CHAPTER

2

Effectiveness and efficiency of food-waste prevention policies, circular economy, and food industry

Henning Wilts, Jennifer Schinkel and Carina Koop

Glossary

Benefit-cost Benefit-cost ratio is the ratio of the benefits of a project, expressed in monetary terms, relative to its costs, also expressed in monetary terms. It is used as an indicator of the future profitability of investment alternatives or project options.

Biowaste Biowaste as defined in the new Waste Framework Directive of the European Union comprises "biodegradable garden and park waste, food and kitchen waste from households, offices, restaurants, wholesale, canteens, caterers and retail premises and comparable waste from food processing plants" (Directive (EU) 2018/851).

Circular economy The concept of a circular economy is based on a system in which waste is prevented, products are used as long as possible, repaired if necessary and utilized as a resource at the end of their useful life. This contrasts with a linear system in which the products are usually disposed of—whether through landfill or incineration—at the end of their life cycle. In the context of food, this means that the primary objective is to prevent food losses and waste and, in cases where this is not feasible, to redistribute surplus food preferably for human consumption or alternatively as animal feed.

Food loss and waste (FLW) A decrease, at any stage in the food chain, from harvest to consumption in mass, of food that was originally intended for human consumption, including the nonedible parts of the food produce, regardless of the cause.

2.1 Introduction

According to the World Food Organization (FAO) about one third of produced food is lost every year on the way from the field to the plate. This level of waste is not only irresponsible from an ethical and social point of view, but also results in the loss of the natural resources (e.g., water, energy, fertilizers) that are necessary for the production and processing of food. Excessive food production and disposal also generate a range of environmental impacts including greenhouse gas emissions (GHG), land-use change, deforestation, and local water pollution. In Germany, the production and consumption of foodstuffs is responsible for up to 30% of all environmental impacts (Umweltbundesamt, 2015). Animal products have a particularly significant impact on the environment in terms of land use and GHG. Producing a single kilogram of beef is associated with around 13–15 kg GHG (Müller-Lindenlauf et al., 2013). The balance of fruit and vegetables is better, but their high losses lead to a large CO_2 footprint and high water loss (FAO, 2013).

In this context interest in food-waste prevention has increased significantly in recent years. There are various reasons why policymakers appear to be interested; in addition to the environmental issues, food losses are considered to be undesirable from an ethical, food security, and economic point of view. The issue also aligns well with other priorities such as health and sustainable growth. It is increasingly clear that food is wasted throughout

Food Industry Wastes.
DOI: https://doi.org/10.1016/B978-0-12-817121-9.00002-4

the entire supply chain, and that its prevention will require profound changes in habits, customs, and the organization of work. The potential effectiveness and limitations of food-waste prevention measures and policies have become a hot topic of debate.

Programs targeting food waste have been introduced at a variety of government levels and at the international level. The UN sustainable development goals (SDGs) include a target to halve per-capita global food waste at the retail and consumer levels, and reduce food losses along production and supply chains, by 2030 (SDG 12.3). Nevertheless and despite these policy initiatives, the generation of food waste stays rather stable and has even increased in some parts of the world.

Against this background, this chapter, which is based on a presentation by Wilts (2017), analyzes specific food-waste prevention policies and instruments, and their role in a circular economy. A circular economy focuses on maintaining the value of products and materials for as long as possible and minimizing waste and resource consumption. The aim of the European Commission is to transform the EU economy into a circular economy. This transformation is associated with new business models and behavior changes and contributes to innovation, growth, and job creation (European Commission, n.d. a.). Fig. 2.1 illustrates the concept of a circular economy.

A specific emphasis of this chapter is put on the economic drivers of food-waste prevention policies—what are the economic costs and benefits of food-waste avoidance? The key objectives of this chapter are to:

- provide new insights into the policy framework of food-waste prevention. Who needs to be involved for successful food-waste prevention? And what policy framework is needed to overcome the key barriers?
- highlight methodological approaches as well as empirical evidence for the business case of food-waste prevention. Which measures should be prioritized from an economic efficiency point of view? Where does one unit of taxpayer's money generate the biggest impact on food-waste generation and related environmental impacts?

To this end, this chapter describes which objectives, instruments and measures are already in place to prevent food waste (Section 2.2) and discusses options to quantify the benefits of different instruments and measures (Section 2.3).

FIGURE 2.1 The concept of a circular economy. *EEA, 2016. Circular economy in Europe. Developing the knowledge base. EEA Report No. 2/2016. <https://www.eea.europa.eu/publications/circular-economy-in-europe>, page 10.*

Cost savings of course always create the risks of rebound effects. Money saved by reduced food expenditures will be spent for other consumption purposes and a holistic approach will have to take these risks and challenges into account. Section 2.4 closes with some remarks on these crucial aspects for successful food-waste prevention in a circular economy context.

2.2 Food-waste prevention in a circular economy policy perspective

At different political levels targets for the reduction of food waste as well as indicators for its monitoring have been introduced. Within the framework of the SDGs adopted in September 2015, the United Nations agreed to halve per-capita global food waste at retail and consumer levels, and to reduce food losses along production and supply chains, by 2030 (SDG 12.3). As an indicator to measure the achievement of the targets of SDG 12.3, it is intended to use the "Global food loss index" supplemented by a "Food Waste Index" to monitor waste generation at the end of the food supply chain (FAO, n.d.). Ahead of the SDG, countries and regions have already set their own targets for reducing food waste, for instance as part of their waste prevention programs (EEA, 2019). The regional waste prevention program of Brussels includes the target to reduce food waste at household level by 5 kg/inhabitant each year until 2020 compared with the 2005 baseline. The Dutch target was a 20% reduction in food waste between 2009 and 2015 and the Danish program states that food waste should be reduced at all stages of the value chain. In addition, a wide range of measures to contribute to the reduction of food losses and waste have already been implemented. These include voluntary commitments, food donation laws, and information campaigns. There is an overall consensus that food losses and waste should be reduced, but the relevance of the activities can only be assessed if they are examined in detail.

The EU action plan for a circular economy (European Commission, 2015) emphasizes that the European Union and its member states are committed to compliance with SDG 12.3. As part of the action plan, the European Commission has set up the "EU Platform on Food Losses and Waste" (European Commission, n.d. b.). This platform aims to contribute to the achievement of SDG 12.3 by supporting and connecting actors, defining measures to prevent food waste, sharing best practices, and evaluating the progress. To support the achievement of SDG 12.3, the European Commission has set the following tasks:

- develop a common EU methodology to measure food waste and define relevant indicators;
- take measures to clarify EU legislation relating to waste, food and feed and facilitate food donation and the use of former foodstuff and by-products from the food chain in feed production without compromising food and feed safety;
- examine ways to improve the use of date marking by actors in the food chain and its understanding by consumers, in particular, the 'best-before' label" (European Commission, 2015).

For this purpose, corresponding subgroups have been established within the EU platform.

In July 2018, the EU's circular economy package came into force. This included amendments to the Waste Framework Directive (WFD; 2008/98/EC) and the Landfill Directive (1999/53/EC). The EU member states had two years from that date to implement these amendments into national law. The new WFD (2018/851) states that member states should take measures to contribute to the achievement of the SDGs. It sets an indicative target for the member states to achieve a unionwide food-waste reduction of 30% by 2025 and 50% by 2030. It is stipulated that the member states shall adopt specific food-waste prevention programs as part of their waste prevention programs. The measures taken by the member states shall also promote food donations and other forms of food redistribution for human consumption. The aim is to give priority to human consumption over use as animal feed and reprocessing into nonfood products. Examples of measures include fiscal incentives for the donation of products (e.g., food), and better information for consumers on the importance of "use-by" and "best-before dates." In order to measure the progress in reducing food waste and to facilitate the exchange of best practices across the European Union, between the member states and between food business operators, the development of a common methodology for measuring food waste is intended. On the basis of this methodology reporting on the quantity of food waste should be carried out annually. In 2019 the WFD was complemented by a legislative act establishing the common methodology for the EU member states. For this purpose, the European Commission and the members of the EU Platform on Food Loss and Waste have developed a methodology to monitor food waste (European Commission, 2019). It is also intended to measure progress to SDG 12.3 (Zambrzycki, 2018). The first reporting period will start in 2020. By the end of 2023, the European Commission will review the data on food waste collected by the member states to determine whether it can set an EU-wide target for the reduction of food waste to be achieved by 2030. With regard to generated food waste, Article 22 of the WFD is of importance and states that by the end of 2023 the member states shall ensure that biowaste is either separated and recycled at the point of generation or collected separately and not mixed with other types of waste.

Furthermore, the amended Landfill Directive (2018/850) includes regulations concerning the disposal of unavoidable food waste. To support the European Union's transition to a circular economy, it aims to ensure a progressive reduction of landfill, in particular waste, which can be recycled or used for other forms of recovery. It stipulates that the member states shall endeavor to ensure that all waste that is suitable for recycling and other forms of recovery, in particular municipal waste, shall not be accepted in landfills as of 2030 (unless landfilling leads to the best possible environmental result in accordance with Article 4 of Directive 2008/98/EC). It is emphasized that biodegradable municipal waste accounts for a large share of municipal waste and the disposal of untreated biodegradable waste on landfills is responsible for a wide range of negative environmental impacts such as GHG and pollution of surface water, groundwater, soil, and air.

Norms and standards for food, for example concerning hygiene or appearance, also have a significant influence on the generation of food waste. There are also activities to develop these norms and standards in a way that contributes to the achievement of the SDG. With regard to management standards referring to the food industry, more than 1600 international standards and related documents of the International Organization for Standardization (ISO) address the food sector. These cover food products, food safety management, microbiology, fisheries and aquaculture, as well as starch and its by-products (ISO, 2017). In terms of food waste the ISO 14000 family is particularly relevant. It deals with environmental management standards and is intended to ensure the reduction of negative impacts on the environment caused by the activities of organizations. The ISO standards also aim to contribute to the SDGs, including SDG 12 on sustainable consumption and production (ISO, n.d. a). For instance, the ISO standard "ISO/DTS 26030—Sustainable development and social responsibility – Guidance for using ISO 26000:2010 [Guidance on social responsibility] in the food chain" is currently under development (ISO, n.d. b).

Another actor aiming to contribute to the achievement of the food-waste reduction target of the SDGs is Champions 12.3, (Champions 12.3, n.d.), a coalition of 30 international leaders including CEOs of major companies, government ministers, research institutions, farmer groups, and civil society groups. Their objectives include the quantification and monitoring of the generation of food waste, the pursuit of food-waste reduction strategies and raising awareness among relevant stakeholders. The study "Business Case for Reducing Food Loss and Waste" (Hanson and Mitchell, 2017), prepared on behalf of Champions 12.3, analyzes the financial impacts of food loss and waste reduction efforts. In September 2017, Champions 12.3 and The Consumer Goods Forum announced a call to action to simplify food date labels worldwide by 2020 (The Consumer Goods Forum and Champions 12.3, 2017). An annual progress report assesses the progress made by governments and companies in meeting the SDG 12.3. The 2017 progress report introduced a roadmap for the achievement of SDG 12.3, including milestones for three-year periods until 2030. The latest report presents the results for period 2016–2018. Their assessment concludes that governments are making progress, but that the current pace is not sufficient to meet the milestones set. Their recommendations state that countries with large populations should adopt prevention targets in line with SDG 12.3, that the monitoring of food waste needs to be improved in many more countries, and that many more governments need to enter into public–private partnerships to reduce food loss and waste, support technological innovation, and change in social norms. The milestones set for companies to be achieved in 2018 have been reached. Nevertheless, further efforts are necessary in the interaction between companies and their suppliers. Therefore the recommendations in this area state that companies should support their suppliers in setting their own prevention targets. More of the world's largest food companies and their suppliers should publish the results of their food-waste monitoring. Additionally, more companies need to actively work with their suppliers to reduce food losses and waste throughout the supply chain and to invest more in new technologies and programs (Flanagan et al., 2018).

Overall, there is no lack of initiatives to reduce or prevent food waste—many countries have already introduced an array of policies and measures aimed at reducing food waste (see Fig. 2.2).

These policies and instruments are used and applied at all levels of the value chain. A great deal of effort is being put into education and awareness-raising campaigns targeted at producers and consumers. In this respect, multistakeholder dialogs are being launched and have resulted in voluntary agreements and declarations on monitoring or reduction of food waste.

Examples from certain countries include encouraging of food donations in France, Spain, and Portugal or the reporting of food-waste generation for mass emitters of food wastes in Japan. A number of policies and

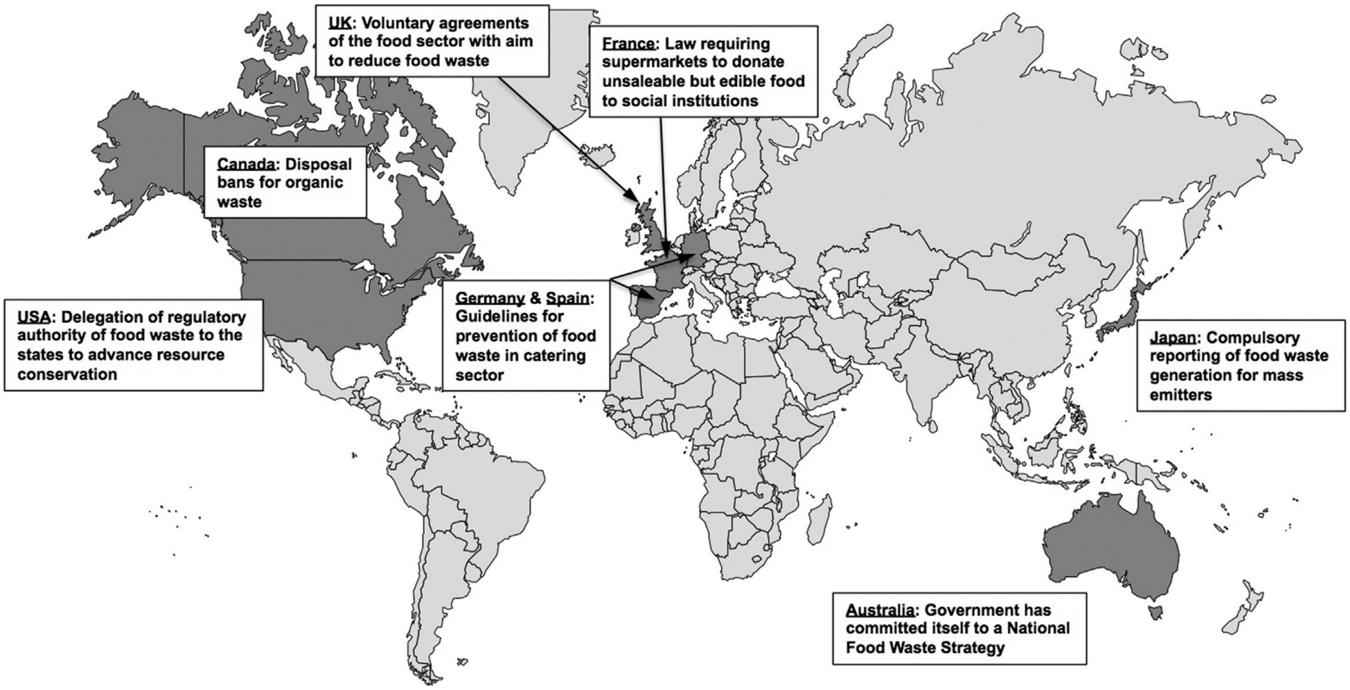

FIGURE 2.2 Exemplary measures for the reduction of food waste in OECD countries.

measures in the Organization for Economic Co-operation and Development (OECD) countries are presented in Table 2.1.

Apart from the potential financial savings associated with reducing food waste, additional arguments have been provided to incentivize waste prevention. For example, it has been suggested that the introduction of food-waste prevention measures can lead to avoided greenhouse gases emissions, less water usage, and the generation of new jobs. This will be discussed in more detail in Section 2.3.

Policy measures can affect the generation of food waste in different ways and can contribute to both reducing and increasing food losses and waste (FUSIONS, 2015; Interreg, 2016). The importance of a thorough selection of policies is underlined by Evans and Nagele: “As policymakers more carefully weigh the relative costs and benefits of proposed food waste policies, they will be better able to identify those laws that are most capable of promoting optimal levels of food waste recovery” (Evans and Nagele, 2018: 249). Nevertheless, uncertainties still remain regarding the appropriate use of instruments, their effectiveness concerning the reduction of food waste, their environmental benefits, and the added value for stakeholders. The following section discusses possible forms of quantifying the value of different instruments.

2.3 (Economic) assessments of food-waste prevention efforts

The lack of data about the relative costs of food-waste prevention measures may be one of the reasons why policy implementation has not been more widespread. Methodological approaches have been developed that could be used as a starting point; the following section assesses their specific strengths and weaknesses. Economic assessments of food-waste prevention policies that have been conducted in the United States, Sweden, and the United Kingdom are being reviewed and discussed. It compares which benefits to the environment, economy and society can be achieved through food-waste reductions. In order to perform such a comparison, the used calculations, data bases and assumptions, such as the definitions of the term “food waste,” are compared with each other along with a conversion into Euro.

TABLE 2.1 Examples of existing directives and measures to reduce food waste.

Prioritization of actions against food waste for better efficiency throughout the whole food chain (e.g., France, Spain)
Law that obliges supermarkets to donate unsalable but edible food to social institutions or to use it alternatively as animal feed or as compost (France)
Law regulating the distribution of surplus products, including food, for charitable purposes (Italy)
Voluntary agreements of the food sector with the aim to reduce food waste (United Kingdom "Courtauld Commitment"; Spain "Decalogue: Food has no waste. Use it.")
Encouraging food donations by fiscal incentives through tax credits and tax deductions (e.g., France, Spain, Portugal)
Clarification of the responsibility of food-related business operators engaged in manufacturing, distribution, and consumption for disposal limitation, reduction, and recycling and stipulation of priority and target value of recycling (Japan)
Compulsory reporting of food waste generation and recycling rate for mass emitters of food wastes (Japan)
Obligatory requirements for registration as food business operator of all charity organizations (that handle the food), liability, traceability, hygiene and other requirements (Lithuania)
Repackaging or sorting food for charitable purposes following mandatory food labeling (Lithuania)
Donation of pre-packaged food labeled "Best before . . ." within the timeframe set in the recommendations (Lithuania)
Collection of donated food for animal nutrition if it is not suitable for trade, and if there are no animal products included (Lithuania)
Donation of food to non-profit organizations by minimizing liability (U.S.)
Deduction of wholesome food donations from tax liability by corporations (U.S.)
Delegation of regulatory authority of non-hazardous waste, such as food waste, to the states to promote and advance resource conservation and recovery (U.S.)
Changing labeling standards—extending deadlines for consumption (Spain)
Facilitation of donation of cooked food from the restaurants, canteens, and catering (Spain)
Guidelines for the prevention of food waste in the catering sector (e.g., Germany, Spain)
Introduction of disposal bans in a number of Canadian provinces and municipalities for organic waste, including food waste providing an incentive for enhanced food waste reduction, surplus food recovery, and food waste diversion (Canada)
Introduction of accreditation mechanism of a collaborative project for food recycling among food waste emitters, food recyclers, and farmers (Japan)

Own compilation, based on Wilts, 2017. Effectiveness and efficiency of food waste prevention measures. Presentation to the 11th Meeting of the Working Party on Integrating Environmental and Economic Policies. July 7th 2017, OECD, Paris.

2.3.1 United States of America: "Roadmap to Reduce U.S. Food Waste by 20%"

ReFED (Rethink Food Waste Through Economics and Data) is a United States based collaboration of businesses, non-profit organizations, foundations and government leaders. It was formed in 2015 to create the "Roadmap to Reduce U.S. Food Waste by 20%." The roadmap provides the basis for the coordination and guidance of key players in the food sector (ReFED, 2016a). Based on economic analyses, the roadmap shows that an investment of 16.5 billion Euro[1] in 27 food-waste solutions could reduce food waste in the United States by 20%, while also generating 92 billion Euro of societal economic value. In more detail, the annual benefits are:

- 1.8 billion meals recovered
- 1600 gallons of water conserved
- A business profit potential of 1.8 billion Euro
- Consumer savings of 5.5 billion Euro
- Creation of 15,000 jobs
- Reduction of 16.2 metric tons[2] of CO_2

[1] The conversion from USD to Euro is based on the exchange rate of 01.01.2016 (USD/Euro: 0.9208). The date was selected to the year of publication of the study.

[2] The American short ton was converted into metric tons for better comparability. 1 short ton = 907,184 kg.

The following definition of food waste was used in the roadmap: "Any food that is grown and produced for human consumption but ultimately is not eaten" (ReFED, 2016a).

2.3.1.1 Calculation of the cost reductions

ReFED's methodology to calculate the financial benefit of reducing food waste is based on four steps: (1) baseline definition, (2) solutions evaluation, (3) data analyses, and (4) data validation (ReFED, 2016b).

2.3.1.1.1 Solutions evaluation

ReFED has identified 50 solutions—divided into those related to waste prevention, recovery, and recycling—that could help to reduce food waste. Solutions for a detailed analysis in the roadmap were prioritized if they met four main criteria: data availability, cost-effectiveness, scalability, and feasibility. From this, 27 solutions were selected and for each solution economic values and nonfinancial impacts were calculated. Examples for the waste prevention solutions are inter alia "standardized date labeling" or "packaging adjustments." An excerpt of the 27 food-waste solutions and the related values and impacts is shown in Table 2.2.

2.3.1.1.2 Baseline definition

The U.S. food-waste generation baseline of 56.3 million metric tons per year was determined through a synthesis of previous studies on food waste and interviews with experts and academics. This amount is divided into 47.1 million metric tons of waste from landfills and incinerators and 9.2 million metric tons of agricultural waste. Landfilled waste includes that from different stages of the supply chain, that is, food manufacturing and processing facilities, food distribution centers, grocers, restaurants, institutional cafeterias, and households (ReFED, 2016a; ReFED, 2016b) (Table 2.3).

The amounts of food waste by category are based on a data set of per-employee waste-generation rates for key industries and a per-capita generation rate for households. The process of determining these amounts was done in four steps:

TABLE 2.2 Food waste solution data set for economical values.

Type	Solution	Benefit (million Euro/year)	Business profit potential (million Euro/year)	Financing cost over 10 years (million Euro)	GHGs (thousand metric tons/year)	Water conservation (billion gallons/year)	Jobs created (partial list)
Prevent	Waste tracking and analytics	1,269	924	81	2,092	317	
Prevent	Standardized date labeling	1,676		75	1,445	192	
Prevent	Produce specifications	358	210	122	383	39	
Prevent	Packaging adjustments	874		1,724	753	100	
Recover	Standardized donation regulation	513		44	648	93	
Recover	Value-added processing	273		99	271	38	153
Recycle	Centralized composting	478	43	903	2,363		9,000
...	...	...	...	...	...	...	...
Total		12,681	1,791	15,710	16,418	1,632	15,165

Modified from ReFED—Rethink Food Waste Through Economics and Data, 2016a. A roadmap to reduce U.S. food waste by 20 percent. <http://www.refed.com/download>, 87,88.

TABLE 2.3 Generation of food waste by category.

Generation by category	Landfill%	Total%	Total (metric tons/year)
Total landfill losses	100%	—	47,132,493
Residential	51%	42%	24,095,546
Restaurants	22%	18%	10,381,561
Supermarket, distribution, and grocery stores	15%	13%	7,232,319
Institutional	9%	8%	4,456,915
Industrial/manufacturing	2%	2%	966,152
On-farm losses	—	16%	9,162,566
Total U.S. food waste	—	100%	56,295,059

Modified from ReFED—Rethink Food Waste Through Economics and Data, 2016b. A roadmap to reduce U.S. food waste by 20 percent. Technical appendix. <https://www.refed.com/downloads/ReFED_Technical_Appendix.pdf>, 8.

1. Initial data set built from BLS[3] Employee and U.S. Census data by country.
2. Waste generation rates complied from literature for each stakeholder type (e.g., the Waste and Resource Action Program [WRAP]'s 2012 study builds the base for the U.S. household food-waste generation rate.)
3. Rates adjusted for existing levels of food donation, recycling, and drain disposal.
4. County data summed within the borders of metropolitan statistical areas for recycling solution modeling (ReFED, 2016b).

2.3.1.2 *Calculation of economic values*

2.3.1.2.1 Data analysis

ReFED carried out a cost-benefit analysis to find out what could be achieved for each solution if they were implemented under real conditions over a period of 10 years. First the *value of food waste* is calculated, therefore data on retail and wholesale food prices are required. To estimate the value of food in retail, data on monthly average food prices were taken from the Bureau of Labor Statistics (BLS) and an advisory board member provided data on wholesale prices for restaurants (ReFED, 2016b). With this basis, the economic value, business profit potential, and financing can be determined.

The *economic value* is defined as the "aggregate financial benefit to society (consumers, businesses, governments and other stakeholders) minus all investments and costs. Economic Value is calculated as an annualized Net Present Value (NPV) that sums all costs and benefits for each solution over 10 years" (ReFED, 2016a). The metric *business profit potential* is intended to describe the annual profits that the private sector could achieve by investing in food-waste solutions (Table 2.2). It takes into account initial investments, differentiated cost of capital, and benefits for nonbusiness stakeholders. The calculation therefore focuses on actual corporate profits after deducting all costs (ReFED, 2016b). In order to calculate the total funding for each solution, the ReFED report determines the value *financing* (Table 2.2). It is estimated that a total financing of 16.4 billion Euro is needed to achieve a 20% food-waste reduction. The financing needs cover all types of capital (grants, equity, debt, tax subsidies) under the assumption that the financing needs will be shared among stakeholders to provide the capital needed to build the solution (ReFED, 2016b).

In the example "standardized date labeling," it can be illustrated how the financial benefit of prevention measures is calculated. First, it is necessary to determine the waste diversion potential. This is the amount of food waste that can be avoided if sufficient resources are provided to scale-up implementation (within existing policy and technology constraints). The diversion potential of "standardized date labeling" is calculated at 363,000 metric tons. It is estimated that the addressable waste of this measure is 7.26 million metric tons and 5% of consumers will change their behavior as a result of a label changes. After estimating the diversion potential, the following calculations were made in order to drive the economic analysis:

- Diversion characterization is the approximate composition of diverted food waste. For this measure the diversion characterization is: 16% grain, 16% meat, 43% fruit and vegetables, 23% milk, and 2% seafood.

[3] BLS = Bureau of Labor Statistics

- Financial costs. For this measure operating costs of 9.17 million Euro/year are assumed for educating consumers about date label changes.

Resulting from these data the financial benefits for "standardized date labeling" would be avoided food costs of 1.68 million Euro per year (Calculation: diversion potential × diversion characterization × food type retail value) (ReFED, 2016b).

2.3.1.3 Calculation of the noneconomic value

In addition to the economic benefits of solutions, ReFED also identifies social and ecological benefits. These include "reduced greenhouse gas emissions," "jobs created," "meals recovered," and "water conserved."

The analysis to determine the *reduced GHG* is based on work by Heller and Keoleian (2015), which examines the underlying GHG impacts from production and transport of nearly 100 food types. ReFED has weighted the GHG emissions data against per-capita retail availability of each food type to obtain weighted average GHG emissions for each of the five food categories (grain, meat, fruits/vegetables, seafood, milk). In addition, the diversion of food waste avoids greenhouse gases caused by organic waste disposal (release of methane gases during decomposition and rotting). In carbon equivalents, this adds up to 0.783kg CO_2e/kg across all food types according to the waste reduction model of the EPA (WARM Model) (U.S. EPA, 2016; ReFED, 2016b).

When calculating the *resulting jobs* it should first be noted that not all solutions are assumed to create new jobs. In the area of recovery solutions "donation storage and handling," "donation transportation." and "value-added processing" can create jobs. For these solutions the costs of additional workload are transformed into jobs created. Overall, recovery and recycling solutions could create around 15,165 new permanent jobs (ReFED, 2016b) but this analysis does not take account possible resulting job losses in other sectors, such as in agriculture.

For more detailed insights into the structures of the different external social costs and the additional calculations for "meals recovered" and "water conserved," readers are advised to refer to the ReFED Roadmap (ReFED, 2016a) and the corresponding ReFED Technical Appendix (ReFED, 2016b) as this cannot be provided in detail here.

2.3.1.3.1 Data validation

To validate data and assumptions of the baseline definition as well as the economic and noneconomic analysis, ReFED conducted more than 80 expert interviews and carried out reviews by a multistakeholder advisory board.

All in all, the four-step methodology is a detailed approach that generates concrete data on the financial saving of food-waste reductions, but there are some limitations. For example the analysis uses generalized data, therefore not the whole U.S. food system is reflected and the ramp-up phases of the 27 solutions are not taken into account (ReFED, 2016b). Besides, it should be pointed out again that the data on financial savings and the reduction of food waste depend on the selected 27 measures. If other measures had been selected, the savings could be also changed.

2.3.2 Sweden: "Reduced food waste—environmental benefits and cost saving"

The Swedish Government set a target for reducing food waste by 20% by 2020 (relative to 2010 levels). The report "Reduced Food Waste—environmental benefits and cost saving" provided by the Swedish EPA (Naturvårdsverket), calculates the gross benefit of decreasing food waste as the sum of economic savings for firms and households, and the value of the avoided environmental costs. With the exception of primary production, benefits throughout the entire food distribution are considered, including food industry, retail, restaurants, institutional kitchens and households. Costs for measures to reduce food waste are not included in the analysis. The report finds that a 20% reduction of food waste in Sweden in 2012 would have resulted in gross benefits of approximately 1.1−1.5 billion Euro[4]. This is divided into:

- Cost reductions for firms and households: 810−910 million Euro
- Benefits from reduced environmental impact: 245−615 million Euro (Naturvårdsverket, 2015)

2.3.2.1 Assumptions and terms

In the report the term "food waste" is used to describe all food products that are thrown away. Food waste is assumed to consist of two parts, unavoidable waste and avoidable waste. Further assumptions of the analysis of benefits are that the total gross benefit consists of cost savings for firms and households and the value of avoided

[4] The conversion from SEK to Euro is based on the exchange rate of 01.01.2015 (SEK/Euro: 0.1060). The date was selected to the year of publication of the study.

environmental damage costs due to decreased production. In addition, it is assumed that a reduction in total waste can only be achieved in the avoidable waste category. It is presumed that waste reduction at one stage of the food chain has no direct impact on waste at other stages of the food chain. It is assumed that waste reductions lead to decreased production and thus to lower environmental impacts. The analysis ignores general equilibrium or rebound effects (Naturvårdsverket, 2015).

2.3.2.2 Calculation of the cost reductions

The amounts of total food waste and avoidable food waste for each sector are presented in Table 2.4. These amounts relate mainly to data from the report "Food waste in Sweden" (Naturvårdsverket, 2014a), an update of previous reports with the same purpose. Additional data about household waste is generated from the report "Amount of food and drink disposed to the drain" that was conducted in 2014 (Naturvårdsverket, 2014b).

Detailed data on food waste from the food industry are based on environmental reports from 135 companies. The companies stated how much vegetable and animal waste is generated in the business (Naturvårdsverket, 2015). The resulting food waste amounts in retail and restaurants have been calculated using a waste factor (kilogram food waste per employee and year). By multiplying the waste factor with the total number of employees in the food retail or restaurants in Sweden, the total amount of food waste from stores and restaurants has been obtained. The food waste amounts in institutional kitchens are based on the same methodology as for retail and restaurants. However, the calculated food-waste factor is not based on the number of employees but on the number of pupils in schools with school kitchens (Naturvårdsverket, 2014a). The amount of food waste in households is divided into solid and liquid waste. The amount of solid food waste was determined by the quantities sorted for biological recovery and the food waste that goes to incineration.

The next step in the analysis was to determine the *value of the reduced food waste* for each sector. For the food industry, the total costs of food waste are estimated at about 228 million Euro and the total amount of waste is estimated at 224,000 metric tons by the Swedish EPA (Naturvårdsverket, 2013). Average cost per metric ton of waste can be calculated by these figures at around 1015 Euro. For households, updated numbers are used from WRAP (2014). The report estimates the value of household food waste (HHFW) to almost 4040 Euro/metric ton. By multiplying these values with the results from the amounts of reduced food waste, it was possible to estimate the cost savings for each sector. The sum of these values for each sector results in the total cost savings per year: 810 million−910 million Euro.

2.3.2.3 Calculation of the environmental benefits

The value of the environmental benefits is calculated in two stages: the environmental impact from food waste, and the monetary value of this impact. For the environmental impact of food waste, the calculations are based on Naturvårdsverket (2012) estimates on data from BIOS (2010) and Moll and Watson (2009). The environmental

TABLE 2.4 Amount of food waste and decrease of avoidable food waste to achieve a total food waste reduction of 20%.

	Food waste (2012)	**Avoidable food waste (2012)**	**Reduction of avoidable food waste to achieve a total food waste reduction of 20%**
	Metric tons	Metric tons	Metric tons
Industry	183,654	183,654	36,731
Retail	70,000	63,700	14,000
Restaurants	142,000	88,040	28,400
Institutional kitchens	58,000	30,160	11,600
Households	995,365	494,215	199,073
Total	1,449,019	859,769	289,804

Note: In the field of industry data for 2010 was used and extrapolated. Household food waste includes data for liquid waste from 2014.

Own compilation based on data from Naturvårdsverket (2015). Minskat matavfall—miljönytta och kostnadsbesparingar (English: Reduced Food Waste—environmental benefits and cost saving), Report 6697, <http://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6697-0.pdf>, 12.

impacts are divided into six load types: GHG, eutrophication, acidification, photochemical oxidation, human toxicity, and ecological toxicity. For monetary valuation, the results from Noring (2014) are used, which are based on the work of Ahlroth and Finnveden (2011).

The analysis is carried out in several steps. First, the environmental impact per metric ton of food waste needs to be assessed and multiplied by the current reductions in waste. For example, food waste from households leads to emissions of approximately 2.07 million metric tons of CO_2 equivalents. When multiplying the CO_2 emissions from all load types, it results in 2.90 million metric tons of CO_2 equivalents. All in all, a 20% reduction of food waste lead to reduced emissions of 568,000−579,000 metric tons of CO_2 equivalents.

In order to attribute the environmental impacts to a monetary value, standardized values per kg CO_2 have been applied. By multiplying the calculated reduction in environmental impact by the monetary standard value for the respective load type, it is possible to calculate the avoided environmental costs for each portion of the food value chain. Summing this data across load type and sector results in 245−615 million Euro total environmental benefit (Naturvårdsverket, 2015).

2.3.3 United Kingdom: "Household Food Waste in the UK, 2015"

The report "HHFW in the UK, 2015" by WRAP contains estimates for total and avoidable HHFW (WRAP, 2017). Since 2007, WRAP has been publishing regular data on HHFW. These previous reports are often used as a database for current estimates. This report does not set out the extent to which certain measures lead to a reduction in food waste, but rather the financial value of the current amount of food waste and for how many greenhouse gases the food waste is responsible. In summary the report shows the following results.

- Amount of HHFW:
  - 7.3 million metric tons per year, or 112.6 kg/person/year
  - 4.4 million metric tons of this (60%), is considered to be avoidable
- Financial and environmental implications:
  - 3,784 Euro[5] (GBP 2,938) financial value of each metric ton of food thrown away
  - 16.7 billion Euro cost of avoidable food and drink waste for the United Kingdom as a whole
  - Avoidable HHFW is associated with 19 million metric tons of CO_2e

The term "food waste" in this report covers the three fractions: avoidable, possibly avoidable, and unavoidable.

2.3.3.1 Calculation of the economic implications

In order to calculate the financial implications it is necessary to determine the amount of food waste that can be saved. The estimated amount of HHFW is 7.3 million metric tons is divided into the following categories:

- Collected by local authorities: 4.9 million metric tons
- Disposed of via the sewer: 1.6 million metric tons
- Either home composted or fed to animals: 0.8 million metric tons

The amount of HHFW collected by local authorities is collated in "Synthesis of Food Waste Compositional Data 2014 & 2015" (WRAP, 2016). To quantify the composition of the food waste generated by United Kingdom households, the synthesis report analyzed waste composition studies and information on the amount of material in different waste streams (WRAP, 2016). Since the synthesis report does not cover all waste streams in households, WRAP estimates the waste volumes associated with three other disposal routes: the sewer, home composting, and feed for animals.

The next step in the analysis was to determine the *financial value of food waste* in United Kingdom households. It was calculated on the basis of WRAP (2013) data on the value of the food that is typically wasted, and taking inflation into account.

To calculate the amount of wasted food, data from Family Food Study for 2011 (Department for Environment Food & Rural Affairs, 2012) on food and drinks brought into the home were used and converted to weight. These data were scaled to the total quantity of food purchased in 2011 using data from the British population census in 2011. Thus a total quantity of 37.7 million metric tons of food and beverages brought into the home was calculated. In order to estimate the amount of edible material, the unavoidable amount of food and drink

[5] The conversion from GBP to Euro is based on the exchange rate of 01.01.2015 (GBP/ Euro: 1,2880). The date was selected to the year of publication of the study.

waste is deducted from the total purchases. This total edible quantity of 36.1 million metric tons is compared to the sum of avoidable and possibly avoidable waste (5.4 million metric tons), which amounts to 15%.

Expenditure on food and drink has been estimated by extrapolating data from the Family Food Survey and amounts to 118 billion Euro. On this basis, the cost of avoidable food and drink waste can be calculated for 2012 (WRAP, 2013). Taking into account the inflation rate between 2012 and 2015, the financial value of food waste by United Kingdom households in 2015 is estimated at 3784 Euro/metric ton. This value multiplied by the amount of avoidable HHFW in 2015 gives a retail value around 16.7 billion Euro that has been thrown away.

2.3.3.2 Calculation of the environmental benefits

The calculation of GHG associated with avoidable HHFW in 2015 is based on a bottom-up approach. This method uses information on the greenhouse gas footprint and quantities of the types of food waste. The current report has updated estimates of greenhouse gas footprints used in previous reports in the following areas:

- Landfill (based on data from MacCarthy et al., 2015)
- The global warming potential of methane (based on data from IPCC, 2014)
- The quantity of gas derived through Anaerobic Digestion (based on information from WRAP, 2014 and U.S. EPA, 2016)

An emission value of 4.4 metric tons per metric ton of food waste is calculated for avoidable HHFW in 2015. The avoidable fraction of HHFW in the United Kingdom is therefore responsible for 19 million metric tons of CO_2e emissions. This is equivalent to the annual emissions of around 30% of cars on British roads. This figure increases to 25.5 million metric tons when the other HHFW fractions (possibly avoidable and unavoidable) are included (WRAP, 2017).

2.3.4 Overview on study methodologies and outcomes

The three studies analyzed in this chapter share a common goal: to analyze the economics of food-waste prevention. Therefore they chose different methodological approaches, highlighting the challenges of assessing specific waste prevention measures from an economic point of view. A key difference is the research design with regard to the estimations on baselines and prevention potentials. The study by Naturvårdsverket calculated the baseline based on assumptions on food-waste generation per employee in different sectors and looked at the costs of a hypothetical reduction of food-waste generation by 20%. The study by ReFED followed a bottom-up approach by analyzing 27 concrete food-waste prevention measures and analyzing their concrete reduction potentials. For the United Kingdom, WRAP focused on the analysis of purchasing expenditures and assumptions on the share of avoidable food waste.

Following these approaches, also rather diverging data sources have been used. The studies by Naturvårdsverket and WRAP are based on detailed empirical studies on the generation of food waste in households and industrial sectors, in combination with, for example, environmental reports from companies in Sweden and statistics on consumption expenditures in the United Kingdom. The study by ReFED put a stronger emphasis on empirical data on the impacts of food-waste prevention measures, analyzing a variety of sources on the 50 measures taken into account for the report.

With regard to the scope of the analysis and the definition of food-waste prevention, Naturvårdsverket and WRAP chose a rather similar approach, implicitly based on the definitions in the European Waste Framework Directive: Both studies only focus on measures that take place before food becomes waste, ReFED follows a broader definition of waste reduction that also takes into account recovery. The study by WRAP focuses on food waste in households, while the other two studies also take into account food waste caused at different stages of the value chain—in the case of ReFED also including the agriculture sector.

In order to compare the three studies, the results from the reports were normalized and calculated per capita. Results are presented in Table 2.5. It turns out that the amount of total food waste in Sweden is estimated at 158 kg/person, while in the United States it is at 177 kg/person. The United Kingdom study did not collect this figure.

The annual HHFW (including drain, composting and pets) was calculated in all three countries and shows that annual HHFW is the lowest in the United States with 76 kg/person, followed by Sweden with 105 kg/person, and the United Kingdom with 113 kg/person. However, the significantly differing figure from the United States should be treated with caution. For the U.S. study, the average value from the WRAP 2012 study was also

TABLE 2.5 Comparisons of methodology and key data in the country studies under review.

	Sweden	United States	United Kingdom
Amount of total food waste (per year)	1.5 million metric tons 158 kg/person	56.3 million metric tons 177 kg/person	Data were not collected
Amount of avoidable food waste (per year)	0.860 million metric tons 90 kg/person	Data were not collected	Data were not collected
Amount of HHFW[a] (per year)	1 million metric tons 105 kg/person	24.1 million metric tons 76 kg/person	7.3 million metric tons 113 kg/person
Amount of avoidable HHFW (per year)	494,000 metric tons 52 kg/person	Data were not collected	4.4 million metric tons 67 kg/person
Value of food waste in households	4040 Euro/metric ton	Data were not collected	3784 Euro/metric ton
Financial Benefit from a 20% reduction of food waste	1.1–1.5 billion Euro 116–158 Euro/person	92 billion Euro 288 Euro/person	Data were not collected
Amount of CO_2 emissions from food waste from households	2.07 million metric tons of CO_2 217 kg/person	Data were not collected	25.5 million metric tons of CO_2 391 kg/person
Reduction of CO_2 emissions from a 20% reduction of food waste	568,000–579,000 metric tons 60 kg/person	16.2 million metric tons 51 kg/person	Data were not collected
Data collection	Data collection from previous reports from the Swedish Environmental Protection Agency (Naturvårdsverket), environmental reports from companies, Avfall Sverige, WRAP and Noring.	Data and assumptions in the analysis were taken from a basic data set, previous studies on food waste, expert interviews, BLS data and Heller/Keoleian.	Data on household food waste from previous reports from WRAP and Defra. Calculation of environmental benefits based on data from MacCarthy et al., IPCC, WRAP and U.S. EPA.
Term food waste	All food products that are thrown away (unavoidable waste and unnecessary waste)	Any food that is grown and produced for human consumption but ultimately is not eaten	Avoidable, possibly avoidable and unavoidable food waste

[a]*Includes drain, composting, pets.*

Own calculations on the basis of: Naturvårdsverket, 2015. Minskat matavfall—miljönytta och kostnadsbesparingar (English: Reduced food waste—environmental benefits and cost saving). Report 6697. <http://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6697-0.pdf>; *ReFED—Rethink Food Waste Through Economics and Data, 2016b. A roadmap to reduce U.S. food waste by 20 percent. Technical appendix.* <https://www.refed.com/downloads/ReFED_Technical_Appendix.pdf>. *WRAP, 2017. Household food waste in the UK, 2015, final report.* <http://www.wrap.wrap-tbx-drupal.torchboxapps.com/sites/files/wrap/Household_food_waste_in_the_UK_2015_Report.pdf>. *Population data from Sweden 2012: 9.52 Mio.; UK 2015: 65.13 Mio.; USA 2014: 318.86 Mio (World Bank).*

chosen as a basis and adjusted. Sweden and United Kingdom studies also calculated the amount of avoidable HHFW. Whereas in Sweden 52 kg of the annual HHFW per person are assessed as being avoidable; it is 67 kg/person in the United Kingdom. Based on these figures on generated and avoidable food waste, also the value of food waste in households was calculated in Sweden and the United Kingdom showing rather similar results. In Sweden, the value is 4040 Euro/metric ton and in the United Kingdom 3784 Euro/metric ton. This similarity can be explained by the fact that both Sweden and the United Kingdom use previous WRAP studies as a basis for the calculation and update them by taking inflation into account.

The financial benefit of reducing food waste by 20% was only calculated in the Swedish and U.S. study. In Sweden the 20% reduction results in 116–158 Euro/person and in the United States 288 Euro/person. Also the estimations for CO_2 emission saving potentials differ between these countries: In Sweden, CO_2 emissions from HHFW account for 217 kg/person, in the United Kingdom this figure is significantly higher, with 391 kg CO_2 emissions/person. A 20% reduction in total food waste in Sweden can reduce CO_2 emissions by 60 kg/person. In the United States, this reduction in food waste can lead to a reduction of 51 kg CO_2 emissions/person. Overall, it can be stated that despite the significant differences in the analytical approaches, the overall assessment for the economic benefit of food-waste prevention leads to results in a comparable range. Nevertheless these differences seem to be based more on diverging approaches in the life cycle assessment of food production and products than on the assessment of prevention activities.

The objective of this analysis was not to compare the effectiveness or efficiency of countries efforts to reduce food-waste generation but to give an overview on different methodological approaches. It should also be noted that the specific figures often depend on estimations and assumptions that not in all cases went through a scientific review process. Nevertheless these studies can be seen as best-practice examples and highlight the opportunities of such evaluations of food-waste prevention measures. But this is only a first step, the development of a common methodology to measure the quantity of food waste annually should follow, as discussed in Section 2.2. A good example is WRAP. They already measure food waste regularly in the United Kingdom. The Belgian region of Flanders has also carried out an extensive monitoring of food losses and waste (Flemish Food Supply Chain Platform for Food Loss, 2017). These three methodologies can also be seen as best-practice examples to measure the quantity of waste for other waste streams, such as packaging or textile waste. There are hardly any models to quantify waste prevention, although this is a valuable tool to convince policy and decision-makers to reduce waste.

2.4 Conclusion

A variety of methodological approaches have been used to assess policies and programs intended to prevent food waste. This final section draws some preliminary conclusions about the effectiveness and efficiency of these programs based on the data presented. It also offers several suggestions for how research in this area could be furthered and highlights the risks of potential rebound effects.

2.4.1 Comparison of the food-waste prevention measures

The effectiveness of prevention measures refers to the environmental benefits achieved by a specific measure or policy instrument, in this case the avoided environmental burden due to reductions in food waste and losses. Determining the environmental benefits of food-waste prevention policies is a crucial precondition in order to assess their economic efficiency and raises a variety of methodological challenges that have been addressed by the studies analyzed in this chapter. As outlined in the introduction, comparing the effectiveness of different measures also requires a common understanding of waste prevention as a concept. It is acknowledged that the analyses with its focus on Sweden, the United States, and Great Britain clearly does not represent the full range of challenges linked to generation of food waste. As highlighted (e.g., by the FAO) many countries in Asia or Africa often face completely different compositions of food waste due to the structure of their agricultural sectors. The biggest differences can be seen in the losses caused by private households. Per-capita food wasted by consumers in Europe and North-America is 95−115 kg/year, while this figure in sub-Saharan Africa and South/Southeast Asia is only 6−11 kg/year (FAO, 2011). These differences must be taken into account for comprehensive food-waste prevention policies; however, this analysis focused on food waste in households and restaurants.

Nevertheless in all regions of the world, the key challenge for analyzing the effectiveness of prevention measures against the background of uncertain baselines and missing data on food-waste generation is estimating the potential food-waste reduction associated with a specific policy intervention. In other words, establishing a causal linkage between specific prevention measures (an awareness-raising campaign for example) and avoided food waste is problematic. The approach developed by ReFED is useful in this respect because it uses a very transparent procedure to derive a "diversion potential" for a variety of measures.

The efficiency of food-waste prevention measures concerns the relationship between food-waste reductions (and their associated environmental benefits) and the public spending or investments required to achieve them. Uncertainties about estimating environmental benefits increase the difficulty of calculating the relative efficiency of measures. The studies considered in Section 2.3 have used different approaches to assess the economic benefits of food-waste prevention. Most studies focus on the financial savings for firms and households from reducing avoidable food waste; however, this overlooks the key drivers for food-waste generation in less-developed areas of the world. Avoided waste treatment or disposal costs are often also calculated. These costs significantly depend on environmental regulations in specific countries (for example, on required treatment for biowaste) and therefore result in diverging saving potentials from country to country. Another key challenge in assessing the efficiency of different food-waste prevention measures is assessing the costs associated with enabling policy measures. In a similar way to valuing environmental benefits, the often-generic description of policy measures makes it difficult to estimate specific costs.

Other studies rather focus on costs and benefits on a company level and estimate return rates on investments instead, as shown in Table 2.6. It should be noted that a lot of the analyzed food-waste prevention measures could also lead to increased costs for consumers. This might of course cause distributional impacts especially on low-income households (Table 2.6).

2.4.2 Food-waste prevention and rebound effects

All of the studies analyzed in this chapter find that food-waste prevention measures have significant cost-saving potential and high returns on investment. Given this, it seems important to gain a better understanding of why food waste continues to be generated in many countries and sectors. Very few studies systematically assess the indirect economic effects of food-waste prevention policies. Reduced food demand from companies and households would lead to reduced economic activity and potential job losses in the agricultural sector, but these are not generally considered. Furthermore, rebound effects are often neglected. Financial savings resulting from throwing away less edible food may be spent on other consumption activities, with uncertain overall environmental outcomes (and even negative if the savings are used, e.g., for additional long-distance travel).

In order to avoid such rebound effects, a holistic change in consumption is necessary. The concept of sufficiency could be a solution. Following its principles, the consumer uses the monetary savings of food-waste consumption to afford products of higher quality. The monetary savings are used as an additional budget to afford, for example, organic food or more durable products. In conclusion, further positive effects regarding ecological impacts can be expected if such cultural and societal changes are achieved.

2.4.3 Further research

The GHG emissions related to consumption show that a true change requires a comprehensive policy framework and societal change toward a sustainable consumption rather than isolated policies. Further research will be needed in order to establish comprehensive policy mixes for food-waste prevention that integrate the ongoing activities alongside the food value chain, including waste prevention production and transport systems, as well as dietary changes toward less meat-based food. Specific emphasis will be necessary on institutional frameworks that internalize environmental costs into the price of food—such concepts of an ecological tax reform will go far beyond isolated food-waste prevention policy instruments. The economic assessments presented in this chapter offer important insights into the overall benefits of such a transformation process toward sustainability.

TABLE 2.6 Median benefit-cost ratios for companies in different sectors.

		Benefit-cost ratio			
Sector	**Example entities**	**Low**	**Median**	**High**	**Number of sites**
Food service (for public sector clients)	Education institutions, hospitals, government restaurants	1.2	1.2	169.0	166
Food production/manufacturing	Crop-producing companies, food and beverage processors	1.1	1.3	318.0	5
Food retail (and manufacturing)	Grocery stores	5.1	5.1	5.1	10
Hotel	Hotels	6.3	7.6	38.2	74
Restaurant	Restaurants, cafés	0.2	8.3	617.7	88
Food service (for private sector clients)		7.3	9.6	17.4	137
Hospitality	Nonhotel leisure, casinos	10.7	22.7	327.1	15
Workplace canteen	Canteens and restaurants located on company premises	1.7	24.7	618.1	673

From Hanson, C., Mitchell, P., 2017. The Business Case for Reducing Food Loss and Waste. A Report on Behalf of Champions 12.3. Champions 12.3, Washington, DC. <http://www.wrap.org.uk/sites/files/wrap/Report_The%20Business%20Case%20for%20Reducing%20Food%20Loss%20and%20Waste.pdf>.

References

Ahlroth, S., Finnveden, G. (2011). Ecovalue08 – a new valuation set for environmental systems analysis tools. *J. Clean. Prod.* 19, 1994–2003. Available from: https://doi.org/10.1016/j.jclepro.2011.06.005.

BIOS (2010). Technical support to identify product categories with significant environmental impact and with potential for improvement by making use of ecodesign measures. European Commission (DG ENV).

Champions 12.3, n.d. Champions 12.3. <https://champions123.org>.

Department for Environment Food & Rural Affairs (2012). Family food 2011. London. <https://www.defra.gov.uk/statistics/foodfarm/food/>.

EEA (2019). Waste prevention in Europe. <https://www.eea.europa.eu/themes/waste/waste-prevention>.

European Commission (2015). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Closing the loop – an EU action plan for the Circular Economy. COM(2015) 614 final, Brussels.

European Commission (2019). Commission delegated decision (EU) .../... of 3.5.2019 supplementing Directive 2008/98/EC of the European Parliament and of the Council as regards a common methodology and minimum quality requirements for the uniform measurement of levels of food waste. C(2019) 3211 final, Brussels. <http://ec.europa.eu/transparency/regdoc/rep/3/2019/EN/C-2019-3211-F1-EN-MAIN-PART-1.PDF>.

European Commission, n.d. a. Sustainability and circular economy. <https://ec.europa.eu/growth/industry/sustainability_en>.

European Commission, n.d. b. EU platform on food losses and waste. <https://ec.europa.eu/food/safety/food_waste/eu_actions/eu-platform_en>.

Evans, A., Nagele, R. (2018). A lot to digest: advancing food waste policy in the United States. *Nat. Resour. J.* 58, 177–214 (Winter).

FAO (2011). Global food losses and food waste: extent, causes and prevention. <http://www.fao.org/3/a-i2697e.pdf>.

FAO (2013). Food wastage footprint: impacts on natural resources. Summary Report.

FAO, n.d. SDG indicator 12.3.1 – global food losses. <http://www.fao.org/sustainable-development-goals/indicators/1231/en/>.

Flanagan, K., Clowes, A., Lipinski, B., Goodwin, L., and Swannell, R. (2018). SDG target 12.3 on food loss and waste: 2018 progress report. Champions 12.3.

Flemish Food Supply Chain Platform for Food Loss (2017). Food waste and food losses: prevention and valorisation. Monitoring Flanders 2015. <http://www.voedselverlies.be/sites/default/files/atoms/files/Monitor_EN_final.pdf>.

FUSIONS (2015). Review of EU legislation and policies with implications on food waste. Final Report.

Hanson, C., Mitchell, P. (2017). The Business Case for Reducing Food Loss and Waste. A Report on Behalf of Champions 12.3. Champions 12.3, Washington, DC. <http://www.wrap.org.uk/sites/files/wrap/Report_The%20Business%20Case%20for%20Reducing%20Food%20Loss%20and%20Waste.pdf>.

Heller, M.C., Keoleian, G.A. (2015). Greenhouse gas emission estimates of U.S. dietary choices and food loss. *J. Ind. Ecol.* 19 (3), 391–401. Available from: http://onlinelibrary.wiley.com/doi/10.1111/jiec.12174/abstract.

Interreg (2016). Report on status quo of food waste prevention and management. Central Europe, Strefowa. Deliverable D.T1.1.1. Version 1, 12 2016.

IPCC (2014). Climate change 2013: the physical science basis. <http://www.climatechange2013.org/>.

ISO (2017). ISO and food: great things happen when the world agrees. Switzerland. <https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/iso_and_food_en.pdf>.

ISO, n.d. a. 12 Responsible consumption and production: ensure sustainable consumption and production patterns. <https://www.iso.org/sdg12.html>.

ISO, n.d. b. ISO/DTS 26030. <https://www.iso.org/standard/71624.html>.

MacCarthy, J., Broomfield, M., Brown, P., Buys, G., Cardenas, L., Murrells, T., et al. (2015). UK greenhouse gas inventory, 1990 to 2013. Annual Report for Submission under the Framework Convention on Climate Change.

Moll, S., Watson, D. (2009). Environmental pressure from European consumption and production. A study in integrated environmental and economic analysis. ETC/SCP Working Paper 1/2009. Copenhagen.

Müller-Lindenlauf, M., Zipfel, G., Münch, J., Gärtner, S., Rettenmaier, N., Paulsch, D., et al. (2013). CO_2-Fußabdruck und Umweltbilanz von Fleisch aus Baden-Württemberg. Endbericht (English: CO_2 footprint and environmental balance of meat from Baden-Württemberg). Ifeu. Heidelberg.

Naturvårdsverket (2012). Nyttan av att minska matsvinnet (English: The benefit of reducing food waste). Report 6527.

Naturvårdsverket (2013). Åtgärder för minskat svinn i livsmedelsindustrin (English: Measures to reduce waste in the food industry). Report 6595.

Naturvårdsverket (2014a). Matavfallsmängder i Sverige (English: Food waste in Sweden).

Naturvårdsverket (2014b). Mängd mat och dryck via avloppet – en enkätundersökning i svenska hushåll (English: Amount of food and drink disposed to the drain – a survey in Swedish households). Report 6624.

Naturvårdsverket (2015). Minskat matavfall – miljönytta och kostnadsbesparingar (English: Reduced food waste – environmental benefits and cost saving). Report 6697. <http://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6697-0.pdf>.

Noring, M. (2014). Valuing Ecosystem Services-Linking Ecology and Policy. Kungliga Tekniska Högskolan, Stockholm, Sweden.

ReFED – Rethink Food Waste Through Economics and Data (2016a). A roadmap to reduce U.S. food waste by 20 percent. <https://www.refed.com/download>.

ReFED – Rethink Food Waste Through Economics and Data (2016b). A roadmap to reduce U.S. food waste by 20 percent. Technical appendix. <https://www.refed.com/downloads/ReFED_Technical_Appendix.pdf>.

The Consumer Goods Forum and Champions 12.3 (2017). Call to action to standardize food date labels worldwide by 2020. <https://champs123blog.files.wordpress.com/2017/09/champions-123-call-to-action-to-standardize-food-date-labels-worldwide-by-2020.pdf>.

Umweltbundesamt (Ed.) (2015). Daten zur Umwelt. Umwelt, Haushalte und Konsum (English: Data on the environment. Environment, households and consumption).

U.S. EPA (2016). Versions of the waste reduction model (WARM) – version 14. <https://www.epa.gov/warm/versions-waste-reduction-model-warm#WARM%20Tool%20V14>.

Wilts, H. (2017). Effectiveness and efficiency of food waste prevention measures. Presentation to the 11th Meeting of the Working Party on Integrating Environmental and Economic Policies. July 7th 2017, OECD, Paris.

WRAP (2013). Household food and drink waste in the United Kingdom 2012. <http://www.wrap.org.uk/sites/files/wrap/hhfdw-2012-main.pdf.pdf>.

WRAP (2014). UK food waste – historical changes and how amounts might be influenced in the future.

WRAP (2016). Synthesis of food waste compositional data 2014 & 2015. <http://www.wrap.org.uk/sites/files/wrap/Synthesis_of_Food_Waste_2014-2015.pdf>.

WRAP (2017). Household food waste in the UK, 2015, final report. <http://www.wrap.wrap-tbx-drupal.torchboxapps.com/sites/files/wrap/Household_food_waste_in_the_UK_2015_Report.pdf>.

Zambrzycki, B. (2018). 3rd outline document on measurement – what's new. Presentation at the meeting of the EU platform on food losses and food waste, subgroup on food waste measurement, 28 February 2018. <https://ec.europa.eu/food/sites/food/files/safety/docs/fw_eu-platform_20180228_sub-fwm_pres-2.pdf>.