli et al., 2018 (Switzerland)	Diners who were prompted asked for leftover bags more frequently than controls; diners who were prompted with an informative and a normative message did not ask for leftover bags more frequently than those prompted with information only	Intervention design (6 weeks): • Intervention 1: table placards: "*Food waste happens in the restaurant too. A third of all foods are thrown away. 45% of waste occurs in households and restaurants. Please ask us to box your leftover pizza slices for takeaway*" • Intervention 2. informational plus normative intervention: placards on table: "*Our guests expect a reduction of food waste. A third of all foods are thrown away. 45% of the waste occurs in households and restaurants. The majority of our guests expect that the wasting of food is reduced. Therefore, many people ask us to wrap their pizza leftovers. Please ask us to box your leftover pizza slices for takeaway to avert food waste.*"	Intervention Types • Appeals • Social comparisons • Information Drivers A-Knowledge H-Marketing practices	Criteria not met: wasted food not measured; other limitations: food was limited to pizza

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Hamerman et al., 2018 (United States)	Envisioning dining with others who they wanted to impress led to greater perceived likelihood of taking home leftovers when the server proactively offered to wrap the leftovers versus when this did not occur; this difference did not hold true when participants imagined dining companions with whom they were comfortable	2 x 2 intervention design: • envision dining at a restaurant with a group of people whom they want to impress or with people with whom they were comfortable • envision the server offering to wrap the leftover to take home	Intervention Types • Social comparisons Drivers F-Different preferences/diets G-Inconvenience H-Marketing practices I-Psychosocial factors	Criteria not met: wasted food not measured; other limitations: questionnaire based, virtual restaurant
Wansink and van Ittersum, 2013 (United States)	Looking at the effect of dinnerware size on plate waste, Chinese buffet diners with large plates served more, ate more, and wasted more food than those with smaller plates; educational intervention had no impact on these results	Interventions: • large vs. small plates in a Chinese buffet • the effect of education (a 60-minute, interactive, multimedia warning on the dangers of using large plates in reducing the effect of plate size)	Intervention Types • Nudges • Information Drivers A-Knowledge F-Dietary differences	Subjects not randomized to plate sizes; small number of observations (N = 43)
Kuperberg et al., 2008 (Canada)	With room service, satisfaction increased, food costs decreased at breakfast and lunch, and reductions in waste occurred at all meals	Room service delivery system in a pediatric hospital compared with the standard a cold-plating tray delivery system where food is chosen 2 days prior and quality of the food is questionable	Intervention Types • Nudges Drivers C-Waste vs. other goals F-Dietary differences J-Built environment	Criteria not met: no control group

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Ahmed et al., 2018 (United States)	Intervention led to a nonsignificant reduction in total food waste with a large portion of waste attributed to post-consumer plate waste	Multifaceted interventions (1.5 weeks): • information-based (educational messaging) • technological solution (reduced portion size and smaller serving utensils)	Intervention Types • Appeals • Feedback • Nudges • Information Drivers A-Knowledge H-Marketing practices I-Psychosocial factors	Criteria not met: no control; other limitations: unable to unpack individual effects of each intervention element
Lorenz-Walther et al., 2019 (Germany)	Portion size reductions for target dishes were found to relate to lower levels of plate waste based on conscious perception, represented in smaller portion size ratings; effects from seeing information posters based on changed personal attitudes, subjective norms, and perceived behavioral control, but depended on how an individual reacts to the information (by only making an effort to finish all food or by making an effort and additionally choosing a different dish in the canteen); opposite effects on these determinants and consequently also on plate leftovers	Two interventions (2 weeks): • information on posters • the reduction of portion sizes Authors also analyzed how the display of information posters and the reduction of portion sizes effect personal, social. and environmental determinants in a structural equation model by applying data from online surveys and observations	Intervention Types • Appeals • Nudges • Information Drivers A-Knowledge H-Marketing practices I-Psychosocial factors	Criteria not met; no control; other limitations: disentanglement of effects of the two interventions relies on respondent survey results and statistical modeling

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Strotmann et al., 2017 (Germany)	The average waste rate in the residential home and in the hospital cafeteria were significantly reduced: in the hospital, the average waste rate remained constant; however, the average daily food provided and wasted per person in the hospital declined	A participatory approach in which the employees of a hospital, hospital cafeteria, and a residential home were integrated into the process of developing and implementing measures to counteract food waste	Intervention Types • Engagement • Feedback • Nudges Drivers A-Knowledge H-Marketing practices I-Psychosocial factors	Criteria not met: no control group; other limitations: unable to unpack individual effects of each intervention element
Setting: Retail Establishment				
Tier 2[b]				
Grewal et al., 2019 (Sweden)	Shoppers exposed to a positive self-esteem ad were significantly more likely to choose unattractive apples than those exposed to the control ad: within each advertising condition, shoppers exposed to the control ad message chose attractive apples more often than unattractive apples; in contrast, for shoppers exposed to the positive self-esteem message condition, the choice of attractive and unattractive apples was split evenly	2 x 2 intervention design: • in-store advertisements were rotated hourly between two conditions (positive self-esteem condition "*You are Fantastic! Pick Ugly Produce!*" vs. control "*Pick Ugly Produce!*") during regular store hours • Signage was displayed behind two unlabeled produce bins: one containing attractive apples and the other containing unattractive apples	Intervention Types • Nudges Drivers H-Marketing practices I-Psychosocial factors	Criteria not met: wasted food not measured (self-report only); other limitations: only short-run effects assessed

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Young et al., 2017 (United Kingdom)	Both the intervention and the control groups self-reported reductions in food waste; the use of social media did not change behavior as self-reported by consumers	Two interventions with messages to encourage reductions in food waste from the standard "Love Food Hate Waste" campaign; interventions differed in the communication channel, not the message: • use of retailer's Facebook pages to encourage its customers to interact, or • multifaceted intervention via two communication channels, the retailer's print and digital magazine and e-newsletter	Intervention Types • Appeals • Engagement • Social comparisons • Information Drivers A- Knowledge	Criteria not met: wasted food not measured; other limitations: control group not randomly assigned

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Young et al., 2018 (United Kingdom)	Both treatment and control groups reported reduced food waste significantly	Various interventions throughout 2 years with messages to encourage reductions in food waste from the standard "Love Food Hate Waste" campaign; interventions differed in the communication channel, not the message: • via an article in retailer's print and digital magazine • via a larger article in retailer's print and digital magazine • via an e-newsletter • via retailer's Facebook pages to encourage its customers to interact with each other • on-pack stickers designed to invoke norms with tips about how to make the most from selected perishable products • in-store events, challenging customers to reduce waste	Intervention Types • Appeals • Engagement • Social comparisons • Information Drivers A- Knowledge	Criteria not met: wasted food not measured (self-report only); control group not randomly assigned

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
van Giesen and de Hooge, 2019 (various countries)	Sustainability and authenticity positioning can motivate consumers to purchase suboptimal products, independently of their prices; respondents exposed to authenticity positioning reported higher quality perceptions than respondents exposed to sustainability positioning	3 x 3 x 2 intervention design in virtual retail store: three signs over suboptimal products: (1) sustainability- "*Embrace imperfection:Join the fight against food waste*!"; (2) authenticity- "*Naturally imperfect: Apples the way they actually Look!*"; (3) control with three prices (discount, moderate, discount, same price) and with two products (apples and carrots)	Intervention Types • Appeals Drivers H-Marketing practices I-Psychosocial factors	Criteria not met: wasted food not measured; other limitations: sample was biased as individuals were already caring for the environment; experiment was conducted in virtual retail store
Aschemann-Witzel, 2018 (Denmark)	Message on the sticker appealing to either a food waste avoidance or to a cost-saving motive did not significantly influence likelihood of choice; however, familiarity and perceived quality was important in whether suboptimal food would be purchased	2 x 4 intervention design in virtual retail store: two product qualities (optimal product vs. suboptimal product) and four messages on stickers: (1) *priced reduced*; (2) *fight food waste*; (3) *reduced item: lower price and save more*; and (4) *fight food waste* and *'lower price—save more*	Intervention Types • Appeals • Financial incentives Drivers H-Marketing practices I-Psychological factors	Criteria not met: food waste not measured; other limitations: experiment was conducted in virtual retail store

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Aschemann-Witzel et al., 2018 (Uruguay)	Communicating the budget saving did not increase choice likelihood of suboptimal product, but communicating the food waste avoidance increases choice likelihood, independent of the product type; when no messages were displayed, there were significant food category differences in choice likelihood	2 x 2 intervention design in virtual retail store (with four food products): two product qualities (optimal product vs. suboptimal product) and two messages on stickers (*Offer! Super saver!* or *Choose this product and help to reduce food waste*).	Intervention Types • Appeals • Financial incentives Drivers H-Marketing practices I-Psychological factors	Criteria not met: food waste not measured; other limitations: experiment was conducted in virtual retail store
Kawata and Kubota, 2018 (Japan)	Willingness to pay for reprocessed domestic and foreign Kara-age was 92.8 percent and 91.7 percent of the prices of regular Kara-age, respectively, showing the feasibility of selling reprocessed form of the product and reducing food waste in the supply chain	Surveys on willingness to pay for three choices: (1) regular Kara-age (i.e., made from fresh raw chicken), (2) reprocessed Kara-age (i.e., made from unsold raw chicken near its sell-by date), and (3) no buy	Intervention Types • Appeals Drivers H-Marketing practices I-Psychological factors	Criteria not met: food waste not measured; other limitations: experiment was conducted as a survey

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Del Giudice et al., 2016 (Italy)	The effect of certification on participants' willingness to pay was significant; the importance of providing footprint information was only observed for the baguette from the retailer with 1 percent food waste certified	An experimental auction to measure willingness to pay for the following choices: • purchasing baguette from retailer certified to reduce food waste by 10, 5, or 1 percent • moderating effect of information about carbon or water footprint	Intervention Types • Appeals Drivers H-Marketing practices I-Psychosocial factors	Criteria not met: food waste not measured; other limitations: related to the experiment being conducted as an auction; population was from undergraduate students who might be more aware than others of environmental effects of food waste
Collart and Interis, 2018 (United States)	Clarifying the meaning of date labels was insufficient to change preferences for food past its best-before date; when information about the environmental implications of food waste was provided, participants' willingness-to-pay for expired food increased, particularly for expired frozen or recently expired semi-perishable products	Participants were asked to choose between food products of varying perishability level at various dates before or after their best-before dates. Interventions: • education about the meaning of labels • same education plus information about the environmental implications of food waste	Intervention Types • Appeals • Financial incentives • Information Drivers B-Assessing risk I-Psychosocial factors K-Policy	Criteria not met: food waste not measured

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Le Borgne et al., 2018 (France)	Consumers' perceived probability of waste had a significant negative effect on consumers' attitude toward promotions and consumers' intention to choose perishable food products (cheese and bread) on sale; participants showed skepticism toward the "Buy Two Get One Free Later" offer.	Hypothetical product purchase setting to assess the impact of multiproduct sales tactics on intended food waste	Intervention Types • Financial incentives Drivers G-Everyday complexity H-Marketing practices	Criteria not met: food waste not measured; other limitations: statistical testing for intention to discard not clearly communicated; effects unclear

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Petit et al., 2019 (United States	Study 1 found that package size affects the anticipated food waste among consumers and that anticipating food waste mediated purchasing intentions, but only observed for perishable products; Study 2 found that priming individuals with information about the consequences of food waste made them more likely to focus on their anticipated food waste and thereby reduce their preference for bonus packs; Study 3 found that anticipated food waste decreased when small packages were sold partitioned, while it increases when large packages were sold partitioned	Consumer survey asking about hypothetical product purchases; four different studies: • the mediating role of anticipated food waste on consumers' purchasing intentions as a function of package size (large vs. small) • the mediating role of anticipated food waste on consumers' purchasing intentions as a function of package size and product perishability (2 x 2 study: package size and perishability)	Intervention Types • Appeals • Financial incentives • Nudges Drivers F-Dietary differences G-Everyday complexity H-Marketing practices	Criteria not met: food waste not measured

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- whether priming individuals with information about the consequences of food waste influenced their preference for bonus packs, 2 x 3 design: priming (food waste information vs. control) and quantity (an 8-cup package vs. a large promotion package of 8 cups plus 8 cups for free vs. a 16-cup package)
- whether large packs sold as individual units has an effect on anticipated food waste, 2 x 2 design: small vs. large package and partitioned vs. nonpartitioned package

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Setting: Household				
Tier 1[b]				
Ilyuk, 2018. Study 3 (United States)	Waste likelihood was higher when consumers purchased food items online than when they purchased them in a store	Participants were randomly assigned to one of three conditions: • in-store (individual selection), • in-store (prepackaged), • online produce purchase	Intervention Types • Nudges Drivers E-Psychological distance	Criteria not met: studies 1 and 2 did not measure actual waste; study 3 measured actual waste, but report did not quantify reduction and relied on university students
Romani et al., 2018 (Italy)	Information intervention led to a *significant effect size* in reducing food waste	Longitudinal study with information intervention to illustrate how to organize a weekly menu quickly and simply and a printable Excel file designed to support meal organization and preparation	Intervention Types • Engagement • Information Drivers A-Knowledge	Reliance on household food waste diaries, which are known for underreporting, and sample attrition of about 10 percent between baseline and post-treatment measurement

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van der Werf et al., 2019 (Canada)	Intervention led to a *significant reduction* in total food waste.	Multifaceted informational intervention in the form of a package designed to extend produce life with the following elements: (1) environmental and social impacts of wasted food; (2) local averages of amount and value of wasted food; (3) reduction tips, such as food planning and use of leftovers; (4) five emails sent over the course of 2 weeks to reinforce the messages	Intervention Types • Appeals • Engagement • Information Drivers A-Knowledge D-Lack of awareness/ monitoring E-Psychological distance	Unable to unpack individual effects of each intervention element
Soma et al., 2020 (Canada)	The passive group and the gamification group had higher self-reported awareness of food wasting and lower food wastage than the control group; waste audits found marginally significant differences between the gamification group and the control group and no difference between the other campaign groups and the control group in edible food wasted; frequent gamers were found to generate less edible food waste than infrequent gamers	Three different interventions: • A passive approach (a booklet with information on why food waste is a problem, tips to reduce food waste at home, and a prompt in the form of a fridge magnet with storage tips) • Information campaign plus a community engagement approach (community workshops) • Information campaign plus a gamification approach (online quiz game with points and rewards)	Intervention Types • Appeals • Engagement • Information Drivers A-Knowledge	

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Lee and Jung, 2017 (South Korea)	The Household-Based Food Waste Charging System can reduce more food waste than the design where all residents pay the same amount for the waste	Household-Based Food Waste Charging System, which uses a weight based payment design, through which each household is electronically charged for the weight of food waste they disposes of Control: residents pay the same price by dividing total amount of waste charge by number of households	Intervention Types • Financial incentives Drivers D-Lack of awareness/ monitoring K-Policy	Natural experiment; no randomization of households
Tier 2[b]				
David et al., 2019 (Australia)	Two behavioral states were identified: fruit and vegetable wasters and nonwasters; following the intervention, a significant percentage of people transitioned away from wasters to nonwasters	Multifaceted intervention (2 weeks) included providing a shopping bag, chopping board, 16 new leftover reuse recipe cards, invitation flyer and a shopping list and in-store cooking demonstrations	Intervention Types • Information Drivers A-Knowledge	Criteria not met: wasted food not measured; no control group; other limitations: only fruit and vegetable waste was considered; unable to unpack individual effects of each intervention element

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Devaney and Davies, 2017 (Ireland)	Participant households reduced their overall food waste generation	Multifaceted intervention directed at changing behaviors toward being more sustainable, through purchasing, storage, and preparation, including information (a guide to smarter food storage), tools (compostable food waste boxes)	Intervention Types • Engagement • Social comparisons • Information Drivers A-Knowledge	Criteria not met: no control group; other limitations: unable to unpack individual effects of each intervention element; only fruit and vegetable waste considered; N = 5.
Dyen and Sirieix, 2016 (France)	Cooking classes were efficient to promote less food waste	Ongoing cooking classes on how to cook with products from the food bank in social center for people with social instability	Intervention Types • Social comparisons • Information Drivers A-Knowledge	Criteria not met: no control group; statistical significance not assessed; other limitations: N = 3

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Graham-Rowe et al., 2019 (United Kingdom)	There was a higher difference in fruit and vegetable waste before and after reading information about the negative consequences of household food waste for the standard self-affirmation group than for the control group	Online questionnaire where participants read information about the negative consequences of household food waste after: • standard self-affirmation manipulation, where participants chose their most important value among those in a list • an integrated self-affirmation manipulation, where the list of values included could influence success at reducing household food waste • control task	Intervention Types • Appeals Drivers H-Marketing practices I-Psychosocial factors	Criteria not met: wasted food not measured; other limitations: only fruit and vegetable waste considered
Gutiérrez-Barba and Ortega-Rubio, 2013 (Mexico)	There was reduction in food waste among families in the intervention group; food waste reduction was not reported for control group	Eight families attending a 32-hour workshop on the health and environmental impacts and skills and technical expertise to reducing food waste in six weekly sessions; the control group was 33 families not attending the workshop	Intervention Types • Social comparisons • Information Drivers A-Knowledge I-Psychosocial factors	Criteria not met: inadequate statistical reporting; other limitations: control group not randomly assigned

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Kowalewska and Kołłajtis-Dołowy, 2018 (Poland)	Questionnaires showed that knowledge about food waste increased after the intervention; analyses of the effect of intervention on food waste was not conducted	Intervention via four short (3- to 4-minute) education videos on food wastage and its prevention	Intervention Types • Information Drivers A-Knowledge I-Psychosocial factors	Criteria not met: wasted food not measured (self-report only); inadequate statistical reporting
Lim et al., 2017 (The Netherlands)	Intervention raised awareness; behavior change was not explored nor claimed in this study	Technology intervention: • combined a social recipe app where users report available and wasted ingredients; based on these, recipes are created and users are sent recipes with smart bins that collects wasted ingredients • social recipes app plus a bin for monitoring food waste and eco-feedback application	Intervention Types • Information Drivers A-Knowledge D-Lack of awareness/ monitoring I-Psychosocial factors J-Built environment	Criteria not met: waste food was not measured (self-report only); inadequate statistical reporting
Morone et al., 2018 (Italy)	The adoption of food sharing practices by households did not automatically translate into food waste reduction	Intervention: students were instructed to purchase, cook, and consume food collectively	Intervention Types • Engagement Drivers A-Knowledge I-Psychosocial factors	Evident problems included participants who dropped out or cheated

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Rohm et al., 2017 (Denmark, Germany, Norway, Sweden and The Netherlands)	Brochures and refrigerator magnets had no detectable effect on consumer attitudes, self-reported behavior, and suboptimal food choice; more consumers bought a banana when the sustainability message was next to them than when the price was lowered or when a taste message was presented	Multifaceted intervention was used to motivate consumers to purchase and accept suboptimal food in stores and in their households: • via a brochure • a refrigerator magnet • a website • a Facebook group on self-reported suboptimal food choices and behaviors An in-store intervention where different messages were tested to identify the potential effects on consumer behavior	Intervention Types • Appeals • Financial incentives Drivers H-Marketing practices I-Psychosocial factors	
Schmidt, 2016 (Germany)	Significant higher increase in the self-reported performance of recorded food waste-preventing behaviors in the experimental group than in the control group	Multifaceted interventions (4 weeks): • providing information (recommendations to prevent food waste) • public commitment • goal-setting measure	Intervention Types • Social comparisons • Information Drivers A-Knowledge I-Psychosocial factors	Criteria not met: wasted food not measured (self-report only); other limitations: unable to unpack individual effects of each intervention element

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Comber and Thieme, 2013 (United Kingdom)	The intervention had no effect on changes in attitude toward recycling and food waste but had an impact on participants' awareness of their own and others' recycling behavior and this awareness prompted self-reflection and reevaluation of the facilities and abilities available to the participants for recycling	Multifaceted intervention: a two-part persuasive technology, which replaced an everyday waste bin with one enabled to capture and share images of disposed of waste on an online social network	Intervention Types • Social comparisons • Feedback Drivers D-Lack of awareness-monitoring I-Psychosocial factors	Criteria not met: no control group; no measure of food waste, but only measure of attitude and behavior related to recycling and food waste
Sintov et al., 2017 (United States)	No evidence for positive spillover effects on energy and water behaviors but none of the three food spillover behaviors were significant (food, energy, and water waste prevention), except for a marginal effect for checking food before shopping	Individuals received curbside organic waste bins (structural intervention) and procedural information about composting (information intervention) were randomly assigned, following the midpoint assessment, to receive weekly descriptive norms messaging for 8 weeks: *75 percent of households in Costa Mesa separated all of their food scraps this week,*	Intervention Types • Social comparisons Drivers C-Waste vs. other goals D-Lack of awareness/ monitoring G-Everyday complexity I-Psychosocial factors J-Built environment	Criteria not met: food waste not measured, but only measure of food waste prevention behaviors (planning out meals and assessing/using food at home before shopping) were recorded by survey

continued

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TABLE D-1 Continued

Study	Findings	Intervention	Intervention Types and Drivers[a]	Limitations
Roe et al., 2018 (United States)	Containers with date labels resulted in increases in discard intentions for milk that is putatively -Past Date- among commercial bottlers compared with containers without such labels; multivariate analysis revealed that discard intentions are lower among participants with higher incomes and fewer household members, but revealed no other significant correlations with personal or household characteristics	A "sell by" label with a date set to 18 days post-bottling	Intervention Types • Nudges Drivers B-Assessing risk I-Psychosocial factors K-Policy	Criteria not met: food waste was not measured
Wilson et al., 2017 (United States)	The willingness to waste was greatest in the -Use By- treatment, the date label which may be the least ambiguous and suggestive of food safety; the willingness to waste was the lowest for the "Sell by: treatment, which may be the most ambiguous date label about safety or quality for consumers	Labels on "Best by", "Fresh by", "Use by" or "Sell by" on three products, two sizes, and three expiration dates	Intervention Types • Nudges Drivers B-Assessing risk I-Psychosocial factors K-Policy	Criteria not met: food waste not measured

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Manzocco et al., 2017 (Italy)	Increase in storage temperature did not affect salad firmness and weight loss but increased color changes, microbial growth, and consumer rejection; the survey showed that fresh-cut salad was mainly consumed within the first 5 days after purchasing	A survey on salad consumption: participants were asked to consider discard of the product, which was presented to them after being held at different refrigeration temperatures, without their knowledge; participants were also asked to report on their usual habits regarding acquisition and shelf life of lettuce in their households	Intervention Types • Nudges Drivers J-Built environment	Criteria not met: food waste not measured; other limitations: effects unclear; estimated a rejection curve but did not provide straightforward tests of the effect of temperature on intended discard rate

NOTES: EPA, U.S. Environmental Protection Agency; FAO, U.N. Food and Agriculture Organization; USDA, U.S. Department of Agriculture.

[a]Drivers are defined as: A-knowledge; B-assessing risk; C-waste vs. other goals; D-lack of awareness/monitoring; E-psychological distance; F-dietary differences; G-everyday complexity; H-marketing practices; I-psychosocial factors; J-built environment; and K-policy.

[b]Tier 1 studies met four criteria: an intervention was implemented; wasted food was measured; causal effect can be attributed; and statistical analysis was adequate. Tier 2 studies failed to meet at least one of the four criteria.

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REFERENCES

Ahmed, S., C.B. Shanks, M. Lewis, A. Leitch, C. Spencer, E.M. Smith, and D. Hess. 2018. Meeting the food waste challenge in higher education. *International Journal of Sustainability in Higher Education* 19(6):1075-1094.

ARAMARK. 2008. *The Business and Cultural Acceptance Case for Trayless Dining*. Available: http://www.elon.edu/docs/e-web/bft/sustainability/ARAMARK%20Trayless%20Dining%20July%202008%20FINAL.pdf.

Aschemann-Witzel, J. 2018. Consumer perception and preference for suboptimal food under the emerging practice of expiration date based pricing in supermarkets. *Food Quality and Preference* 63(63):119-128.

Aschemann-Witzel, J., A. Giménez, and G. Ares. 2018. Consumer in-store choice of suboptimal food to avoid food waste: The role of food category, communication and perception of quality dimensions. *Food Quality and Preference* 68:29-39.

Barnes, J.L., and C.A. Warren. 2017. Development of food group books for three- and four-year-old children. *Family and Consumer Sciences Research Journal* 45(3):272-284.

Bel, G., and R. Gradus. 2016. Effects of unit-based pricing on household waste collection demand: A meta-regression analysis. *Resource and Energy Economics* 44:169-182.

Belavina, E., K. Girotra, and A. Kabra. 2017. Online grocery retail: Revenue models and environmental impact. *Management Science* 63(6):1781-1799.

Bergman, E.A., N.S. Buergel, T.F. Englund, and A. Femrite. 2004. The relationship of meal and recess schedules to plate waste in elementary schools. *The Journal of Child Nutrition and Management* 28(2).

Berkowitz, S., L. Marquart, E. Mykerezi, D. Degeneffe, and M. Reicks. 2016. Reduced-portion entrées in a worksite and restaurant setting: Impact on food consumption and waste. *Public Health Nutrition* 19(16):3048-3054.

Cardwell, N.T., C. Cummings, and M. Kraft. 2019. *Toward Cleaner Plates: A study of plate waste in food service*. Available: https://www.nrdc.org/resources/toward-cleaner-plates-study-plate-waste-food-service.

Chan, H.W., T.B. Champoux, M. Reicks, Z. Vickers, and L. Marquart. 2008. White whole-wheat flour can be partially substituted for refined-wheat flour in pizza crust in school meals without affecting consumption. *Journal of Child Nutrition & Management: A publication of the American School Food Service Association* 32:1.

Chen, H.S., and T.M.C. Jai. 2018. Waste less, enjoy more: Forming a messaging campaign and reducing food waste in restaurants. *Journal of Quality Assurance in Hospitality and Tourism* 19(4):495-520.

Chitnis, M., D. Angela, S. Steve, K.F. Steven, and J. Tim. 2014. Who rebounds most? Estimating direct and indirect rebound effects for different UK socioeconomic groups. *Ecological Economics* 106(106):12-32.

Cohen, J.F.W., L.A. Smit, E. Parker, S.B. Austin, A.L. Frazier, C.D. Economos, and E.B. Rimm. 2012. Long-term impact of a chef on school lunch consumption: Findings from a 2-year pilot study in Boston middle schools. *Journal of the Academy of Nutrition and Dietetics* 112(6):927-933.

Cohen, J.F., S. Richardson, E. Parker, P.J. Catalano, and E.B. Rimm. 2014. Impact of the new U.S. Department of Agriculture school meal standards on food selection, consumption, and waste. *American Journal of Preventive Medicine* 46(4):388-394.

Collart, A.J., and M.G. Interis. 2018. Consumer imperfect information in the market for expired and nearly expired foods and implications for reducing food waste. *Sustainability (Switzerland)* 10(11).

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Comber, R., and A. Thieme. 2013. Designing beyond habit: Opening space for improved recycling and food waste behaviors through processes of persuasion, social influence and aversive affect. *Personal and Ubiquitous Computing* 17(6):1197-1210.

David, P., S. Rundle-Thiele, and J.I. Pallant. 2019. Re(focussing) on behavioural change: An examination of the utility of hidden Markov modelling. *Journal of Social Marketing* 9(2):130-145.

Del Giudice, T., F. La Barbera, R. Vecchio, and F. Verneau. 2016. Anti-waste labeling and consumer willingness to pay. *Journal of International Food & Agribusiness Marketing* 28(2):149-163.

Devaney, L., and A.R. Davies. 2017. Disrupting household food consumption through experimental homelabs: Outcomes, connections, contexts. *Journal of Consumer Culture* 17(3):823-844.

Duret, S., H.M. Hoang, E. Derens-Bertheau, A. Delahaye, O. Laguerre, and L. Guillier. 2019. Combining quantitative risk assessment of human health, food waste, and energy consumption: The next step in the development of the food cold chain? *Risk Analysis: An Official Publication of the Society for Risk Analysis* 39(4):906-925.

Dyen, M., and L. Sirieix. 2016. How does a local initiative contribute to social inclusion and promote sustainable food practices? Focus on the example of social cooking workshops. *International Journal of Consumer Studies* 40(6):685-694.

Ellison, B., O. Savchenko, C.J. Nikolaus, and B.R.L. Duff. 2019. Every plate counts: Evaluation of a food waste reduction campaign in a university dining hall. *Resources, Conservation and Recycling* 144:276-284.

Freedman, M.R., and C. Brochado. 2010. Reducing portion size reduces food intake and plate waste. *Obesity* 18(9):1864-1866.

Gee, I.M., F.T. Davidson, B.L. Speetles, and M.E. Webber. 2019. Deliver me from food waste: Model framework for comparing the energy use of meal-kit delivery and groceries. *Journal of Cleaner Production* 236:117587.

Graham-Rowe, E., D.C. Jessop, and P. Sparks. 2019. Self-affirmation theory and pro-environmental behaviour: Promoting a reduction in household food waste. *Journal of Environmental Psychology* 62:124-132.

Grewal, L., J. Hmurovic, C. Lamberton, and R.W. Reczek. 2019. The self-perception connection: Why consumers devalue unattractive produce. *Journal of Marketing* 83(1):89-107.

Gutiérrez-Barba, B.E., and A. Ortega-Rubio. 2013. Household food-waste production and a proposal for its minimization in Mexico. *Life Science Journal* 10(3):1772-1783.

Hamerman, E.J., F. Rudell, and C.M. Martins. 2018. Factors that predict taking restaurant leftovers: Strategies for reducing food waste. *Journal of Consumer Behaviour* 17(1):94-104.

Hamilton, S.F., and T.J. Richards. 2019. Food policy and household food waste. *American Journal of Agricultural Economics* 101(2):600-614.

Heard, B.R., M. Bandekar, B. Vassar, and S.A. Miller. 2019. Comparison of life cycle environmental impacts from meal kits and grocery store meals. *Resources, Conservation and Recycling* 147:189-200.

Ilyuk, V. 2018. Like throwing a piece of me away: How online and in-store grocery purchase channels affect consumers' food waste. *Journal of Retailing and Consumer Services* 41:20-30.

Jagau, H.L., and J. Vyrastekova. 2017. Behavioral approach to food waste: An experiment. *British Food Journal* 119(4):882-894.

Kallbekken, S., and H. Sælen. 2013. 'Nudging' hotel guests to reduce food waste as a win–win environmental measure. *Economics Letters* 119(3):325-327.

Kandemir, C., T. Quested, C. Reynolds, K. Fisher, and R. Devine. 2019. *Household food waste simulation model: Investigation of interventions for staple food items waste*. Paper read at Proceedings of 26th EurOMA Conference.

Copyright National Academy of Sciences. All rights reserved.

Kawata, Y., and S. Kubota. 2018. Consumers' willingness to pay for reprocessed fried chicken: A way of reducing uneaten food. *Appetite* 120:571-577.

Khan, U., and R. Dhar. 2006. Licensing effect in consumer choice. *Journal of Marketing Research* 43(2):259-266.

Kim, K., and S. Morawski. 2013. Quantifying the impact of going trayless in a university dining hall. *Journal of Hunger and Environmental Nutrition* 7(4):482-486.

Kowalewska, M.T., and A. Kołłajtis-Dołowy. 2018. Food, nutrient, and energy waste among school students. *British Food Journal* 120(8):1807-1831.

Kuo, C., and Y. Shih. 2016. Gender differences in the effects of education and coercion on reducing buffet plate waste. *Journal of Foodservice Business Research* 19(3):223-235.

Kuperberg, K., A. Caruso, S. Dello, and D. Mager. 2008. How will a room service delivery system affect dietary intake, food costs, food waste and patient satisfaction in a paediatric hospital? A pilot study. *Journal of Foodservice* 19(5):255-261.

Lazell, J. 2016. Consumer food waste behaviour in universities: Sharing as a means of prevention. *Journal of Consumer Behaviour* 15(5):430-439.

Le Borgne, G., L. Sirieix, and S. Costa. 2018. Perceived probability of food waste: Influence on consumer attitudes towards and choice of sales promotions. *Journal of Retailing and Consumer Services* 42:11-21.

Lee, S. and K. Jung. 2017. Exploring effective incentive design to reduce food waste: A natural experiment of policy change from community based charge to RFID based weight charge. *Sustainability* 9:1-17.

Lim, V., M. Funk, L. Marcenaro, C. Regazzoni, and M. Rauterberg. 2017. Designing for action: An evaluation of social recipes in reducing food waste. *International Journal of Human-Computer Studies* 100:18-32.

Liz Martins, M., S.S. Rodrigues, L.M. Cunha, and A. Rocha. 2016. Strategies to reduce plate waste in primary schools—experimental evaluation. *Public Health Nutrition* 19(8):1517-1525.

Lorenz-Walther, B.A., N. Langen, C. Gobel, T. Engelmann, K. Bienge, M. Speck, and P. Teitscheid. 2019. What makes people leave less food? Testing effects of smaller portions and information in a behavioral model. *Appetite* 139:127-144.

Manomaivibool, P., C. Chart-asa, and P. Unroj. 2016. Measuring the impacts of a save food campaign to reduce food waste on campus in Thailand. *Applied Environmental Research* 38:13-22.

Manzocco, L., C. Lagazio, M. Alongi, M.C. Nicoli, and S. Sillani. 2017. Effect of temperature in domestic refrigerators on fresh-cut iceberg salad quality and waste. *Food Research International* 102(102):129-135.

Morone, P., M. Andrea, I. Enrica, and F. Pasquale Marcello. 2018. Does food sharing lead to food waste reduction? An experimental analysis to assess challenges and opportunities of a new consumption model. *Journal of Cleaner Production* 185(185):749-760.

Petit, O., R. Lunardo, and B. Rickard. 2019. Small is beautiful: The role of anticipated food waste in consumers' avoidance of large packages. *Journal of Business Research* 113:326-336.

Pinto, R.S., R. Pinto, F.F.S. Melo, S.S. Campos, and C.M. Cordovil. 2018. A simple awareness campaign to promote food waste reduction in a university canteen. *Waste Management* 76:28-38.

Prescott, M.P., X. Burg, J.J. Metcalfe, A.E. Lipka, C. Herritt, and L. Cunningham-Sabo. 2019. Healthy planet, healthy youth: A food systems education and promotion intervention to improve adolescent diet quality and reduce food waste. *Nutrients* 11(8).

Qi, D., and B.E. Roe. 2017. Foodservice composting crowds out consumer food waste reduction behavior in a dining experiment. *American Journal of Agricultural Economics* 99(5):1159-1171.

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Roe, B.E., S.B. Aishwarya, T.S. Christopher, M.P. David, R.H. Dennis, and E.B. Kathryn. 2018. Discard intentions are lower for milk presented in containers without date labels. *Food Quality and Preference* 66(66):13-18.

Rohm, H., M. Oostindjer, J. Aschemann-Witzel, C. Symmank, V.L. Almli, I.E. de Hooge, A. Normann, and K. Karantininis. 2017. Consumers in a sustainable food supply chain (COSUS): Understanding consumer behavior to encourage food waste reduction. *Foods* 6(12):27.

Romani, S., S. Grappi, R.P. Bagozzi, and A.M. Barone. 2018. Domestic food practices: A study of food management behaviors and the role of food preparation planning in reducing waste. *Appetite* 121:215-227.

Sandson, K., and E. Broad Lieb. 2019. *Bans and Beyond: Designing and Implementing Organic Waste Bans and Mandatory Organics Recycling Laws*. Harvard Law School Food Law and Policy Clinic; Center for EcoTechnology. Available: https://www.chlpi.org/wp-content/uploads/2013/12/Organic-Waste-Bans_FINAL-compressed.pdf.

Sarjahani, A., E.L. Serrano, and R. Johnson. 2009. Food and non-edible, compostable waste in a university dining facility. *Journal of Hunger and Environmental Nutrition* 4(1):95-102.

Schmidt, K. 2016. Explaining and promoting household food waste-prevention by an environmental psychological based intervention study. *Resources, conservation, and recycling* 111(111):53-66.

Schwartz, M.B., K.E. Henderson, M. Read, N. Danna, and J.R. Ickovics. 2015. New school meal regulations increase fruit consumption and do not increase total plate waste. *Childhood Obesity* 11(3):242-247.

Sintov, N., S. Geislar, and L.V. White. 2017. Cognitive accessibility as a new factor in proenvironmental spillover: Results from a field study of household food waste management. *Environment and Behavior* 51(1):50-80.

Soma, T., B. Li, and V. Maclaren. 2020. Food waste reduction: A test of three consumer awareness interventions. *Sustainability (Switzerland)* 12(3):907.

Somkun, P.N. 2017. Stochastic mathematical model for food waste reduction in a two-level supply chain for highly perishable products. *International Journal of Supply Chain Management* 6(1):165-171.

Stockli, S., M. Dorn, and S. Liechti. 2018. Normative prompts reduce consumer food waste in restaurants. *Waste Management* 77:532-536.

Strotmann, C., S. Friedrich, J. Kreyenschmidt, P. Teitscheid, and G. Ritter. 2017. Comparing food provided and wasted before and after implementing measures against food waste in three healthcare food service facilities. *Sustainability (Switzerland)* 9(8).

Thiagarajah, K., and V.M. Getty. 2013. Impact on plate waste of switching from a tray to a trayless delivery system in a university dining hall and employee response to the switch. *Journal of the Academy of Nutrition and Dietetics* 113(1):141-145.

van der Werf, P., J.A. Seabrook, and J.A. Gilliland. 2019. "Reduce food waste, save money": Testing a novel intervention to reduce household food waste. *Environment and Behavior*. Available: https://doi.org/10.1177/0(0):0013916519875180.

van Giesen, R.I., and I.E. de Hooge. 2019. Too ugly, but I love its shape: Reducing food waste of suboptimal products with authenticity (and sustainability) positioning. *Food Quality and Preference* 75:249-259.

van Holsteijn, F., and R. Kemna. 2018. Minimizing food waste by improving storage conditions in household refrigeration. *Resources, Conservation & Recycling* 128(128):25-31.

Vermote, M., V. Versele, M. Stok, P. Mullie, E. D'Hondt, B. Deforche, P. Clarys, and T. Deliens. 2018. The effect of a portion size intervention on French fries consumption, plate waste, satiety and compensatory caloric intake: An on-campus restaurant experiment. *Nutrition Journal* 17(1).

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Wansink, B., and K. van Ittersum. 2013. Portion size me: Plate-size induced consumption norms and win-win solutions for reducing food intake and waste. *Journal of Experimental Psychology: Applied* 19(4):320-332.

Whitehair, K.J., C.W. Shanklin, and L.A. Brannon. 2013. Written messages improve edible food waste behaviors in a university dining facility. *Journal of the Academy of Nutrition and Dietetics* 113(1):63-69.

Wikström, F., H. Williams, and G. Venkatesh. 2016. The influence of packaging attributes on recycling and food waste behaviour—an environmental comparison of two packaging alternatives. *Journal of Cleaner Production* 137:895-902.

Williamson, S., L.G. Block, and P.A. Keller. 2016. Of waste and waists: The effect of plate material on food consumption and waste. *Journal of the Association for Consumer Research* 1(1):147-160.

Wilson, N.L.W., B.J. Rickard, R. Saputo, and S.-T. Ho. 2017. Food waste: The role of date labels, package size, and product category. *Food Quality and Preference* 55:35-44.

WRAP. 2013. *The Milk Model: Simulating Food Waste in the Home*. Available: https://www.wrap.org.uk/sites/files/wrap/Milk%20Model%20report.pdf.

Young, W., S.V. Russell, C.A. Robinson, and R. Barkemeyer. 2017. Can social media be a tool for reducing consumers' food waste? A behaviour change experiment by a UK retailer. *Resources, Conservation and Recycling* 117:195-203.

Young, C.W., S.V. Russell, C.A. Robinson, and P.K. Chintakayala. 2018. Sustainable retailing—influencing consumer behaviour on food waste. *Business Strategy and the Environment* 27(1):1-15.

Yu, Y., and E.C. Jaenicke. (2020). The effect of sell-by dates on purchase volume and food waste. *Food Policy.* Available: https://doi.org/10.1016/j.foodpol.2020.101879.

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Appendix E

Research on Behavioral Change from Other Domains

The committee examined a significant body of research on consumer behavior from six domains: energy conservation, water conservation, waste prevention and management, recycling, diet change, and weight management. Key findings from this work are discussed in the body of the report; this appendix presents a more detailed discussion of the work reviewed. It begins with a brief historical overview of the literature and then summarizes findings from the research, including general themes about consumer behaviors and themes related to both drivers of consumer behavior and interventions. It closes with an overview of suggestions for further research made by scholars in these fields.

The committee gathered 406 peer-reviewed and published articles that were classified as systematic reviews, narrative reviews, and meta-analyses about behavior change in these six domains and reviewed their abstracts for applicability to the committee's task. From this set, 46 articles were selected to be reviewed in full; details of the literature search can be found in Appendix B.

An important caveat of this appendix is the focus on meta-analyses, systematic reviews, and narrative reviews. While these types of analyses are helpful in presenting distilled information and can present the weight of the evidence on a topic, they can bias evidence (Sorrell, 2007). This is because these types of analyses and reviews often focus on a narrow set of questions, such as whether certain types of interventions "work" (Sorrell, 2007). But they often do not capture the important implementation and qualitative studies that answer questions about how something works or

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the cost of an intervention (Sorrell, 2007). This neglects the complexities about how something works and often overlooks important information.

HISTORY OF BEHAVIOR CHANGE RESEARCH

Awareness of behavior change science and how it has transformed over time is an important backdrop to the scientific findings from current work. Numerous behavior change theories and frameworks have been used to understand and predict individual behavior. One systematic review of research on diet change mentioned that a total of 83 theories of behavior change had been identified (Samdal et al., 2017). There has been no consensus on which theories and frameworks are most useful, and some have been more commonly applied than others. Importantly, the dominant theories in use have evolved over time. Early theories of behavior change, such as social cognitive theory, theory of planned behavior, and the transtheoretical model, were most often used to explain why people adopt a behavior.

For much of the 20th century, these theories characterized human behavior as being predominately conscious and reason driven; these theories and behaviors are sometimes referred to as System 2 (Koop et al., 2019; Marteau, 2017) Because of this focus, the drivers that were captured and interventions that were designed were often centered around knowledge transfer and ways to improve self-efficacy (Koop et al., 2019). By the end of the 20th century, it was apparent that these theories were limited in their ability to explain behavioral outcomes and that there was another set of automatic and emotion-driven factors that needed to be captured (Marteau, 2017).

At this point, models of behavior emerged that depicted two or three sets of parallel processes that characterized human behavior as being more automatic and emotion-driven. These processes were described as reflective, semireflective, and automatic processes (Koop et al., 2019), with reflective being aligned with System 2, and automatic sometimes being referred to as System 1 (Marteau, 2017). Because of widespread use of these processes across domains, the drivers that were captured and interventions that were designed in the studies included in this appendix were often centered on social norms, framing, priming, nudging, and emotions (Koop et al., 2019). In addition, the evolution in these fields over time has meant that the meta-analyses reviewed in this appendix often contain more studies on System 2 interventions and more recent, but sparse, studies on System 1 interventions. Most recently, it has been recognized that individual behaviors are responsive to both System 1 and 2 processes and that a combination of the two can be more effective. Thus, researchers have begun to measure drivers and create study designs that combine System 1 and 2 into more complex

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and multicomponent interventions; these studies, because they are more recent, are rarely included in the meta-analyses discussed in this appendix.

GENERAL THEMES IN CURRENT RESEARCH

Literature from the six domains uses many terminologies to categorize and measure behavioral predictors or drivers, behavioral interventions, and other related factors. The multiplicity of terms and measures used within domains can be a barrier to identifying commonalities and differences, to designing and evaluating programs and interventions, and to aligning current and future research. However, there are some common threads in the terms used for processes (e.g., reflective, semireflective, and automatic or System 2 and System 1) and for intervention types (e.g., social comparison, feedback, information, appeals, engagement, choice architecture/nudges). This section summarizes two general themes in the research from the six domains: the use of theory to drive terminology and guide programs, and the fact that intention does not always drive behavior.

Use of Theory to Drive the Use of Common Terminology and Guide Program Design and Evaluation

The terminology used to categorize behavioral drivers and interventions is inconsistent within fields and across fields even though terms often described the same phenomena. This inconsistency makes it challenging to compare within and across literatures. For example, drivers of behavior were categorized within studies in the following ways:

- individual and contextual;
- individual, behavior-specific, and general;
- sociopsychological, technical-organizational, individual, sociodemographic, and study-specific;
- sociopsychological, sociodemographic, contextual (situational);
- perceived and objective;
- demographic, institutional, economic, social/cultural; and
- environmental, situational, psychological.

The definitions for these categories often differed or only overlapped partially between studies, making it challenging to know in which category a driver belonged. Drivers were also often interchangeably termed as determinants, determining factors, motivations, predictors, or moderators. Because these terms can take different levels of meanings (e.g., statistical meanings of prediction and moderation) or serve as a determining construct within a behavioral model (e.g., motivation), it can be challenging to parse

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meaning. Similarly, the terms behaviors, actions, and outcomes were often used synonymously. An analysis of household waste prevention interventions by Sharp et al. (2010) found that many studies that describe behavior change are ultimately measuring outcome change but not necessarily the behaviors leading up to the change in outcome.

Behaviors were also often subdivided into categories differentially (Koop et al., 2019; Scott et al., 2015). For example, in the waste management literature, some studies used the well-known reduction, reuse, and recycling categories while other studies created a suite of composite behaviors, including:

- basic environmental, decision-making environmental, interpersonal environmental, and civic environmental behavior (Li et al., 2019) and
- citizenship, financial, persuasion, and ecological management behaviors (Li et al., 2019).

Behaviors were also categorized as one-off, continuous or repeated, or dynamic (i.e., a mix of one-off and repeated) acts (e.g., procuring a recycling bin from the county, turning off lights, recycling) or purchases (e.g., buying an energy efficient appliance or organic food). Some studies recommended that it was more useful to conceptualize actions or behaviors by activity type (i.e., one-off, repeated) than by sector (e.g., waste management behaviors, energy conservation behaviors) because of the similarities and differences between one-off actions and habits or routines, even across domains. Consistent categorizations and terminology would allow the literatures to share common findings more easily.

Similarly, the meta-analyses and systematic reviews included in this appendix categorized interventions in many different ways (e.g., by construct, by strategy, and by process, often relating it to more reasoned behaviors or more automatic behaviors, or both), and, in many cases, described interventions as bundled strategies. For example, one meta-analysis on validated field interventions to promote household recycling appealed to psychological constructs and categorized interventions by type as information, feedback, incentives, commitment, behavior modeling, and environmental alterations (Varotto and Spagnolli, 2017). Another meta-analysis testing behavioral interventions to promote household action on climate change categorized interventions by type as information, appeals, engagement, social comparison, and choice architecture (Nisa et al., 2019). Both studies commented on the frequency with which interventions incorporated bundled strategies. Another waste prevention meta-analysis found that bundled strategy interventions often do not disaggregate which behaviors relate to which strategies and this could be improved by the use of theory

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as a guide (Sharp et al., 2010). In addition, other studies categorized interventions by information processing routes. For example, Koop et al. (2019) used reflective (i.e., conscious, reason driven), semireflective (i.e., heuristics, simple cues), and automatic processing routes to categorize interventions on water conservation behavior within households. Other studies often compared only reflective and automatic processing routes and used various terms, such as System 2 or System 1, hot or cold, and reflective or impulsive (Marteau, 2017).

The use of theories of change and conceptual frameworks can help resolve these inconsistencies in terminology to an extent. In addition, theories and frameworks can guide the design of behavioral interventions, including identifying behavioral constructs and mechanisms and various levels of variables and outcomes that will need to be measured in order to disaggregate effects (Thomson and Ravia, 2011). Despite this, not enough studies use theoretical frameworks to guide design (Sweet and Fortier, 2010; Thomson and Ravia, 2011; Varotto and Spagnolli, 2017). One meta-analysis of health behavior interventions estimated that only about 30 percent of studies used theoretical frameworks to guide their interventions (Sweet and Fortier, 2010).

A significant body of research has demonstrated the efficacy of theory-driven interventions targeting modifiable behaviors (Haggar and Weed, 2019). One review of behavior change related to diet and physical activity found only sparse and inconsistent evidence that theory-based interventions are effective or lead to better outcomes (Samdal et al., 2017), while another review found that interventions structured on behavioral theory techniques are more effective (Belogianni and Baldwin, 2019). In addition, behavioral theories are often poor at explaining how the initiation and the maintenance of behavior might differ (Samdal et al., 2017). Despite this, studies in these domains discuss how theories and frameworks can help to standardize monitoring and evaluation practices and reporting of outcomes (Cox et al., 2010). By standardizing common elements, the next generation of studies could develop new methods for easier interpretability and comparison that investigate change across multiple behaviors and bundled strategies. For example, one meta-analysis suggested exploring the following new methods to capture the complexity of actions underlying behavior change: combining change scores, creating an index score, expanding the impact formula, and using an overarching measure of change (Sweet and Fortier, 2010).

Intention Does Not Always Lead to Behavior

Based on behavioral theories that are widely applied across these domains, there is an assumption that self-reported behavioral intentions lead

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to implementation of a behavior. In other words, intended or self-reported behaviors are often considered synonymous with actual behavior change. However, numerous studies have documented that self-reported intentions and their actual behavior frequently do not match (Li et al., 2019; Varotto and Spagnolli, 2017). As such, many authors have suggested future studies move away from or be aware of the use of intentions or clearly distinguish between intention and actual behavior when collecting and interpreting data (Li et al., 2019; Nisa et al., 2019; Varotto and Spagnolli, 2017). For example, one meta-analysis on household recycling behaviors found that individual and contextual factors often predicted intention to recycle, but they did not observe recycling behavior (Geiger et al., 2019). Another review of health communication campaigns found that an increase in knowledge, awareness, or beliefs did not necessarily change targeted behaviors, and it recommended that campaigns should aim to target specific behavior change goals rather than only awareness and should plan to evaluate both (Snyder, 2007). The value-action gap, the awareness-behavior gap, communications gap, and the knowledge gap are also terms that are used to refer to this phenomenon (Li et al., 2019; Sharp et al., 2010; Snyder, 2007).

DRIVERS OF CONSUMER BEHAVIOR

The committee's review found several themes in the research on drivers of consumer behavior summarized in this section.

Not One but Many Behaviors

Across the domains, the literature suggests that not one but many behaviors determine the outcomes of interest to policy makers and practitioners (Cox et al., 2010). There is no standard set of behaviors that is widely accepted as the set that determines outcomes. In the recycling domain, which has one of the more extensive and well-developed literatures, Li et al. (2019) explained that the behaviors shaping this domain are so complex that a single model would be unable to encompass all the relevant factors. In the waste prevention literature, Cox and colleagues (2010) reported that the vast majority (~70–85 percent) of behavior cannot be explained in current studies due to the multiplicity of behaviors.

A majority of interventions in the six domains were designed as packages of strategies to target several behaviors aimed at an outcome. This approach made it challenging for the meta-analyses and systematic reviews to measure, depict, and disaggregate which strategies influence which behaviors. However, Sharp et al. (2010) and Sweet and Fortier (2010) suggest this may not matter because often an individual strategy might be more influential on a single behavior and less influential on the targeted outcome,

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while a package of strategies can be less influential on a single behavior but, additively, more influential on the broader outcome. For example, a review of meta-analyses comparing single and multiple health behavior interventions found that multiple health behavior interventions were more effective at reducing body weight than single behavior interventions (Sweet and Fortier, 2010). The authors explained that multiple behavioral improvements in individual behaviors (e.g., diet, physical activity) added up to greater effects on weight loss when combined (Sweet and Fortier, 2010). Notably, combining such strategies may be more cost-effective, as the additional costs of adding another mode of intervention is likely smaller than the base costs of undertaking an intervention.

Predictive Power of Sociodemographic Variables

Sociodemographic variables were assessed across all domains in terms of their ability to predict proenvironmental behavior. People who were higher income, more educated, older, living in detached properties, and women were more likely to engage in water conservation and recycling behaviors (Addo et al., 2018; Cox et al., 2010; Whitmarsh et al., 2018). People who were younger, more educated, and lower income were more likely to engage in waste reduction behaviors (i.e., buying less, avoiding buying new things) (Whitmarsh et al., 2018). People who were higher income, older, and owned a home were more likely to conserve energy (Karlin et al., 2015). Other studies reported that sociodemographic variables have no significant influence on proenvironmental behavior (Li et al., 2019), that only income predicts recycling behavior (Miafodzyeva and Brandt, 2013); or, that while well-educated people are generally more committed to resource conservation, they actually consume more (Koop et al., 2019). Studies of waste prevention find that while both genders contribute equally to municipal solid waste production, females are more willing to recycle or participate in reduction behaviors, and men are more willing to pay for waste reduction (Ma and Hipel, 2016). Similarly, young people have been found to be more willing to pay for waste prevention and reduction than older people (Ma and Hipel, 2016).

While there are trends by domain in how sociodemographic variables are associated with behaviors, many studies find that these variables do not contribute much to understanding of proenvironmental behavior and that psychological factors are more successful in predicting behavior and behavior change (Li et al., 2019). One meta-analysis suggested that there was no need to tailor recycling interventions to different target groups, such as households, students, or employees, because similar factors seemed to underlie their behavior and the relationship between individual and contextual factors did not differ by group (Geiger et al., 2019). Other studies

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have illustrated that as a behavior becomes well established (e.g., recycling), external social pressure no longer predict or significantly influence behavior (Miafodzyeva and Brandt, 2013; Soderhorn, 2010).

Predictive Power of Motivational Factors

It is somewhat tempting to think that simply having enough information about a given behavior or its effects will change individuals' choices. However, knowledge or information alone was found to be insufficient as a predictor of ability (i.e., knowledge for action) to change and maintain behavior (Abrahamse et al., 2005). By contrast, motivational factors, which take a wide range of forms, seem to be more effective. For example, motivational tools—such as altered attitudes toward outcomes, personal norms, agency or perceived control, and social norms—have turned out to be the most successful predictors and influencers of proenvironmental and weight management behaviors (Li et al., 2019; Miafodzyeva and Brandt, 2013; Samdal et al., 2017). Literature in the weight management domain indicates that people who have self-efficacy and are motivated by their own needs and desires can more readily sustain a behavior (Samdal et al., 2017; Thomson and Ravia, 2011).

Not all motivational factors are egocentric: several meta-analyses illustrate that proenvironmental behavior is more motivated by normative and sometimes environmental concerns than by individual costs and benefits (Geiger et al., 2019; Miafodzyeva and Brandt, 2013). Similarly, environmental attitudes and beliefs, concerns for the future, and an individual's sense of responsibility—all of which can shape motivation—contribute more to understanding proenvironmental behavior than sociodemographic variables (Li et al., 2019). Norms play a particularly important role in behavior change. Moral norms (i.e., when people feel that doing something aligns with an abstract right or wrong), injunctive social norms (i.e., what one ought to do), and descriptive social norms (i.e., perceptions of what most people are doing) have increased in many societies and are strongly correlated with behavior (Miafodzyeva and Brandt, 2013; Whitmarsh et al., 2018).

These findings suggest that behaviors that are presented as useful, pleasant, important, and widely accepted activities are more likely to be adopted and sustained (Miafodzyeva and Brandt, 2013); conversely, behaviors that are viewed as someone else's responsibility, inconvenient, or that require a high bar of self-efficacy or locus of control are less likely to be adopted and sustained (Cox et al., 2010). One caveat to this finding is that it may not apply to prevention behaviors that are unseen (e.g., changing acquisition behaviors in order to purchase less in the first place). In instances where

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an action is not visible—frequently those categorized as prevention—social norms are unlikely to develop (Cox et al., 2010).

Contextual Factors Affect Opportunities to Initiate and Sustain Behaviors

Several meta-analyses of household recycling interventions found that contextual factors were seldom considered (Geiger et al., 2019; Varotto and Spagnolli, 2017). Studies that included contextual factors, such as having curbside or convenient recycling, a bin at home, or other (e.g., space at home to store recycling), found them to be very strong predictors of waste reduction and recycling behavior (Geiger et al., 2019; Whitmarsh et al., 2018). In one study by Guagnano et al. (1995), the explanatory power of personal norm beliefs decreased when curbside pickup was included. A review of the literature on water conservation behavior found that water pricing was the most important variable explaining differences in domestic consumption in 10 Organisation for Economic Co-operation and Development countries (Koop et al., 2019). Moreover, studies have found that psychosocial factors, such as attitudes and norms, are insufficient for overriding structural barriers to behavior (Karlin et al., 2015).

Interactions among Psychosocial and Contextual Factors

Contextual and psychosocial factors were often found to interact to promote behavior change and maintenance. Households were more likely to adopt behaviors when they felt capable, motivated, and had the opportunity (Addo et al., 2018; Geiger et al., 2019). In a meta-analysis of the causal mechanisms of water conservation behavior, opportunity was a moderate predictor of behavior, followed by motivation and then capability; the three together explained 37 percent of the variance in household behavior (Addo et al., 2018). In this analysis, opportunity was defined as any external physical and social environment factor, such as time, resources, location, and finances, that enables an individual's behavior; motivation was defined as intrinsic and extrinsic factors, such as attitudes, norms, values, and beliefs; and capability was defined as physical and psychological ability to enact the behavior, such as skills (Addo et al., 2018).

Proximal and Automatic Behaviors Compared with Reasoned Behaviors

More proximal and automatic behaviors have higher behavioral plasticity potential, meaning behavior can change more rapidly or with greater magnitude in response to a stimulus. Choice architecture (i.e., nudges,

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removing external barriers) and social comparison interventions (i.e., comparing one's behavior with others) have been found to be the most efficacious for behavior change when compared with traditional interventions, such as information (e.g., statistics, simple messages, energy labels), appeals (e.g., requests to change behavior for humanity), and engagement (e.g., goal setting, implementation intentions) (Nisa et al., 2019). Thus, proximal and automatic behaviors can be an effective intervention focus.

Habits

There has been inadequate attention paid to habits in comparison with infrequent or one-off behaviors; more recent literature is finding that habits are powerful drivers of behavior. Habits predict and sustain behaviors because they are automatic (Whitmarsh et al., 2018). Habits and established behaviors are powerful because they are not easily influenced by values and norms (Cox et al., 2010; Miafodzyeva and Brandt, 2013), which can be both positive and negative. For example, as waste reduction has become relatively normative in most developed countries, social norms have become insignificant influencers in any context (Whitmarsh et al., 2018). Behavioral interventions aimed at altering habits have been less effective than interventions aimed at influencing one-off behaviors (Nisa et al., 2019). At the same time, interventions that have been successful in creating a new habit find that automatized behaviors are easier to sustain (Nisa et al., 2019). To form new habits, action repetition is needed, and this finding underscores the need for interventions that frequently reinforce or give feedback on actions (Nisa et al., 2019).

How Drivers of Behavior May Differ over Time and Context

Context cues much of human behavior, and different motivations and barriers operate in different contexts, meaning that many actions are inconsistent across different times and places (Nash et al., 2017; Whitmarsh et al., 2018). Some literatures indicate that grouping drivers and tailoring interventions by different contexts is more important than by sociodemographic groups (Cox et al., 2010; Whitmarsh et al., 2018). Similarly, behavioral drivers may differ over time, both societally and individually. However, little is known about how drivers may differ at different phases in the behavior change process (Samdal et al., 2017).

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Differences between Drivers that Initiate and Those that Maintain Behavior

There are important differences in how behaviors are formed and sustained and in how established behaviors are broken to form new behaviors (Miafodzyeva and Brandt, 2013). Interventions designed to help people initiate behavior may need to target different behavioral drivers than those that help people maintain behavior (Samdal et al., 2017). For example, once behaviors are established (e.g., recycling), they are less affected by such factors as social norms and expectations (Miafodzyeva and Brandt, 2013). One systematic review of 100 theories of behavioral change found five explanations of the differential roles of motives: self-regulation, psychological resources, physical resources, contextual influences, and habits from initiation to maintenance (Kwasnicka et al., 2016). This review found that people need at least one sustained motivator to maintain a behavior change and that people will often initiate a change when motivation is high and effort is low. When motivation is reduced and effort or costs increase, people will often need some way to self-monitor in order to sustain the change, which can be challenging when other things in their lives are simultaneously occurring, such as stress, tiredness, other more precarious issues (such as finances). Thus, turning a new behavior into a habit can be advantageous because external factors (e.g., changes in motivation or effort) are less likely to affect the behavior. Stable contexts can make behavior maintenance easier (Kwasnicka et al., 2016).

INTERVENTIONS

The literature on interventions was difficult to compare and contrast because of differences in terminology and how interventions were categorized, but a number of topics were addressed across the six domains. This section summarizes research on key questions about intervention effectiveness and some themes identified by researchers in these areas.

Intervention Approaches

Single or Combined Behavioral Interventions

Consistent with the broader psychological literature, the vast majority of the reviews found that behavioral interventions were only mildly to moderately effective on their own (Cox et al., 2010; Koop et al., 2019; Marteau, 2017; Thomson and Ravia, 2011; Varotto and Spagnolli, 2017).

A review by Sweet and Fortier (2010) examined whether interventions focused on a single behavior (e.g., physical activity or diet) were more or

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less effective than interventions focused on multiple behaviors (e.g., physical activity and diet) by reviewing meta-analyses and reviews. They also explored the differential effects of these interventions on weight outcomes. Notably, the analysis found that while single behavior interventions were more effective at improving the targeted behavior, multiple behavior interventions produced greater weight loss even though they appeared to be less effective at changing the individual behaviors. The authors hypothesized that this occurred because changing several behaviors at once in small, nonsignificant ways might add up to a greater overall effect. This result suggests that if a single behavior is the target that a single behavior intervention might be the most effective, but if the aim is to change more behaviorally complex outcomes, such as weight, multiple behavior interventions might be more effective. Finally, while the samples were too small to draw conclusions, there may be differences in whether multiple behavior interventions introduce behavior changes simultaneously or sequentially (Sweet and Fortier, 2010).

Targeting One-Time or Single-Action Behaviors as Well as Habits

Single-action behaviors may be less resistant to change as compared with habits and may be more effectively targeted by behavioral interventions (Nisa et al., 2019). One-off actions (e.g., purchase of energy efficient appliance) have been found to have higher behavioral plasticity, meaning they are more likely to change in response to the application of effective intervention (Nisa et al., 2019). However, emerging evidence indicates that behavioral interventions can be better designed to target habits and habitual thinking by incorporating more regular and frequent delivery of information or feedback, by providing specific tips or skills, or by disrupting existing habits to embed new habits (Cox et al., 2010). For example, behavior change techniques that facilitate self-regulation of behavior (e.g., goal setting of behavior and self-monitoring of behavior) can be effective in helping people to both initiate and maintain dietary changes, while techniques that facilitate person-centered or autonomy supportive communication (e.g., problem solving, review of behavioral goals and receiving social support) are important to maintain behavior change (Samdal et al., 2017). Behavior change techniques that combine the "how to" (i.e., facilitate behavior self-regulation, such as skills) with "the why" (i.e., addresses the underlying reasons for motivation) can reinforce both an individual's competence and need for meaning, value, and satisfaction in order to change behavior (Samdal et al., 2017). This finding is corroborated by other reviews that have indicated that successful weight management interventions are composed of an integrated mix of information, support, encouragement, progress monitoring, and feedback (Sharp et al., 2010).

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Contextual or Environmental Factors as Barriers to Behavior Change

Contextual factors can support or override an individual's desires and attempts to consume or waste less (Cox et al., 2010). Varotto and Spagnolli (2017) conducted a random-effects meta-analysis of 36 studies (1990-2015) reporting 70 psychological strategies to promote household recycling in the home environment: they found environmental alterations to be the second most effective strategy, after social modeling. Environmental alterations were described as modifying the existing physical environment, such as adding home equipment for waste sorting (Varotto and Spagnolli, 2017). The effectiveness of this strategy was attributed to the presence of environmental cues that prompted behavior and minimized the effort required to implement the behavior. For example, the addition of bins can initiate behavior but the presence of bins in a neighborhood can increase awareness of a program and reinforce social norms. In a review of health communication campaigns, Snyder (2007) acknowledged the necessity to change other people or contexts in order to change the target population and explained that campaigns can vary in their use of communication strategies "to try to change the behavior of the target population, including strategies that attempt to change the political and economic context in which people are making decisions, those aimed directly at the populations, and those aimed at people who may have influence with the target population" (Snyder, 2007, p. S35). Often, environmental changes are needed first, and campaigns can serve the role of publicizing them or attempting to stimulate demand for a new option.

A study by Whitmarsh et al. (2018) looking at behavioral consistency across contexts examined waste reduction behaviors at home, at work, and on vacation to determine whether consistency was a function of proenvironmental identity. The study found that the proportion of waste recycled at home was greater than that in the workplace or on holiday (67 percent, compared with 39 percent and 38 percent, respectively) and that repair and reuse behaviors were more common at home than at work. The prevalence of behaviors by context was consistent with the literature that describes work and vacation contexts as places when people are less motivated to act proenvironmentally or experience less control over barriers to behavior (Whitmarsh et al., 2018). Contextual factors and perceived behavioral control were found to be as important for predicting recycling behavior as motivational and normative factors. Recycling knowledge and personal norms predicted behavior. The authors concluded that proenvironmental identity was not a significant predictor of cross-contextual consistency (Whitmarsh et al., 2018, p. 10):

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> [T]hese findings suggest there are more barriers to waste reduction (recycling and reuse) outside the domestic context than within it; and that contextual factors (e.g., facilities) are at least as predictive of waste reduction as individual factors . . . At the same time as there being considerable variation across contexts, though, we also see heterogeneity across behaviors: recycling is more common than other waste reduction behaviors . . . and apparently more transferable across contexts than repair/reuse behaviors.

Preventing Consumption in the First Place Compared with Promoting Reuse or Recycling

Modern culture's drive to consume and the fact that waste prevention behaviors lack the same visibility as such activities as recycling make preventing overacquisition of items more challenging than reuse or recycling (Cox et al., 2010). In the recycling literature, one of the biggest barriers to household waste prevention was the fact that people often mistake recycling as waste prevention (Cox et al., 2010). Households are more likely to participate in reuse than reduce behaviors (e.g., donation vs. avoidance) (Cox et al., 2010). Moreover, because waste prevention behaviors are often not visible, there are no descriptive or injunctive social norms to support this identity (Cox et al., 2010). Thus, the notion of tapping into an individual's intrinsic identity around "ethic of care" for products, the environment, or wider society was highlighted as a generally successful way to raise participation in the hidden behaviors of waste prevention (Cox et al., 2010).

Behavioral Boomerang or Rebound Effects

The tendency when given feedback (e.g., social comparison) for individuals that are performing better than average to increase their consumption is known as a "boomerang" or "rebound" effect (Andor and Fels, 2018). Andor and Fels (2018) performed a systematic review of causal studies and compared four behavioral economic intervention types on energy conservation: social comparison, commitment devices, goal setting, and labeling. Only 1 study of 24 found a "boomerang effect." However, this individual study also noted that this boomerang effect could be eliminated by adding an injunctive message (Schultz et al., 2007). Similarly, Gillingham et al. (2013) looked at the rebound effect of energy efficiency policies: "studies and simulations indicate that behavioral responses shave 5-30 percent off intended energy savings, reaching no more than 60 percent when combined with macroeconomic effects" (Gillingham et al., 2013, p. 476). Even when taking rebound effects into account, interventions can result in substantial change.

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Interventions Using Financial Strategies and Their Possible Moderation by Intrinsic Motivation

Financial interventions have been found to be more influential for behavior change than psychosocial behavioral interventions (Nisa et al., 2019). Within the diet change literature, both taxation and subsidization were consistently found to influence dietary behaviors in the directions in which they were designed to work (i.e., subsidies increase consumption of healthier foods, taxes reduce purchases of less healthy foods) and to work well in tandem (Niebylski et al., 2015). In the research on residential solid waste management, studies have examined the effectiveness of fees to reduce residential solid waste disposal. Facing high costs for solid waste disposal and difficulties in locating new landfill and incineration sites, about one-quarter of U.S. communities charge a fee for residential solid waste collection (Skumatz, 2008). These programs, which are also known as pay-as-you-throw or unit-based pricing programs, shift the costs faced by the community to individual households and are intended to reduce total household disposal amounts. Given estimates that about 20 percent of landfill content is wasted food and food scraps (U.S. Environmental Protection Agency, 2015), such policies have immediate implications for community efforts to reduce wasted food within households.

Bel and Gradus (2016) conducted a meta-analysis of 25 studies (1970–2013) that estimated the responsiveness (i.e., elasticity) of household disposal levels to the imposition of such fees. Across all studies, they found an average elasticity estimate of -0.34, that is, that a 10 percent increase in the price charged for solid waste collection led to a 3.4 percent reduction in the amount of waste collected. However, the responsiveness was significantly greater when fees were applied separately to compostable waste or when the price charged was based on the weight of the solid waste rather than on the number of bins or bags of waste from a household. This led Bel and Gradus (2016, p. 178) to summarize that ". . . a fee for compostable waste is . . . therefore highly effective," while questioning the efficacy of imposing fees that did not vary with the weight of the material to be discarded. A key issue with imposing such fees is that residents may respond by disposing of materials outside the fee-based system. Fullerton and Kinnaman (1996) found that about 28 percent of the reduction in waste from a fee-based disposal program in Charlottesville, Virginia, was actually being disposed of illegally through other outlets. However, Allers and Hoeben (2010) report the most municipalities that have imposed fee-based systems are generally satisfied with the system, suggesting illegal dumping is not a large enough issue to disillusion adopters. One important caveat to financial strategies may be that they can negatively affect intrinsic motivations. Prior studies have found that while household demand responds to price, price elasticity

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can be low in the short term or counterproductive because it crowds out other more altruistic or prosocial motivations (Delmas et al., 2013).

Reflective (i.e., System 2) Interventions

Reflective interventions aim at giving people information or appealing to their self-efficacy and rational decision making. Such interventions, designed to increase a person's knowledge about reasons for performing a behavior or appealing to their self-efficacy, are insufficient to promote behavior change (Koop et al., 2019; Sharp et al., 2010; Thomson and Ravia, 2011; Varotto and Spagnolli, 2017). However, reflective or information campaign interventions may promote behavior when people are motivated but do not know exactly how to implement a behavior (Varotto and Spagnolli, 2017). Samdal et al. (2017) corroborated these findings by concluding that behavior change interventions that combine motivation with opportunity and ability can be effective in initiating and sustaining behavior change. Reflective interventions can reinforce an individual's competence, as well as their need for meaning, value, and satisfaction in order to change behavior. Further, Ma and Hipel (2016) pointed out that while public education interventions are insufficient to change societal behavior around municipal solid waste, they can represent a long-term path to societal consciousness. In order to shift societal norms, interventions might best be designed to change beliefs, motivations, and attitudes toward policies and programs rather than having a sole focus on behavior change (Ma and Hipel, 2016).

Semireflective Interventions for Long-Term Behavior Change

Social norms, framing, and tailoring are categorized as semireflective interventions because they represent an individual's attempt to use simple cues or rules about which choices should be made (Koop et al., 2019). In particular, normative messages are effective and repeating these messages can support long-term behavior change (Koop et al., 2019). The framing of messages appears to be important, and messages framed as suggestive, emphasizing direct impacts or real-time information, or that appeal to intrinsic motivation (e.g., conserve for the future) as opposed to extrinsic motivation (e.g., save water and reduce costs) are the most persuasive (Koop et al., 2019). In addition, messages of competitive peer ranks (i.e., social comparison) are more effective with low-consuming households than neutral rank (e.g., average neighbor household consumption), which are more effective with high-consuming households (Koop et al., 2019). Personalized messages or those that reveal attitude behavior discrepancies also invoke behavior change (Koop et al., 2019).

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Automatic Interventions (i.e., System 1)

Automatic interventions are those that use emotional cues, primes, and nudges to change behavior. Using emotional shortcuts, priming, and nudging are categorized as automatic because they represent automatic responses by people (Koop et al., 2019). Koop et al. (2019) found that while the use of emotional cues, primes, and nudges to stimulate domestic water consumption has only been explored in small samples or short-duration studies, they show promise due to the amount of water savings they produced. Similarly, Nisa et al. (2019) conducted a meta-analysis of 83 randomized controlled trials (1976-2017) to explore the most effective mechanisms (i.e., choice architecture, social comparison, information, appeals, and engagement) for promoting household action on climate change. While fewer in number, the strategies that had the highest effect sizes and showed the most promise were choice architecture (i.e., nudge) approaches.

Social Influence Approaches

Varotto and Spagnolli (2017) conducted a random-effects meta-analysis of 36 studies (1990-2015) reporting 70 psychological strategies to promote household recycling in the home environment. They found social modeling to be the most effective strategy, compared with environmental alterations, combined strategies, prompts and information, incentives, commitment, and feedback. The analysis found that social modeling, which was described as the passing of information by people (e.g., block leaders, children to their parents) who also personally engage in the behavior, was effective because it engendered social norms.

Abrahamse and Steg (2013) conducted a random-effects meta-analysis of 29 studies that used social influence approaches to improve resource conservation (e.g., energy savings and use, gas and electricity savings and use, showering time, water use, recycling). The results of the analysis found that, compared with control groups, social influence approaches were effective and that greater effect sizes were found with the block leader, public commitment, and modeling approaches and smaller effect sizes with group and socially comparative feedback and social norms in information and feedback provision approaches. The authors suggested that the approaches that were found to be more effective might be due to their face-to-face delivery mode, and they questioned whether this was cost-effective. The magnitude of the effect depended on the target group but not the type of proenvironmental behavior. Specifically, employees appeared to be the most affected by social influence approaches, followed by students, households, farmers, and hotel guests.

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Andor and Fels (2018) performed a systematic review of 44 causal-effect studies and compared 4 behavioral economic intervention types on energy conservation: social comparison, commitment devices, goal setting, labeling. The authors found that social comparison interventions were the most effective (ranging from 1.2 to 30 percent reduced energy consumption) as well as the most researched, both in terms of quantity and quality. Social comparison interventions appeared to differ in effect on the basis of the mode of delivery, with online or in-home displays being more effective than letters. Nisa et al. (2019), in a meta-analysis of 83 randomized controlled trials to explore the most effective mechanisms for promoting household action on climate change, found social comparisons to be the second most effective approach for behavior change after choice architecture (i.e., nudges).

Despite these supportive findings of social influence approaches, there may be implementation challenges, such as whether such a strategy can be consistently scaled in areas with low social connectedness or where block leaders are unavailable (Varotto and Spagnolli, 2017).

Feedback Approaches

Giving people information about their behaviors that they can use to modify future actions could be effective and engaging ways to alter behavior. Delmas et al. (2013) performed a meta-analysis of 156 information-based energy conservation trials in residential settings (1975-2012) and found that nonmonetary, information-based approaches can be effective for reducing energy usage. Information strategies included in the analysis were savings tips, energy audits, different forms of energy use feedback, and monetary feedback. They found that, on average, individuals in the trials reduced their electricity consumption by 7.4 percent. In general, individuals receiving real-time feedback or experiencing high involvement interventions, such as home energy audits, reduced their electricity use, and individuals receiving lower-level information or less intensive feedback, such as energy saving tips or individual usage feedback and comparative feedback, did not.

Karlin et al. (2015) performed a meta-analysis on the effectiveness of feedback intervention studies in residential settings for conserving energy, as well as how they vary by the treatment moderators of frequency, medium, measurement (e.g., cost or carbon), combination with other interventions, comparison message, granularity, and duration. Feedback resulted in an average energy savings of 12 percent across studies, which was consistent with prior research that found a range of 8 to 12 percent (Karlin et al., 2015). Variables that moderated this effect included medium, comparison message, duration, and combination with other interventions (e.g., goal,

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incentive), while feedback frequency, granularity, and medium did not. More engaging mediums (e.g., computer) appeared more effective than less engaging mediums (e.g., a utility bill). Studies using goal-based comparisons showed significant effects compared with controls, while social and historical comparisons did not. The authors underscored the relevance of this finding because the use of social comparisons is the most commonly used type of feedback by industries, such as public utilities. Users' attention to feedback can vary over the duration the feedback is provided, with users generally engaging more initially and then less over time. At the same time, longer durations of feedback may be necessary to allow habits to be created and maintained. Finally, feedback was most effective when it was combined with goal-setting or external incentive interventions.

Promoting Healthy Behaviors Compared with Reducing Unhealthy Behaviors

Carrero et al. (2019) conducted a meta-analysis of 70 interventions to assess the efficacy of implementation intention interventions for promoting healthy eating behaviors. Implementation intention interventions are defined as "volitional planning interventions that support the realization of goal intentions by delegating the control of goal-directed responses to anticipated situation cues that elicit these responses automatically" (Carrero et al., 2019, p. 239). For example, using if-then plans to detail where, when, and how one intends to behave in a future situation. These interventions are less effective at reducing unhealthy behaviors (e.g., eating less fat) and more effective when promoting healthy eating behaviors (e.g., eating more fruit), possibly because of the challenge of breaking a habit compared with initiating a new behavior (Carrero et al., 2019). Moderators for unhealthy and healthy eating goals differed. For unhealthy eating, plan formulation was the only significant moderator variable and implementation intention interventions had low efficacy regardless of intervention design. The variable plan formulation indicated that when these plans were designed only to avoid the unhealthy food, they were less effective than when they were planned with an alternate positive action in mind. For healthy eating, moderator variables explained 53 percent of the variance; effect size was negatively predicted by age, with younger people having more favorable outcomes than older people. It was also affected by an implementation intention check, meaning that an instructor checking the plans reduce the intervention's efficacy. Effect sizes were positively predicted by initial training, off-line delivered interventions, and specific if-then plans and action plans, in comparison with more complex plans.

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Communication Campaigns Aimed at One-Time or Infrequent Behaviors

In a narrative review on how health communications campaigns affect behavior, Snyder (2007) described the overall impact of communication campaigns and some of the most important lessons learned from prior health campaigns in terms of campaign planning (i.e., goals and strategies of the campaigns). The review found that, on average, health campaigns can positively affect outcomes in interventions communities by about 5 percent and have an average reach of 40 percent of their target populations. Short-term and intense campaigns with more frequent exposures resulted in greater short-term effects. In general, campaigns that promoted the adoption of new or replacing an old behavior with a new behavior or a change in an infrequent or one-time behavior were more successful than campaigns aimed at a habit, such as stopping an unhealthy behavior already in practice, or preventing initiation of risky behaviors.

Gamification Interventions

In an interesting systematic review of the use of gamification and serious games on domestic energy consumption, Johnson et al. (2017) systematically reviewed 26 studies to assess the potential of using well-designed digital games to change energy consumption behavior. Serious games were defined as "fully fledged games (e.g., a digital role-playing game in which the player completes challenges or quests designed to educate them about nutrition), while gamification refers to the application of parts of games in a non-game setting (e.g., a mobile phone app designed to track and encourage exercise that uses levels, points, and badges" (Johnson et al., 2017, p. 249). While differing widely in methodology, intervention design and framework, and disciplinary focus, the studies found that applied games had a positive effect on behavior or behavioral antecedents. Two high-quality studies in the sample compared different gaming elements, such as feedback, challenges, social sharing, rewards, leaderboards, and points, and found that competition and social sharing showed effectiveness for encouraging participants to adopt specific behaviors. Only two high-quality studies looked at cognitive outcomes; they both found positive changes in attitudes toward and awareness of energy consumption. Several studies in the sample reported improvements in general but not specific energy consumption and conservation knowledge. Interestingly, the games appeared to have led to improvements in self-reported and actual energy conservation behavior in the short term. The authors concluded that while these initial studies were far from conclusive, the use of applied games holds promise for positively impacting energy consumption.

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Applying Research Findings to Intervention Design

Researchers across the six domains have begun to identify ways to apply their findings about the nature and operation of interventions to provide broader guidance to intervention designers. This section summarizes the support for some key ideas.

Targeting Multiple Behaviors Using Multiple Approaches

Based on their analyses, several authors concluded that the best approach to behavior change was a comprehensive approach that combined behavioral interventions with other approaches such as partnerships with influential organizations, social marketing programs, economic incentives, regulations, or technology (Cox et al., 2010; Koop et al., 2019; Niebylski et al., 2015; Nisa et al., 2019; Sharp et al., 2010; Thomson and Ravia, 2011). Nisa et al. (2019) underscored that behavioral interventions would not be enough because of the low behavioral plasticity of most behaviors and recommended that behavioral interventions might be more effective when used in combination with other strategies, such as financial incentives or policy regulations. For example, financial incentives might initiate behaviors but then be reinforced by behavioral strategies. Or, interventions could be sequenced to initiate with motivating, eye-catching strategies (e.g., financial incentives, social marketing) and move to or add on more information-based strategies to reinforce change (Nisa et al., 2019). Cox et al. (2010) emphasized that interventions are a part of wider social, institutional, and political conditions. Ma and Hipel (2016) explained that successful interventions should also involve all stakeholders (e.g., government, private sector, nongovernmental organizations, the informal economic sector), all factors (e.g., economic, environmental, and social), and incorporate public participation. An integrated range of intervention tools and partnerships can effectively make collective and cumulative impacts (Koop et al., 2019; Sharp et al., 2010).

Comprehensive Interventions

Many studies recommended the development of more comprehensive and conjunctive approaches that address intrinsic and extrinsic motivation, opportunity, and ability; appeal to both rational and emotional processes; and use a systems approach. The goal is to address the complexities of influences on targeted outcomes. As Geiger et al. (2019) explained, the application of several theories of behavior change are needed simultaneously in order to account for the variety of individual costs and benefits and normative and environmental concerns that play a role in explaining behavior,

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illustrating the need for an integrated approach. Cox et al. (2010, p. 211) concurred: "[N]o single approach is sufficient on its own, rather a 'hybrid' method using a suite of monitoring approaches" and recommended that behavior change interventions be composed of a suite of interventions and measures that are needed simultaneously to facilitate and evaluate change.

Koop et al. (2019) recommended conjunctive use of reflective, semireflective and automatic tactics (i.e., reasoned, rational, and emotional processes) to influence behavior, such as persuasive technologies. In particular, the authors recommended interventions that consisted of repetitive messages, primes, and nudges that reinforce previously introduced normative messages, tailored feedback and knowledge. They found that knowledge transfer is only meaningful when people know they can change their behavior and consider it feasible and when tailored feedback is reinforced by repetition, social norms, and message framing (Koop et al., 2019). Miafodzyeva and Brandt (2013) proposed a framework for effective recycling interventions that combined the moral reasons and environmental concerns of the household with the awareness and knowledge of recycling programs and the removal of any major convenience barriers. Snyder (2007, p. S38) concluded that "a comprehensive strategy that addresses policy and environmental constraints, individual factors in behavior change, and social influences on the target population should be considered." In a meta-analysis by Maki et al. (2019) on proenvironmental behavior spillover, the authors found that positive spillover was most likely when interventions target intrinsic motivation.

Interventions that Are Tailored by Context, Phase, and Segment

One study recommended segmenting audiences by context or behavior rather than by demographic group in order to target messages and recommendations, such as "targeting by behavior, actual and perceived risk, misinformation and beliefs, environmental barriers, and communication patterns" (Snyder, 2007, p. S35) Another study suggested that large-scale strategies can be implemented without need for tailoring as long as context was at the forefront (Geiger et al., 2019). One author underscored results showing that implementation intentions (i.e. planning interventions that support the realization of goal intentions) interventions are more effective in young adults—a time when there is a marked increase in initiation and maintenance of habits (Carrero et al., 2019).

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Measuring both Isolated and Combined Effects of Different Behavioral Strategies

There is value in trying to understand both isolated and combined effects of different behavioral strategies (Nisa et al., 2019). In addition, interventions that are well designed to account for intermediate and outcome variables can best assess how a combination of variables adds up to reach an impact (Miafodzyeva and Brandt, 2013). For example, how improving recycling facilities and giving bins to homes interacts to strengthen attitudes and perceived behavioral control (Geiger et al., 2019). Belogianni and Baldwin (2019) emphasized the need to measure actual behaviors over intentions and that changes in intermediate variables, such as knowledge, self-efficacy, and attitude, were important for understanding the mechanisms of behavior change.

Increased Study Duration to Track Maintenance

More understanding is needed of how to prolong and reinforce newly formed habits (Koop et al., 2019). Future studies should be of longer duration in order to maintain and monitor behavior change (Fjeldsoe et al., 2011). Fjeldsoe et al. (2011) conducted an interesting systematic review examining the effect of physical activity and dietary intervention trials on behavior maintenance (n = 29), with maintenance defined as "a physical activity, dietary or combined intervention trial that was considered to demonstrate maintenance of behavior change if a statistically significant between-groups difference in favor of the intervention group was reported at end-of-intervention and at follow-up for at least one behavioral outcome" (Fjeldsoe et al., 2011, p. 102). After a minimum of 3 months post-intervention, Fjeldsoe et al. (2011) noted several interesting findings. First, of the 157 trials initially examined, only 35 percent included behavior maintenance outcomes. Second, of the 29 trials that included maintenance outcomes, participants in 72 percent of studies achieved maintenance of at least one outcome, and 38 percent achieved maintenance on all outcomes. In addition, trials with retention rates of greater than 70 percent were less likely to achieve maintenance than those with lower retention rates. Longer duration trials (more than 24 weeks) were more likely to achieve maintenance, as were trials that included face-to-face contact, used more than six intervention strategies, and included follow-up prompts after the main part of the intervention to reinforce intervention content.

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Readiness for Scaling Up

A few studies cautioned against scaling up before understanding more about which strategies affected which behaviors and outcomes because of the costs of large-scale interventions, particularly face-to-face interventions (Abrahamse and Steg, 2013; Andor and Fels, 2018). Nisa et al. (2019) illustrated the reduced effects on behavior that occur when an intervention is scaled up to the general population. Andor and Fels (2018) described the interventions in their analysis as potentially combining too many strategies, which made it difficult to discern the "pure effects" that should be scaled up. These authors recommended the practice of performing impact evaluations prior to rolling out policy or large-scale interventions. Sweet and Fortier (2010) recommended that it would be useful to understand whether strategies should be deployed simultaneously or sequentially.

Positive or Negative Messaging

Carrero et al. (2019) recommended that policy makers avoid negatively framed policies. Cox et al. (2010) and Sharp et al. (2010) discussed how tapping into a culture or ethic of care was more important than aligning with "green" behavior. And Li et al. (2019) described that focusing on the positive benefits of a particular behavior could bring higher place attachment and improve quality of life.

SUGGESTIONS FOR FURTHER STUDY

Researchers in the six domains have made suggestions for further study on behavioral change, covering a wide range of topics: habits, interventions on contextual factors, understanding why interventions work, equity, the generalizability of interventions, the persistence of intervention effects over time, the dearth of effectiveness studies in comparison with efficacy studies, better study design to track pathways, the need for more cross-context understanding, evaluation studies, and cost-effectiveness studies.

Not enough is known about habits. More understanding is needed about habits, such as how habits differ from more one-off and infrequent behaviors, how to undo old and create new habits, how to prolong and reinforce newly formed habits, and how interventions may differ between those that target one-off and infrequent behaviors and those that target habits (Koop et al., 2019).

Interventions targeting contextual factors are underrepresented. Linking the drivers-based evidence with the intervention-based research is

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challenging as some determinants and interventions (e.g., contextual) are systematically underrepresented and some are widely covered (e.g., psychological: motivation, information and knowledge, beliefs/perception, social influence) (Koop et al., 2019; Nisa et al., 2019; Varotto and Spagnolli, 2017).

The vast majority of existing interventions illuminate whether specific interventions work but not why. Many meta-analyses and systematic reviews found that relatively few studies included measures of behavioral antecedents, such as social norms, attitudes, or knowledge, and thus could not explain why an intervention worked or what it changed, only whether it worked (Abrahamse and Steg, 2013; Abrahamse et al., 2005). Both the "how to" and the "why" are important in learning how to design an effective intervention that includes techniques to both initiate and maintain behavior change (Samdal et al., 2017).

Few studies addressed equity or equity components. Few studies included measures of outcomes or discussions related to equity. In one of the only studies to do so, Ma and Hipel (2016) conducted a systematic literature review on municipal solid waste management to understand the social dimensions of that management. The review highlighted that the negative effects of solid waste were inequitably distributed among populations and that more vulnerable populations often bear the negative consequences of being near or able to see waste sites. This inequity means that more vulnerable populations often have to advocate for waste management and often do not gain traction because it is not a problem equally experienced by all. For example, in many cases more vulnerable populations were more exposed to the environmental contamination of solid waste disposal and while this affected their awareness and attitudes, it did not affect other societal strata in the same way. In addition, these populations lacked the agency to change.

Little is known about the extent to which interventions are generalizable to large-scale populations. Most studies mention the challenges of generalizability in terms of the extent to which findings from a behavioral intervention implemented in a specific (geographical, cultural, and behavioral) context can be transferred to a different population. In particular, there is a question about whether the small-scale experiments that often show bigger effects can be effectively scaled up and at what cost (Sharp et al., 2010). In a meta-analysis by Nisa et al. (2019), when interventions were restricted to more generalizable studies (i.e., those with large samples and naïve subjects), the expected probability was reduced to 2-3 percent, a reminder that experimental intervention effects will be more tempered when

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applied to a general population. These authors recommended conducting trials in large samples with naïve populations or restricting subanalyses within systematic reviews to large, naïve samples to understand how effect sizes might be lowered in more general populations.

Little is known about how intervention effects persist over time. Little is known about the long-lasting effects of interventions over time (Abrahamse and Steg, 2013; Koop et al., 2019; Nisa et al., 2019; Snyder, 2007; Varotto and Spagnolli, 2017). Future research is needed to understand which behaviors can be sustained and which interventions stand the test of time (Belogianni and Baldwin, 2019; Niebylski et al., 2015).

The literature has efficacy studies but is remiss in effectiveness studies. Literature in all the domains was largely focused on the efficacy of behavior change interventions but not effectiveness (Bowen et al., 2015). There is an over-emphasis in these studies on whether an intervention is successful, but not why (Abrahamse and Steg, 2013).

Better study designs are needed for parsing impact pathways. More sophisticated study designs are needed that allow for the parsing of study variables (e.g., behaviors, outcomes) so one can learn what can be expected from different approaches and different strategies within these approaches. The majority of current research does not evaluate behavior constructs or how they influence intervention efficacy and therefore best practices cannot be identified (Sweet and Fortier, 2010; Thomson and Ravia, 2011). Most meta-analyses and systematic reviews mentioned the need for a better understanding of the particular pathways of change. For example, how behavior change pathways differ for initiation versus maintenance, for one-off or infrequent behaviors versus habits, and for forming new habits versus breaking old habits, as well as for impact patterns, change over time, and how variables interact with one another.

There is not enough cross-context understanding. There needs to be a better understanding of behaviors and outcomes across contexts. There are different motivations and barriers operating in different contexts, and no single model will transfer across contexts (Whitmarsh et al., 2018). These differences are nuanced. For example, recycling is more common and more transferable across contexts than behaviors aimed at reducing, repairing, and reusing, and there are more barriers to waste reduction (i.e., recycling and reuse) outside the domestic context than within it (Whitmarsh et al., 2018).

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Evaluation studies of intervention implementation are needed. There is a need for formative research, monitoring research, and evaluative research to design, monitor implementation, and evaluate how implementation affects impacts (Snyder, 2007).

Cost-effectiveness studies are needed. There was a common call among researchers for better understanding of the costs of interventions at scale (Snyder, 2007).

REFERENCES

Abrahamse, W., and L. Steg. 2013. Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change* 23(6):1773-1785.

Abrahamse, W., L. Steg, C. Vlek, and T. Rothengatter. 2005. A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* 25(3):273-291.

Addo, I.B., M.C. Thoms, and M. Parsons. 2018. Household water use and conservation behavior: A meta-analysis. *Water Resources Research* 54(10):8381-8400.

Allers, M.A., and C. Hoeben. 2010. Effects of unit-based garbage pricing: A differences-in-differences approach. *Environmental and Resource Economics* 45(3):405-428.

Andor, M.A., and K.M. Fels. 2018. Behavioral economics and energy conservation—A systematic review of non-price interventions and their causal effects. *Ecological Economics* 148:178-210.

Bel, G., and R. Gradus. 2016. Effects of unit-based pricing on household waste collection demand: A meta-regression analysis. *Resource and Energy Economics* 44:169-182.

Belogianni, K., and C. Baldwin. 2019. Types of interventions targeting dietary, physical activity, and weight-related outcomes among university students: A systematic review of systematic reviews. *Advances in Nutrition* 10(5):848-863.

Bowen, D.J., W.E. Barrington, and S.A. Beresford. 2015. Identifying the effects of environmental and policy change interventions on healthy eating. *Annual Review of Public Health* 36:289-306.

Carrero, I., I. Vilà, and R. Redondo. 2019. What makes implementation intention interventions effective for promoting healthy eating behaviours? A meta-regression. *Appetite* 140:239-247.

Cox, J., S. Giorgi, V. Sharp, K. Strange, D.C. Wilson, and N. Blakey. 2010. Household waste prevention—A review of evidence. *Waste Management & Research* 28(3):193-219.

Delmas, M.A., M. Fischlein, and O.I. Asensio. 2013. Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012. *Energy Policy* 61:729-739.

Fjeldsoe, B., M. Neuhaus, E. Winkler, and E. Eakin. 2011. Systematic review of maintenance of behavior change following physical activity and dietary interventions. *Health Psychology* 30(1):99-109.

Fullerton, D., and T.C. Kinnaman. 1996. Household responses to pricing garbage by the bag. *The American Economic Review* 86(4):971-984.

Geiger, J.L., L. Steg, E. van der Werff, and A.B. Ünal. 2019. A meta-analysis of factors related to recycling. *Journal of Environmental Psychology* 64:78-97.

Gillingham, K., M.J. Kotchen, D.S. Rapson, and G. Wagner. 2013. Energy policy: The rebound effect is overplayed. *Nature* 493(7433):475-476.

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Guagnano, G.A., P.C. Stern, and T. Dietz. 1995. Influences on attitude-behavior relationships: A natural experiment with curbside recycling. *Environment and Behavior* 27(5):699-718.

Hagger, M.S., and M. Weed. 2019. Debate: Do interventions based on behavioral theory work in the real world? *International Journal of Behavioral Nutrition and Physical Activity* 16(1):36.

Johnson, D., E. Horton, R. Mulcahy, and M. Foth. 2017. Gamification and serious games within the domain of domestic energy consumption: A systematic review. *Renewable and Sustainable Energy Reviews* 73:249-264.

Karlin, B., J.F. Zinger, and R. Ford. 2015. The effects of feedback on energy conservation: A meta-analysis. *Psychological Bulletin* 141(6):1205-1227.

Koop, S.H.A., A.J. Van Dorssen, and S. Brouwer. 2019. Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics. *Journal of Environmental Management* 247:867-876.

Kwasnicka, D., S.U. Dombrowski, M. White, and F. Sniehotta. 2016. Theoretical explanations for maintenance of behaviour change: A systematic review of behaviour theories. *Health Psychology Review* 10(3):277-296.

Li, D., L. Zhao, S. Ma, S. Shao, and L. Zhang. 2019. What influences an individual's pro-environmental behavior? A literature review. *Resources, Conservation and Recycling* 146:28-34.

Ma, J., and K.W. Hipel. 2016. Exploring social dimensions of municipal solid waste management around the globe—A systematic literature review. *Waste Management* 56:3-12.

Maki, A., A.R. Carrico, K.T. Raimi, H.B. Truelove, B. Araujo, and K.L. Yeung. 2019. Meta-analysis of pro-environmental behaviour spillover. *Nature Sustainability* 2(4):307-315.

Marteau, T.M. 2017. Towards environmentally sustainable human behaviour: Targeting non-conscious and conscious processes for effective and acceptable policies. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 375(2095).

Miafodzyeva, S., and N. Brandt. 2013. Recycling behaviour among householders: Synthesizing determinants via a meta-analysis. *Waste and Biomass Valorization* 4(2):221-235.

Nash, N., L. Whitmarsh, S. Capstick, T. Hargreaves, W. Poortinga, G. Thomas, E. Sautkina, and D. Xenias. 2017. Climate-relevant behavioral spillover and the potential contribution of social practice theory. *Wiley Interdisciplinary Reviews: Climate Change* 8(6):e481.

Niebylski, M.L., K.A. Redburn, T. Duhaney, and N.R. Campbell. 2015. Healthy food subsidies and unhealthy food taxation: A systematic review of the evidence. *Nutrition* 31(6):787-795.

Nisa, C.F., J.J. Belanger, B.M. Schumpe, and D.G. Faller. 2019. Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. *Nature Communications* 10(1):4545.

Samdal, G.B., G.E. Eide, T. Barth, G. Williams, and E. Meland. 2017. Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. *International Journal of Behavioral Nutrition and Physical Activity* 14(1).

Schultz, P.W., J.M. Nolan, R.B. Cialdini, N.J. Goldstein, and V. Griskevicius. 2007. The constructive, destructive, and reconstructive power of social norms. *Psychological Science* 18(5):429-434.

Scott, A., C. Oates, and W. Young. 2015. A conceptual framework of the adoption and practice of environmental actions in households. *Sustainability (Switzerland)* 7(5):5793-5818.

Sharp, V., S. Giorgi, and D.C. Wilson. 2010. Delivery and impact of household waste prevention intervention campaigns (at the local level). *Waste Management & Research* 28(3):256-268.

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Skumatz, L.A. 2008. Pay as you throw in the US: Implementation, impacts, and experience. *Waste Management* 28(12):2778-2785.

Snyder, L.B. 2007. Health communication campaigns and their impact on behavior. *Journal of Nutrition Education and Behavior* 39(2 SUPPL.):S32-S40.

Soderhorn, P. 2010. *Environmental Policy and Household Behavior: Sustainability and Everyday Life*. Abingdon, UK: Earthscan.

Sorrell, S. 2007. Improving the evidence base for energy policy: The role of systematic reviews. *Energy Policy* 35(3):1858-1871.

Sweet, S.N., and M.S. Fortier. 2010. Improving physical activity and dietary behaviours with single or multiple health behaviour interventions? A synthesis of meta-analyses and reviews. *International Journal of Environmental Research and Public Health* 7(4):1720-1743.

Thomson, C.A., and J. Ravia. 2011. A systematic review of behavioral interventions to promote intake of fruit and vegetables. *Journal of the American Dietetic Association* 111(10):1523-1535.

U.S. Environmental Protection Agency. 2015. *Advancing sustainable materials management: 2013 fact sheet*. Available: https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_fs.pdf.

Varotto, A., and A. Spagnolli. 2017. Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology* 51:168-188.

Whitmarsh, L.E., P. Haggar, and M. Thomas. 2018. Waste reduction behaviors at home, at work, and on holiday: What influences behavioral consistency across contexts? *Frontiers in Psychology* 9:2447.

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Appendix F

Committee Member Biographical Sketches

Barbara O. Schneeman (*Chair*) is professor emerita of the University of California, Davis (UC Davis) and currently serves on the Food and Nutrition Board of the National Academies of Sciences, Engineering, and Medicine (NASEM). She previously served as director of the Office of Nutrition, Labeling, and Dietary Supplements at the Food and Drug Administration (FDA), where she oversaw the development of policy and regulations for dietary supplements, labeling, food standards, infant formula, and medical foods. Her prior positions include serving on the nutrition and food science faculty at UC Davis, as well as chair of the Department of Nutrition, dean of the College of Agricultural and Environmental Sciences, and associate vice provost for university outreach. She is a fellow of the American Society of Nutrition and of the American Association for the Advancement of Science and a National Associate of NASEM. She is a recipient of the Conrad Elvehjem Award for Public Service in Nutrition, the Gilbert Leveille award and lectureship, Carl Fellers award and the Samuel Cate Prescott award for research and of the commissioner's special citation, the Harvey W. Wiley Medal, and the merit award from the FDA. She has B.S. degree in food science from UC Davis, a Ph.D. in nutrition from the University of California, Berkeley, and postdoctoral training in gastrointestinal physiology at Children's Hospital in Oakland, California.

Robert B. Cialdini (*Consultant)* is the Regents' professor emeritus of psychology and marketing at Arizona State University. He is also chief executive officer and president of Influence at Work, Tempe, Arizona, which

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focuses on ethical influence training, corporate keynote programs, and the Cialdini method certified trainer program. He has held visiting scholar appointments at Ohio State University, the University of California, the Annenberg School of Communications, and the Graduate School of Business of Stanford University. His research is devoted to the science of influence and its contributions to the fields of persuasion, compliance, and negotiation. His book *Influence: Science & Practice*, a *New York Times* bestseller, distilled research on why people comply with requests. He has a Ph.D. in social psychology from the University of North Carolina.

Cait Lamberton is Alberto I. Duran Presidential Distinguished Professor of Marketing at the University of Pennsylvania's Wharton School of Business. Her research focuses on consumer behavior, with particular focus on topics related to self-control, the reduction of waste in retail and policy settings, scarcity, and online consumer experience. She was an affiliated researcher in the first year of the White House's social and behavioral science team and is currently a team scientist at the University of Pennsylvania's Behavior Change for Good Initiative. She has also been a consultant to the U.S. Department of Education, the U.S. Department of Labor, and to major food manufacturers and financial services firms. She was identified as one of the 25 most productive marketing scholars in the world by the American Marketing Association, and she is a recipient of the Erin Anderson award of the American Marketing Association, the Hunt/Maynard award of the *Journal of Marketing*, and the Lazaridis prize for her work on digital and social media, also from the *Journal of Marketing*. She has a B.A. in English literature from Wheaton College and an M.B.A. and a Ph.D. in business administration and marketing from the University of South Carolina.

Laura C. Moreno is a recent graduate of UC Berkeley's doctoral program in energy and resources. Her research centers around food wasted in households in the United States with a focus on measurement and behavior; how food becomes "waste" within the broader contexts of the food system, health, and everyday life. As part of her research, she worked with the Natural Resources Defense Council, leading the first-of-its-kind household level measurement in the United States, and with Oregon Department of Environmental Quality on a study of wasted food in urban and rural Oregon households. Previously, she worked as an environmental scientist at the U.S. Environmental Protection Agency, focusing on reducing organic waste materials, including food waste, from reaching landfills. In addition to her Ph.D., she has a B.S. in conservation and resources studies and a Master's in energy and resources from the University of California, Berkeley.

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Roni Neff is an associate professor in the Department of Environmental Health and Engineering and the Department of Health Policy and Management at the Johns Hopkins Bloomberg School of Public Health. She also is a program director at the Johns Hopkins Center for a Livable Future, an academic center focused on food systems and public health. Her research focuses on food system environmental sustainability and resilience, including equity. She performs interdisciplinary, applied social science research targeting wasted food from a variety of angles, from the consumer level to policy interventions to food donation and distribution, including leading a 4-year study of seafood waste across the U.S. supply chain. She is on the executive team for the National Food Access and COVID Research Team and is studying food security and food worker issues during COVID. She co-directs a new Ph.D. track in sustainability, resilience and health, and graduate-level food systems concentration and certificate programs. She has an A.B. from Brown University, an M.S. from the Harvard School of Public Health, and a Ph.D. from the Johns Hopkins Bloomberg School of Public Health.

Richard E. Nisbett is the Theodore M. Newcomb distinguished university professor of psychology emeritus and research professor emeritus at the Institute for Social Research of the University of Michigan. He is former director of the university's Cognitive Science Program and former codirector of the university's Culture and Cognition Program. His research interests focus on reasoning and basic cognitive processes, especially induction, statistical reasoning, causal attribution, cost-benefit analysis, and logical versus dialectical approaches to problem solving. He is a recipient of the distinguished scientific contribution award and the William James fellow award of the American Psychological Society and the distinguished senior scientist award of the Society for Experimental Social Psychology. He is a member of the National Academy of Sciences and of the American Academy of Arts and Sciences. His book *The Geography of Thought: How Asians and Westerners Think Differently and Why* won the William James Award from the American Psychological Association. He has a Ph.D. in social psychology from Columbia University.

Jennifer J. Otten is an associate professor and food systems director in the Department of Environmental and Occupational Health Sciences, a core faculty member in the Nutritional Sciences Program at the University of Washington School of Public Health, and co-director of the university's Livable City Year. Her research focus is at the intersection of food systems, population health, and nutrition. She studies the effects of policies and the policy process on diet-related health behaviors and health outcomes; food systems, including school food waste as a community food security

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Appendix G

Glossary

Ability (to prevent food waste): A person's proficiency at solving the problems encountered when performing actions that help prevent food waste. Relevant aspects of ability are knowledge and skills (Van Geffen et al., 2016).

Appeals: A type of intervention to change behavior for the social good (environment, other humans, etc.) where messages are provided containing statistics, factors, narratives, but also possibly normative or descriptive content, including explicit persuasive framing and behavior change prompts with the intention of changing behavior. Appeals can be explicit (ask individuals directly to act) or implicit (give motivational factoids or information).

Behavioral plasticity: The capacity and degree to which human behavior can be altered by environmental factors such as learning and social experience. In theory, a higher degree of plasticity makes an organism more flexible to change, whereas a lower degree of plasticity results in an inflexible behavior pattern.

Behaviors: An individual, group, organization or system's external reactions to both internal factors and external stimuli in its environment.

Built environment: Refers to the human-made environment that provides the setting for human activity, ranging in scale from buildings to cities and

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beyond. It has been defined as "the human-made space in which people live, work and recreate on a day-to-day basis" (Roof and Oleru, 2008).

Choice architecture: A type of intervention that influences behavior by removing external barriers, expediting access, or altering the structure of the environment in which people make choices. They are usually designated as nudges. There are many different types of nudges, such as those that shift perception of the quantity of food (e.g., changing plate sizes), those that shift perceived appeal or quality of the food (e.g., increasing the appeal of healthy foods) and nudges to shift behaviors to what is easier (e.g., offering healthy food in a cafeteria at the beginning of the line).

Cognitive processing: Ability to take in information and transform it, store it, recover it, and put it to work. "Reflective processing" refers to conscious processing of information where attitudes are formed in light of rational arguments, relevant experiences, and knowledge. Tactics for interventions that appeal to this type of processing include knowledge transfer designed to increase self-efficacy. "Semireflective processing" refers to the formation of attitudes through rules of thumb and simple heuristics or cues. Tactics for interventions that appeal to this type of processing include those focused on social norms, framing, and tailoring. "Automatic processing" refers to choices made on the basis of an automatic response, without the intervention of cognition. Tactics for interventions that appeal to this type of processing include emotional shortcuts, priming, and nudging.

Context: The circumstances, conditions, or objects by which one is surrounded.

Contextual factors: Characteristics unique to a particular group, community, society, or individual. These factors include, but are not limited to, personal, social, cultural, economic, and political factors that exist in differing ways and have varying impacts across population groups.

Descriptive social norm: Informal rules that describe the perception of what most people do.

Driver: The factors that may either promote or mitigate the amount of food they discard. Includes causal factors; those that may be statistically correlated; and "intervening factors," which are sometimes called "mediators" or "moderators" that help to explain causal pathways. In addition, drivers can include both the presence of factors that tend to promote a given behavior, such as, in the case of food waste, large portion sizes offered at

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restaurants, and the absence of factors that discourage a behavior, such as lack of knowledge of the negative consequences of an action.

Efficacy: Efficacy is the extent to which an intervention produces the desired results under ideal circumstances.

Effectiveness: Effectiveness is the extent to which an intervention produces the desired results when provided under the usual circumstances or real world environment.

Engagement: A type of intervention that creates involvement or commitment by cueing individuals (e.g., via goal setting or commitments) toward active psychological interaction with the focal content.

Equity: The absence of avoidable, unfair, or remediable differences among groups of people, whether those groups are defined socially, economically, demographically, geographically, or by other means of stratification.

Exhortation: Synonymous with advice: "a form of relating personal or institutional opinions, belief systems, values, recommendations or guidance about certain situations relayed in some context to another person, group or party often offered as a guide to action and/or conduct." (Bonaccio and Dalal, 2006).

Feedback: A type of intervention where individuals are given information about their behaviors such that this information can be used to modify future actions. Feedback interventions are often effective to alter behavior (Delmas et al., 2013).

Financial incentive (or economic incentive): A type of intervention offering financial motivations for people to take actions. Examples are taxes, changes in monetary rewards or prices that make someone alter behavior.

Food literacy: A set of knowledge and skills that help people with the daily acquisition, preparation, consumption, and storage of healthy, tasty, affordable meals for themselves and their families.

Framing: Selecting and emphasizing certain aspects to achieve a desired interpretation by using unconscious biases in information processing (Koop et al., 2019).

Gamification: The use of parts of games (e.g., a digital role-playing game in which the player completes challenges or quests designed to educate them about nutrition) in a non-game setting, such as an app designed to

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track a behavior by using points and badges (Johnson et al., 2017). As an intervention type, gamification could be considered either an engagement (i.e., it prompts people to set goals and then captures goal pursuit behavior) or feedback (i.e., feedback that is given a hedonic, motivational structure through the addition of incentives).

Habits: Context-behavior associations in memory that develop as people repeatedly experience rewards for a given action in a given context. Habitual behavior is cued directly by context and does not require supporting goals and conscious intentions (Mazar and Wood, 2018).

Injunctive messages: Communications that tell actors what to do or avoid doing in a given context; also called prescriptive messages (Winter et al., 2000).

Information interventions: A type of intervention where messages are offered containing statistics, facts, or narratives, but without explicit persuasive framing or behavior change prompts. For example, statistics about amounts of food waste or their impacts.

Injunctive social norm: Informal rules that describe the perception of what most people approve or disapprove (Cialdini et al., 1991).

Intention: An anticipated outcome that is intended or that guides your planned actions.

Intervention: An intervention is a combination of program elements or strategies designed to produce behavior changes among individuals or an entire population. Interventions that include multiple strategies are typically the most effective in producing desired and lasting change. For this report, the committee categorizes interventions into information, appeals, engagement, social comparison/social influence approaches, and choice architecture/nudges, feedback approaches, financial incentives (Nisa et al., 2019).

Knowledge: Familiarity, awareness, or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning. Knowledge can refer to a theoretical or practical understanding of a subject.

Licensing effect: A case where a prior normatively desirable behavior boosts people's self-concepts, thus reducing negative self-attributions associated

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with subsequent behaviors that may not align with norms (Khan and Dhar, 2006).

Moral norms: Informal rules establishing that something aligns with an abstract right or wrong.

Motivation (to prevent food waste): A person's willingness to perform actions that reduce the likelihood or amount of food waste being generated. Relevant aspects of motivation are attitude, awareness, and social norms (Van Geffen et al., 2016).

Norms: Informal rules that govern behavior in groups and societies. Norms in this context refers to moral norms (i.e., when people feel that doing something aligns with an abstract right or wrong), injunctive social norms (i.e., feelings about what one ought to do), and descriptive social norms (i.e., perceptions of what most people are doing) that are strongly correlated with behavior.

Nudge: A modification of the way choices are presented (choice architecture) that influences behavior by such means as removing external barriers, expediting access, or altering the structure of the environment. In the context of food waste, a nudge might, for example, shift perception of the quantity of food (e.g., changing plate sizes); shift the appeal or quality of food (e.g., increasing the appeal of healthy foods); or make a behavior easier (e.g., offering healthy food in a cafeteria at the beginning of the line). Nudges may involve relatively small amounts of economic value—those that do not substantially change one's economic position or power, but that may cue a feeling of loss or gain that is disproportionate to the actual loss or gain experienced. Economic incentives, by contrast, are explicitly intended to shape behavior by changing one's economic position or power in consequential ways.

Opportunity (to prevent food waste): The availability and accessibility of materials and resources required to prevent food waste. Relevant aspects of opportunity are time and schedule, material and technologies, and economic and other contextual factors, material and technologies, policy, and infrastructure (Van Geffen et al., 2016).

Personal value: Internalized cognitive structures that guide choices by evoking a sense of basic principles of right and wrong, a sense of priorities, and a willingness to make meaning and see patterns (Oyserman, 2015).

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Practices: Practices are broadly recognizable activities or groups of behaviors such as throwing out food, cooking food, wasting food, or shopping for food. Behavior focuses on the individual; practices focus on the activities and the groups of behaviors (Lee and Soma, 2016).

Priming: The exposure to one stimulus—such as words or a smell—influences a response to a subsequent stimulus. Unconsciously processed cues (primes) can lead to goal-directed cognition and behavior (Koop et al., 2019).

Proenvironmental identity: The extent to which people indicate that environmentalism is a central part of who they are.

Punishment: Linking a behavior to any consequence that decreases the behavior's rate, frequency or probability. Punishment needs to be tailored to the individual, group, or organization, to follow the behavior in time, and to be seen as a consequence of the behavior. Punishment should be avoided because of negative side effects. If used, emphasis should be on positive reinforcement.

Regulations: A rule or directive made and maintained by an authority.

Self-efficacy: A person's estimate or personal judgment of his or her own ability to succeed in reaching a specific goal, for example, quitting smoking or losing weight, or a more general goal, for example, continuing to remain at a prescribed weight level.

Skills: A subset of ability that reflects the use of one's knowledge effectively and readily in execution or performance. For example, a person needs the skills to integrate knowledge about preventing food waste into their daily life and into their current food management behaviors.

Social comparisons: A type of intervention that provides a comparative reference with respect to the behaviors of others, such as neighbors, colleagues/friends or fellow citizens, based on principles of social influence and social comparison. These principles explain how individuals evaluate their own opinions and abilities by comparing themselves to others in order to reduce uncertainty in these domains, and learn how to define the self.

Social marketing: The adaptation of commercial marketing technologies to programs designed to influence the voluntary behavior of target audiences to improve their personal welfare and that of the society of which they are a part (Andreasen, 1994).

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Social modeling: Learning that occurs by observing others' behavior, also known as *social learning*. This behavior forms an idea of how new behaviors are performed, and on later occasions, this coded information serves as a guide for action (Bandura, 1962).

Societal values: Norms, priorities, and guidelines, which describe what people ought to do if they are to do the "right," "moral," "valued" thing, specifically as held by a group or community; scripts or cultural ideals held in common by members of a group; the group's "social mind." (Oyserman, 2015).

Strategy: In general, a plan of action or policy designed to achieve a major or overall aim. In behavioral science, strategies are combined into a specific intervention to produce behavior changes among individuals or an entire population.

REFERENCES

Andreasen, A.R. 1994. Social marketing: Its definition and domain. *Journal of Public Policy & Marketing* 13(1):108-114.

Bandura, A. 1962. Social leaning through imitation. In *Nebraska symposium on motivation*, edited by M.R. Jones. Lincoln: University of Nebraska Press. Pp. 211-272.

Bonaccio, S., and R.S. Dalal. 2006. Advice taking and decision-making: An integrative literature review, and implications for the organizational sciences. *Organizational Behavior and Human Decision Processes* 101(2):127-151.

Cialdini, R.B., C.A. Kallgren, and R.R. Reno. 1991. A focus theory of normative conduct: A theoretical refinement and reevaluation of the role of norms in human behavior. In *Advances in experimental social psychology*. Vol. 24, edited by M.P. Zanna. Academic Press. Pp. 201-234.

Delmas, M.A., M. Fischlein, and O.I. Asensio. 2013. Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012. *Energy Policy* 61:729-739.

Johnson, D., E. Horton, R. Mulcahy, and M. Foth. 2017. Gamification and serious games within the domain of domestic energy consumption: A systematic review. *Renewable and Sustainable Energy Reviews* 73:249-264.

Khan, U., and R. Dhar. 2006. Licensing effect in consumer choice. *Journal of Marketing Research* 43(2):259-266.

Koop, S.H.A., A.J. Van Dorssen, and S. Brouwer. 2019. Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics. *Journal of Environmental Management* 247:867-876.

Lee, K., and T. Soma. 2016. From "farm to table" to "farm to dump": Emerging research on urban household food waste in the global south. In *Conversations in food studies*, edited by C.R. Anderson, J. Brady and C.Z. Levkoe. Winnipeg, Manitoba: University of Manitoba Press.

Mazar, A., and W. Wood. 2018. Defining habit in psychology. In *The psychology of habit: Theory, mechanisms, change, and contexts*, edited by B. Verplanken. Cham: Springer International Publishing. Pp. 13-29.

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Nisa, C.F., J.J. Belanger, B.M. Schumpe, and D.G. Faller. 2019. Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. *Nature Communications* 10(1):4545.

Oyserman, D. 2015. Values, psychology of. *International Encyclopedia of the Social and Behavioral Sciences* 25:36-40.

Roof, K., and N. Oleru. 2008. Public health: Seattle and King County's push for the built environment. *Journal of Environmental Health* 71(1):24-27.

Van Geffen, L.E.J., E. van Herpen, and J.C.M. van Trijp. 2016. *Causes & determinants of consumers food waste. Refresh deliverable 1.1*. Available: https://eu-refresh.org/causes-determinants-consumers-food-waste.

Winter, P.L., B.J. Sagarin, K. Rhoads, D.W. Barrett, and R.B. Cialdini. 2000. Choosing to encourage or discourage: Perceived effectiveness of prescriptive versus proscriptive messages. *Environmental Management* 26(6):589-594.

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