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Drivers of Food Wastage and their Implications for Sustainable Policy Development

Krista L. Thyberg
SUNY Stony Brook, krista.thyberg@stonybrook.edu

David J. Tonjes
SUNY Stony Brook, david.tonjes@stonybrook.edu

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Krista L. Thyberg *
David J. Tonjes

Department of Technology and Society
Stony Brook University, Stony Brook, NY 11794-3760, USA

* Corresponding author:
Krista L. Thyberg
Department of Technology and Society
Stony Brook University
Stony Brook, NY 11794-3760
KLThyberg@gmail.com
P: 631-632-8770

Abstract

There has been growing interest in establishing food waste prevention and recovery programs throughout the world. The drive to target food waste stems from increasing concerns about resource conservation, food security, food waste's environmental and economic costs, and a general trend in the waste management industry to transition to more sustainable practices. Here the drivers of residential, institutional, and commercial food waste generation in developed countries, particularly in the U.S., are explored. The impacts of food system modernization on food waste generation are examined, particularly impacts related to food system industrialization, urbanization, globalization, and economic growth. Socio-demographic, cultural, political, and economic drivers of food wastage are described with emphasis on how food waste perspectives may vary globally. Specific behaviors and attitudes which result from many of these waste drivers are then discussed. The examination of the range of food wastage drivers are used to provide insight into the best policy approaches to sustainably manage food waste. Food waste prevention policies are placed in context of the waste generating behaviors and attitudes that they address. A review of important background information on food waste is also provided, including definitions of key terms, food waste history, quantities of food waste generated, and the importance of food waste prevention for sustainability, as this information is all critical for effective policy development.

Keywords: food waste, waste management, waste prevention, sustainability, behavior, policy

1. Introduction

In the U.S., food waste makes up nearly 15 percent of the disposed municipal waste stream and Americans dispose over 0.6 pounds of food waste per person per day. The amount of food waste disposed has been increasing over time (Thyberg et al. 2015). Globally, it has been estimated that one third of the edible parts of food produced for human consumption is lost or wasted (Gustavsson et al. 2011). Wasted food is a considerable component of the world's food system challenges. The global population is quickly growing, urbanizing, and becoming wealthier, leading to a diversification of dietary patterns and an increase in demand for land,

resources, and greenhouse gas intensive foods, such as meat and dairy. It is estimated that continuing population and consumption growth worldwide will lead to an increase in the global demand for food for at least 40 more years, leading to intensified use of natural resources, especially land, water, and energy (Godfray et al. 2010). These difficulties are exacerbated by the world's changing environmental conditions which cause food production to be unpredictable and increasingly difficult globally (Garnett 2014).

It is becoming clear that the many negative environmental effects of food systems must be minimized to ensure enough food is available to feed the world's growing population in a sustainable way (Tilman et al. 2001). Shifting toward more sustainable food systems is both essential and urgent, and actions are needed throughout food systems on moderating demand, producing more food, improving governance, and reducing waste (Godfray and Garnett 2014). By wasting edible food, all of the resources spent growing, producing, processing, and transporting that food are also wasted, resulting in potentially needless environmental impact (Gustavsson et al. 2011). Reduced food waste and proper waste management can also save economic resources, contribute to food security, and minimize negative impacts of food waste on waste management systems.

Interest in food waste prevention and recovery has grown rapidly in the U.S. and abroad, as reflected in federal and state policies (Pearson et al. 2013, Platt et al. 2014). A recent survey indicated that awareness of food waste has begun to grow among U.S. consumers (Neff et al. 2015). However, currently very little food waste is recovered (USEPA 2014) and prevention initiatives are limited. Prevention programs aim to reduce the amount of food waste generated and recovery programs typically aim to divert food waste from disposal (landfilling or incineration) and treat it with biological treatment (composting or anaerobic digestion [AD]) to capture nutrients and/or energy. Food waste prevention has the highest economic, social, and environmental benefit relative to other waste management approaches. The environmental benefits related to prevention are largely explained by avoided food production (Schott and Canovas 2015). Prevention also enables economic and social priorities to be achieved (e.g., money saved by not purchasing food that is disposed, reallocated excess food to charity).

Effective policies for food waste prevention should address the behaviors and motivations of food waste generation. Some past work has focused on identifying behavioral causes of food waste using surveys and interviews (e.g., Graham-Rowe et al. 2015, Jorissen et al. 2015, Neff et al. 2015, Parizeau et al. 2015). Here the drivers of these behaviors are first explored to provide a broad picture of food waste generation. The impacts of food system modernization on food waste generation are examined, particularly impacts related to food system industrialization, urbanization, globalization, and economic growth. Socio-demographic, cultural, political, and economic drivers of food wastage are reviewed with emphasis on how food waste perspectives may vary globally. Next, specific behaviors which result from many of these waste drivers are discussed. This knowledge of food wastage drivers and behaviors are then used to provide insight into the best policy approaches to sustainably manage food waste. Food waste prevention policies are placed in context of the waste generating behaviors and attitudes that they address. This research can be used to guide the development and implementation of multi-faceted food waste prevention programs which address the three aspects of sustainability (economic, environmental, and social factors).

2. Background: Food Waste Definitions, History, and Quantities Generated

2.1 Food Waste Definitions

Definitions of food waste are not universally agreed upon (Lebersorger and Schneider 2011), which makes studying and quantifying food waste difficult (Buzby and Hyman 2012). Different categorizations are generated based on what materials are included, means of production, and management approaches (Gjerris and Gaiani 2013). Multiple terms have been used interchangeably, such as food loss, food waste, biowaste, and kitchen waste (Schneider 2013a). Also, often the same terms are used, but with different meanings (Gjerris and Gaiani 2013). This is exacerbated when reports are translated (Schneider 2013a). Table 1 provides an overview of previously used definitions; Table 2 provides a complete definition of both food loss and food waste as used in this paper. Here focus is placed on food waste rather than food loss because in the developed world, food waste is generated in higher quantities than food loss. Therefore, the greatest potential for reduction lies with the generators of food waste (retail and consumer sectors) rather than loss (production and processing sectors) (NRDC 2012, Papargyropoulou et al. 2014, Parfitt et al. 2010).

Table 1. Food Waste Definitions

Author	Year	Definition
Kling	1943	Food waste is the destruction or deterioration of food or the use of crops, livestock and livestock products in ways which return relatively little human food value.
Food and Agriculture Organization (FAO)	1981	Food waste is all food products allocated for human consumption that are instead discarded, lost, degraded, or consumed by pests at any stage of the food chain.
FAO	2013	Food waste is food appropriate for human consumption that is discarded (generally at retail and consumption stages).
European Commission	2014	Food waste is food (including inedible parts) lost from the food supply chain, not including food diverted to material uses such as bio-based products, animal feed, or sent for redistribution.
United States Environmental Protection Agency (USEPA)	2014	Food waste is uneaten food and food preparation wastes from residences, commercial, and institutional establishments. So, food wastes from homes, grocery stores, restaurants, bars, factory lunchrooms, and company cafeterias are included. Pre-consumer food waste generated during food manufacturing and packaging are excluded.
United States Department of Agriculture (USDA) (Buzby et al. 2014)	2014	Food waste is a subset of food loss and occurs when an edible item goes unconsumed. Only food that is still edible at the time of disposal is considered waste.
World Resources Institute (WRI)`	2015	Food loss and waste refers to food, as well as associated inedible parts, removed from the food supply chain.

Table 2. Food Waste and Loss Definitions Used in this Study

Term	Definition	Drivers	Sectors Included	Examples
Food Loss	Decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption	-Infrastructure limitations -Climate and environmental factors -Quality, aesthetic, or safety standards	Production, post-harvest, and processing	-Edible crops left in the field -Food that spoils due to poor transportation infrastructure from factory to supermarket -Food that is contaminated during food processing

Food Waste	Food which was originally produced for human consumption but then was discarded or was not consumed by humans. Includes food that spoiled prior to disposal and food that was still edible when thrown away	-Decisions made by consumers and businesses -Quality, aesthetic, or safety standards	Retail and consumer	-Plate waste -Food that spoils due to poor storage in home or restaurant -Restaurant food prepared but discarded due to lack of demand

106
107 **2.2 Food Waste History**
108 A history of food waste issues in the U.S. is given in Table 3. Examining the history of
109 food waste provides a foundation for understanding how perceptions of food waste have evolved
110 over time and why certain food wasting behaviors occur today.
111
112 Table 3. U.S. Food Waste History Timeline

Period	Food Waste Activity
Pre-Industrial (1750-1850)	-Food waste accounted for the majority of household solid waste -In the U.S., these wastes were often fed to animals, usually pigs, because pigs are effective at turning food and plant wastes back into food (Ackerman 1997)
1895	-Atwater (1895) conducted a visual survey of residential New York waste bins and noted upper class areas showed a large portion of food purchased but thrown away; waste was less in more moderate neighborhoods
1902	-Atwater (1902) found student clubs wasted 10-14% of nutritive value of food; institutions wasted up to 25%
Early 1900's	-Organized waste collection became common in the U.S.
World War I (1917-1918)	-U.S. government encouraged pig feeding with food waste as a patriotic means to increase food production
World War II (1941-1945)	-Wartime food scarcities increased attention to food waste (Kling 1943b) -Rationing helped control food panics and discouraged wasting food -U.S. government helped people cope with limited supplies of certain foods (USDA 1943) and encouraged consumers and handlers of food to save every salvageable bit (Kling 1943b) -Williamson and Williamson (1942) noted that considerable food loss and waste was taking place; a large portion of food was wasted by the consumer during food preparation and as plate waste -U.S. Food Distribution Administration (1943) estimated that overall U.S. food wastage was 20-30% of all food production -Kling (1943b) estimated that 24% of produced food was lost or wasted -In 1945, the FAO was established and listed food loss reductions as a priority
Post-World War II	-U.S. consumer culture evolved from one of thrift (widespread during wartime), to one of abundance and waste because it was no longer patriotic to conserve food and food became less expensive (Bloom 2010)
1950s	-Because pigs fed garbage are particularly susceptible to diseases and food systems were becoming industrialized, regulations prohibited use of raw garbage as animal feed (Ackerman 1997) -USDA began to formally study food waste, generating small, non-representative samples (Adelson et al. 1961, Adelson et al. 1963); they determined household food waste was 7-10% of total calories
1973-1974	-Extensive surveys of household food waste were conducted by the University of Arizona Garbage Project (Rathje and Murphy 2001); they determined food was 9.7% of total household waste output (by weight) in 1973; in 1974, it was 8.9% (Harrison et al. 1975)
1974	-First World Food Conference (Rome) identified reduction of post-harvest food losses as an element of the solution to global hunger; post-harvest losses were estimated at 15% and a decision was made to reduce this by 50% by 1985 through the Special Action Programme for the

	Prevention of Food Losses (in 2010, Parfitt et al. noted no progress had been made toward this goal)
1977	-U.S. General Accounting Office issued a report to Congress titled 'Food Waste: An Opportunity to Improve Resource Use' urging the U.S. to examine food loss and waste
1980-1981	-Food waste was the focal point of Garbage Project research; participant surveys and food waste diaries were integrated into research; they found households wasted considerable amounts of food, but survey participants greatly underestimated the amount of waste (Rathje and Murphy 2001)
1992	-Garbage Project researchers concluded food was a significant portion of household waste (10-15% of all food bought)
1997	-Kantor et al. (1997) published quantitative estimates of food waste across U.S. food system and concluded 25% of food produced in the U.S. was wasted annually (96 billion pounds)
2010's	-Renewed interest in food waste; calls for waste reduction (Lundqvist et al. 2008) and better management (Lamb and Fountain 2010) -Increased effort to quantify food waste disposal (see Table 4)

2.3 Food Waste Quantification

Quantification of the magnitude of food waste is essential for the development of effective, well-planned food waste management policies, and can be used to determine if future food waste recovery and prevention efforts considerably change the residual waste stream (Thyberg et al. 2015). Understanding the extent of food waste may provide an impetus for people to change their attitudes and potentially their behaviors toward food waste. However, definitional issues, the absence of sound quantification methods, and a general lack of imperative or political will have led to considerable data gaps regarding food waste quantities (Parfitt et al. 2010). A range of diverse methodologies have been used to quantify food waste, all of which have some drawbacks. Some approaches, such as waste characterization sorts and materials flow modeling, attempt to quantify the amount of food waste disposed in municipal solid waste (MSW) (wastes from residential, institutional, and commercial sectors). Other methods (e.g., food diaries, qualitative surveys/interviews, and food supply and nutrition data analyses) focus on overall generated food waste amounts from specific sectors (e.g., households, restaurants) or aim to link disposal amounts with behavioral actions. Some studies focus only on formal wastes and exclude wastes that escape through pathways other than the traditional waste management systems (e.g., waste that goes down the drain, food that is composted at home, food fed to animals). An Australian study estimated that informal food waste disposal represented 20 percent of Australian food waste flows (Reynolds et al. 2014), which suggests that informal disposal of food waste in the U.S. may be considerable.

Some recent efforts have been made to standardize or improve quantification methods (e.g., WRI 2015, Thyberg et al. 2015), although estimates are still varied and differ in their definitions and methodologies (WRI 2015). Table 4 presents some recent published countrywide and global estimates of food loss and waste and illustrates the diversity in scope, scale, and quantification methodologies.

Table 4. Recent Estimates of Food Loss and Waste

Reference	Estimate [a]	Location	Method	Food Loss [b]	Food Waste [b]
Pekcan 2006	816.4 grams/household/day	Turkey	FAO food supply data, household expenditures & survey		√[c]
Lundqvist et al. 2008	Up to 50% of total production	Global	Food supply and loss data from Smil 2000	√	√

WRAP 2009	8.3 million tonnes/year (22% of purchases)	U.K.	Food diary, composition analysis, and local data		√[c]
Hall et al. 2009	40% of total food supply (1,400 calories/person/day)	U.S.	FAO food supply data & human energy expenditure model	√	√
DEFRA 2010	15% of edible food & drink purchases (16% of edible calories)	England	Food purchasing data and WRAP 2009 waste estimates		√[c]
Australian Government 2010	4.06 million tonnes/year (2.67 million tonnes from households and 1.39 million tonnes from commercial/industrial sources)	Australia	State and local waste data	√	√
Buzby et al. 2011	29% of available food supply	U.S.	USDA food supply data & loss factors		√[d]
Gustavsson et al. 2011	33% of total food production	Global	FAO food supply data & loss factors developed by the authors	√	√
Koivupuro et al. 2012	23 kilograms/person/year	Finland	Food diary		√
Kummu et al. 2012	25% of total food production (614 kcal/person/day)	Global	FAO food supply data & loss factors from Gustavsson et al. 2011	√	√
WRAP 2013	4.2 million tonnes/year	U.K.	Food diary, composition analysis, and local data		√[c]
Beretta 2013	48% of total calories	Switzerland	Mass & energy flow model	√	√
USEPA 2014	34.69 million tons/year	U.S.	Materials flow model		√[e]
Oelofse and Nahman 2013	9.04 million tonnes/year (177 kg/person/year)	South Africa	FAO food supply data & loss factors from Gustavsson et al. 2011	√	√
Buzby et al. 2014	31% of available food supply (133 billion pounds)	U.S.	USDA food supply data & loss factors		√[d]
FUSIONS 2015	100 million tonnes/year	European Union	National waste statistics and selected research study findings	√	√
WasteMinz 2015	148 kg/household/year	New Zealand	Waste audits		√[e]
Reynolds et al. 2015a	7.3 million tonnes/year (4.1 million tonnes from municipal sources and households and 3.2 million tonnes from industry)	Australia	Estimation approach using data from government and industry reports	√[f]	√[f]
Thyberg et al. 2015	0.615 pounds/person/day (35.5 million tons/year)	U.S.	Waste characterization studies		√[g]

[a] Estimates as reported in each study. Exact definitions of food loss and waste used may differ from the definitions used here. Some of these differences are noted.
[b] Food loss and waste are defined in Table 2
[c] Only residential waste included
[d] Only retail and consumer waste included
[e] Only household food waste disposed with refuse collected curbside included
[f] Only food waste disposed in formal solid waste routes included
[g] Only food waste disposed in the MSW stream included

3. The Importance of Food Waste Prevention

A sound understanding of the importance of studying food waste provides a foundation for developing sustainable policies to address it. In particular, teaching people about the implications of food waste can alter their perceptions and attitudes toward it, potentially yielding behavior changes that can reduce waste. Therefore, the four primary motivations for studying food waste which address environmental, economic, and social issues are reviewed here.

3.1 Environmental Impacts of Food Production, Storage, and Transportation

There is growing recognition that there are substantial environmental burdens associated with the food supply system (production, packaging, distribution, and marketing). Producing food affects the environment to the detriment of humans, animals, plants, and ecosystems generally (Gjerris and Gaiani 2013). There has been a decadal shift in demand from local and seasonal foods toward imported, non-seasonal fruits and vegetables, increasing transportation and energy use. More food processing also has led to increased energy and material inputs. The increased demand for resource intensive foods, such as meats, makes the environmental impact greater.

Food production and distribution requires large amounts of energy and other resources (Cuellar and Webber 2010). Key environmental risk areas include water, soil, and air. Food production can contribute to water pollution and eutrophication, particularly due to the seepage of nutrients, such as manure and fertilizers, into the broader environment. Agriculture is the largest human use of water so it is a great consumer of a limited resource (Lundqvist et al. 2008). Agriculture may lead to sediment transport and deposition downstream, as well degradation of aquifers (Trautmann et al. 2015). Food supply chains can also have negative emissions to air, including greenhouse gas emissions from agricultural machines and food transport vehicles (Weber and Matthews 2008). Direct effects of food supply systems on the land include soil erosion, nutrient depletion (Nellemann et al. 2009), on and off site pollution (Trautmann et al. 2015), deforestation, desertification, and biodiversity loss. A large percentage of the world's land area is in agriculture; approximately 51 percent of U.S. land is used for growing food (USDA 2015). Land use changes resulting from agriculture can result in biodiversity loss, natural ecosystem loss, and overall ecological degradation (Pretty et al. 2005).

By wasting edible food, all of the resources that went into growing, producing, processing, and transporting that food are also wasted, resulting in potentially needless environmental impact (Gustavsson et al. 2011). The production of this lost and wasted food globally has been estimated to account for 24 percent of total freshwater resources used in food production, 23 percent of global cropland, and 23 percent of global fertilizer use (Kummu et al. 2012). In the U.S., the production of wasted food requires the expenditure of over 25 percent of the total freshwater used in the U.S., about 300 million barrels of oil (Hall et al. 2009), and represents two percent of annual energy consumption (Cuellar and Webber 2010). Venkat (2011) estimated that 112.92 million metric tons of carbon dioxide equivalent per year were emitted from the production, processing, and disposal of avoidable food waste in the U.S.

The impact of food waste on the environment is particularly concerning because population growth and changing consumption patterns will continue worldwide, leading to higher global demand for food and amplified environmental pressures. Thus, it is critical that the impact of food systems on the environment be reduced, yet still produce enough food to feed the world (Tilman et al. 2001). One means of reducing the environmental impact of food systems on the environment is to minimize the amount of food that is produced but is discarded (Godfray et al. 2010).

3.2 Economic Losses

The large economic impact of throwing food away affects all the individuals and organizations involved in the food supply chain. Understanding the economic costs of wastage may encourage behavioral changes to prevent waste, as saving money has been documented as a driving factor in food waste prevention behaviors (Graham-Rowe et al. 2014, Quested et al. 2013, WasteMinz 2014). Table 5 provides recent estimates of the financial cost of wasted and lost food.

Table 5. Economic Costs of Food Waste and Loss

Country	Year	Estimate [a]	Sectors Included	Reference
New Zealand	2015	$589 million/year	Avoidable household waste	WasteMinz 2015
Australia	2015	$5.8 billion/year	All sectors	Food Wise 2015s
Global	2013	$750 billion/year	All sectors (seafood excluded)	FAO 2013
U.K.	2012	$18.3 billion/year, $689/household/year	Household	WRAP 2013
U.S.	2011	$197.7 billion/year, $643.3/person/year	Avoidable distribution, retail & consumer waste	Venkat 2011
U.S.	2010	$161.6 billion/year, 1,249 calories/person/day	Avoidable retail & consumer food waste	Buzby et al. 2014
Canada	2010	$21.1 billion/year	All sectors	Gooch et al. 2010
U.S.	2008	$165.6 billion/year, $390/person/year	Avoidable retail & consumer food waste	Buzby and Hyman 2012

[a] Estimates given in currencies other than U.S. dollars were converted to U.S. dollars

3.3 Food Insecurity

Food security, the availability of and access to sufficient and healthy foods and good nutrition, is imperative for the wellbeing of individuals and nations (Soussana 2014). Although there appears to be sufficient food available to feed the world's population, nearly 11 percent of the global population is food insecure (FAO 2015). In the U.S., nearly 15 percent of households were food insecure some time in 2012 (Coleman-Jensen et al. 2013). Due to this high prevalence of food insecurity, food wastage has an important ethical dimension (Gjerris and Gaiani 2013). If food resources were managed better and wastes were minimized, resources could be used to help feed the hungry, such as by diverting excess food through charitable donations. A theoretical estimate by Reynolds et al. (2015b) found that if all avoidable food waste in Australia were rescued by charity, it could feed 921 thousand people for a year.

Furthermore, food loss and waste amplify the environmental impact of food production along the entire supply chain by requiring more production than is needed based on market demand. Therefore, reducing food waste, while maintaining current production levels, could help meet global food needs. Essentially, food waste avoidance in one region could lead to a higher availability of food elsewhere (Gentil et al. 2011). If less food were wasted, fewer resources would be required to produce food that is not consumed, and these agricultural lands and resources could be liberated for other uses, such as growing food for the world's hungry (Stuart 2009).

Reducing food waste will improve future food availability in the context of global population growth and increasing resource scarcity (Buzby et al. 2014, Godfray et al. 2010, Pearson et al. 2013). The United Nations estimate that the world population will reach 9.3 billion by 2050 (United Nations 2013) and this growth will require an increase in food production by about 70 percent (FAO 2009). To produce enough food to sustain this high

population, pressure will be increased on agricultural land and other limited resources. It is necessary to develop ways to provide more food with fewer inputs so that the world's food system can deliver better nutritional outcomes at a smaller environmental cost (Garnett 2014). Reducing food waste across the entire food chain will be a key part of any strategy to sustainably and equitably feed the world's growing population (Foresight 2011).

3.4 Environmental Impacts of Food Waste Disposal

Food waste may have negative environmental impacts at the end of its life depending on how it is managed. In landfills, food waste converts to methane, a greenhouse gas with a global warming potential 25 times greater than carbon dioxide on a 100 year time scale (IPCC 2007). Although one quarter of U.S. landfills capture methane to create energy, fugitive emissions and landfills without collection systems cause landfills to be the third largest source of anthropogenic methane in the U.S. (USEPA 2011). Food waste tends to degrade faster than other landfilled organic materials, has a high methane yield, and does not contribute to considerable biogenic sequestration in landfills (Levis and Barlaz 2011); therefore, reducing the amount of food waste landfilled should be a priority. Treatment of food waste with waste-to-energy incineration (WTE) is not considered to be energetically favorable due to the high moisture content of food waste (which results in a lower heating value than other materials). Additionally, WTE is unable to capture valuable nutrients within food waste and various environmental pollution problems may arise from inefficient air pollution control measures. As a result, methods other than WTE for the handling of food waste are preferred (Pham et al. 2015).

Food waste can generate benefits (e.g., energy, compost) if managed through composting or anaerobic digestion (AD) or in landfills with efficient gas collection systems. Management of food waste through informal routes, such as donating it to charity or feeding it to pets, may also provide environmental benefit (Reynolds et al. 2014, Reynolds et al. 2015b). Reducing and diverting food waste from disposal may be a means to increase stagnant recycling rates and improve the overall environmental performance of waste management systems.

4. Drivers of Residential, Institutional and Commercial Food Waste Generation

There are many drivers of food waste generation from residential, institutional, and commercial sectors, although detailed information on the exact causes is limited (Lebersorger and Schneider 2011). In the developed world, particularly the U.S., increases in the volume, availability, accessibility (Rozin 2005), affordability, and caloric density of food have led to increased overconsumption and waste (Blair and Sobal 2006). There tends to be little understanding regarding what food is, where it comes from, and what its production entails (Stuart 2009). Culture and personal choice affect decisions regarding what is too good to throw away and these perceptions can change over time. Specific socio-demographic characteristics have also been associated with increased food wastage. Striking differences in attitudes toward food and food waste have been documented both within and across nations (Stuart 2009). Therefore, food waste generation is a function of cultural, personal, political, geographic, and economic forces that influence behavior in specific ways (Pearson et al. 2013) and it may differ from person to person, year to year, or from society to society.

4.1 Modernization of Food Systems

Modernization in food supply chains is associated with industrialization, economic growth, urbanization, and globalization. It is manifested through dietary transitions and affects the amount and type of food that is wasted (Table 6). Countries move through nutritional transitions and food supply changes at different rates, often directly related to cultural and

economic factors (Hawkes 2006, Drewnowski 1999). Those cultures which place emphasis on food as a finite, valuable resource that is to be cherished are likely to modernize at slower rates and ultimately have differing wastage patterns (Stuart 2009).

Table 6. Modernization's Effects on Food Systems

Factor	Description	Effects on Food Systems
Industrialization	Transition from food production and preparation at home to large-scale operations and factories	- Increases distancing of people from food production and preparation - Increases food preparation outside the home - May reduce food costs - Contributes to abundance and variety of food
Economic Growth	Increase in disposable income	- Increases diet diversification, particularly a transition away from traditional foods - May cause reductions in disposable income spent on food
Urbanization	Population shift from rural to urban areas which requires the extension of food supply systems to feed urban populations	- Increases diet diversification - Increases distancing of people from food production
Globalization	Shift from local to global food sources; transition of dietary patterns away from traditional ways toward global trends	- Increases diet diversification away from local foods - Increases distancing of people from food production

4.1.1 Industrialization

Industrialization of food systems, which results in a transition of food production and preparation from the home to factory and from handcraft to purchasing (Strasser 1999), affects the foods that people consume, the types and quantities of food waste, and contributes to increased physical distancing of people from food production and preparation. In areas with industrialized food systems with large amounts of food processing, people often purchase pre-made foods, or canned and frozen vegetables. As a result, pea pods and corns husks, for example, become industrial wastes, while packaging becomes more common in household waste. In industrialized food systems, consumers often purchase pre-cut meats, such as chicken legs, so there are no other components of the chicken to be disposed as waste at the consumer level; the other parts of the chicken are utilized or disposed by industry during the chicken processing.

Increased frequency of eating at restaurants and consumption of takeout food (commercially prepared but consumed at home) (Sobal 1999) have been observed in the developed world. This is partly due to the dramatic rise of two-earner households, leading to little available time for food selection and preparation. As food preparation and consumption is increasingly accomplished in restaurants, some shifts in food waste from homes to the commercial sector may occur. It is estimated that almost half the U.S. food budget is spent eating away from home; USDA estimated that in 2012, $672 billion was spent for food prepared in the home and $630 billion was spent on food outside of the home. This is a dramatic change from the early twentieth century where almost all food expenditures were spent on food prepared within the home; in 1929, $15.3 billion was spent on food in the home and $3.5 billion was spent on food from outside (USDA 2013). Adults tend to be less likely to waste food that they prepared themselves or that a loved one prepared. In cultures based on handwork, handmade things are valuable as they embody many hours of labor. People who have not created or

prepared something themselves, or watched a loved one do so, value labor less than those who have, and therefore, are more likely to throw it away (Strasser 1999). As food preparation and consumption is increasingly done in restaurants, factories, or supermarkets, there is likely to be shifts in the types and quantities of food waste generated by residences, industry, and commercial establishments.

4.1.2 Economic Growth

Higher incomes have generally been associated with the consumption of a more varied diet (Drewnowski 1999, Pingali and Khwaja 2004). Growth in household incomes is associated with a decline in starchy food staples and a diversification of diet toward more meats, dairy, fish, and poultry (Fischler 1999, Parfitt et al. 2010), per Bennett's Law (food share of starchy staples decreases as income increases) (Bennett 1941). This worldwide trend with increases in consumption of protein and energy rich foods, and convenience foods, and decreases in rice consumption, has been documented. Particularly, Asian diets are shifting toward more Western foods (Pingali and Khwaja 2004). Western diets, with vulnerable, shorter shelf-life foods, are associated with greater food waste and a greater drain on environmental resources (Lundqvist et al. 2008). Rathje and Murphy (2001) point out that diet diversification may lead to more food waste, and the more repetitive the diet, the less food wasted. Thus, census tracts with mostly Mexican-American families had less food waste because the ingredients for Mexican food are consistent, making it easy to incorporate leftovers into new meals and staple ingredients are used in almost every meal. In restaurants, larger menus lead to more waste because there are additional ingredients to manage.

As incomes rise, people may be able to waste food because food expenditures are not considerable portions of their income. In wealthy countries, such as the U.S., food is relatively inexpensive compared to other expenses (e.g., housing) and people can afford to waste food (Pearson et al. 2013). The FAO suggest that the careless attitude of consumers who can afford to waste food is a large contributor to household food wastage (Gustavsson et al. 2011). The proportion of U.S. household income spent on food has steadily declined as people have gotten wealthier, food prices have decreased, and the cost of other necessary items have increased. The USDA determined that in 1929, Americans spent 19.3 percent of their disposable personal income on food; the percentage steady declined and in 2012, it was 6.1 percent. In poorer countries, however, expenditures on food are still high. For example, in Pakistan 47.7 percent of disposable income was spent on food in 2012; in Cameroon, it was 45.9 percent (USDA 2013).

4.1.3 Urbanization

Urbanization requires extensions of food supply systems (Parfitt et al. 2010). It leads to diet diversification and a disconnection from food sources which ultimately may increase food waste. Urbanization has increased substantially in the U.S.; in 1790, five percent of Americans lived in urban areas, by 1890 it was 35 percent, and in 2010, it was 81 percent (U.S. Census Bureau 2012). Urbanization is expected to continue increasing globally; one estimate was 70 percent of people worldwide will live in urban environments by 2015 (United Nations 2008). Concentrated, population dense urban food systems are different from those of dispersed, low density rural systems (Solomons and Gross 1995). There are far fewer farms and farmers in urbanized areas, so fewer people interact directly with agricultural processes or live near places where food is produced, hindering knowledge about food origins. This promotes disconnections from food (Parfitt et al. 2010), so that people have no sense of what their food is made of or how it was produced (Fischler 1999). Since food sources are not local, there are more opportunities to market diverse foods, different from those grown locally. Lebersorger and Schneider (2011)

found residual waste from urban Austrian households contained significantly more food waste than rural areas.

4.1.4 Globalization

Food systems have changed due to the shift from local to regional to global foods in terms of quantity, type, cost, variety, and desirability (Hawkes 2006). Globalization means the linkage and integration of previously local, national and regional phenomena into organizational arrangements at a global scale (Sobal 1999). Food supply globalization was made possible by social and technological changes occurring after food supply industrialization (Robertson 1990). New dietary patterns reflect global patterns and may differ significantly from traditional food practices, particularly because non-local foods are available for consumption and there is an overall increase in the range and quantities of available foods (Pingali and Khwaja 2004). Globalization has been associated with the consumption of fewer locally produced plant foods and more imported and processed foods, particularly animal products (Pingali and Khwaja 2004, Sobal 1999). Food now travels long distances (Pretty et al. 2005), and to more supermarkets in place of small, local markets, and so consumers purchase more non-local foods. Changes in diets spurred by globalization affect the type of food that is disposed; people also may be more likely to waste food as they do not have a deep connection and understanding of it.

4.2 Cultural Factors

Culture plays a fundamental role in shaping food, eating, and nutrition (Rozin 2005, Sobal 1998), as well as waste generation. The amount of food a society wastes is dependent on cultural habits and attitudes. People from different cultures regard different foods and food parts as edible, and throw different parts away (Strasser 1999). Pollan (2007) points out that some cultures, particularly the U.S. and Australia, have weak food traditions of their own, meaning there are few longstanding rules and rituals about what to eat and when to eat it, and there are weak connections between the production and preparation of food and its consumption. Bloom (2010) has argued that the U.S. has an unhealthy relationship with food, and overall, the U.S. food culture places little value on food, leading to waste. Other societies have a strong appreciation for food, including production and preparation. Countries such as France have deep food cultures which are deeply embedded in culture and which have been developed over long periods of time (Gatley et al. 2014). French attitudes toward food tend to emphasize moderation and quality, rather than abundance and quantity as in the U.S. (Rozin 2005). Countries with deep food cultures tend to be more resistant to change (or at least change slower) primarily due to strong values surrounding what foods can be grown during certain seasons and how foods are prepared. Many cuisines depend on the longevity of traditional recipes and cooking techniques (Conveney et al. 2012). Deep food cultures may be less affected by changes brought on by modernization of the food supply system.

Furthermore, there are cultural differences in daily food practices which may affect wastage. For instance, there may be cross-national differences in shopping patterns in terms of the amount of food purchased in a single trip, the number of days between shopping trips, and the amount of food stored in the household (Neff et al. 2015). Household shopping practices, particularly the size of the store where groceries are purchased and the frequency of shopping, have been shown to affect wastage (Jorissen et al. 2015). In developing countries, consumers generally buy smaller amounts of food each time they shop (compared to developed countries), often just enough for meals that day (Pearson et al. 2013), which may reduce waste. Extant educational campaigns may also cause differing waste patterns. Mena et al. (2015) found that Spanish retail food managers did not see food wastage as a major problem, but managers in the

U.K. placed waste on a higher agenda. This is possibly due to recent campaigns in the U.K. emphasizing food waste as a problem.

4.3 Socio-Demographic Factors

Surveys of attitudes and behaviors have shown some correlations between food wasting behaviors and certain socio-demographic characteristics (Pearson et al. 2013), although there is no clear consensus regarding which socio-demographic factors relate to more waste. Understanding demographic patterns can lead to a better understanding of how wastage patterns may change as demographics change (e.g., ageing populations). Age has been shown to affect food waste generation, with young people wasting more than older people (Cox and Downing 2007, Hamilton et al. 2005, Quested and Johnson 2009, WasteMinz 2014). In Australia, food waste fell sharply as age increased; among 18 to 24 year olds, 38 percent of respondents wasted more than $30 (Australian) on fresh food over two weeks, compared to seven percent of people aged 70 and up (Hamilton et al. 2005). In the U.K., people over age 65 wasted considerably less food than the rest of the population (approximately 25 percent less when household size was controlled for). These older participants felt that wasting food was wrong, which may be based on the fact that many people of this age group experienced austerity and food rationing during World War II, establishing attitudes against wastefulness (Quested et al. 2013). It is unknown if current young people will waste less as their knowledge, attitudes, and lifestyle change as they age (Pearson et al. 2013).

Family composition and household size significantly affect food waste generation. Households with children waste more than households without children (Cox and Downing 2007, Hamilton et al. 2005, Parizeau et al. 2015, WasteMinz 2014). One common cause for food waste in Swedish households was that children often did not want to finish their food. Larger households waste less per capita than smaller households (Baker et al. 2009, Parizeau et al. 2015, WasteMinz 2015, Williams et al. 2012), especially those where people live alone (WasteMinz 2014). Koivupuro et al. (2012) found no significant difference in waste per capita based on household size, but people that lived alone generated the most waste per capita. In particular, women that lived alone generated the most food waste per capita. Jorissen et al. (2015) also found that single person households wasted the most per capita.

Food is wasted across all levels of income (Pearson et al. 2013). Lower food waste has been found in low-income compared to high-income households (Cox and Downing 2007, WasteMinz 2014) and food waste has also been shown to increase with household income (Baker et al. 2009). However, others found little or no correlation between income and food wastage (Koivupuro et al. 2012, Van Garde and Woodburn 1987, Wenlock et al. 1980).

4.4 Policies Driving Food Waste Generation

There are policies which contribute to food waste by mandating food disposal under certain conditions or by preventing its redistribution elsewhere. These policies aim to achieve some overall benefit (food safety or enhanced nutrition), but they may also lead to increased food wastage. Furthermore, litigation concerns may discourage the reuse or redistribution of edible food. As a result, there is tension between the need for food safety and nutrition and the desire to reduce food waste (Watson and Meah 2012).

A policy which may lead to food wastage is the 2010 Healthy, Hunger-Free Kids Act which required USDA to update nutrition standards of the National School Lunch and Breakfast Program. The revised standard emphasized nutritional quality improvements for student meals. This policy has been criticized for leading to substantially more food waste because students dislike the new meals and are throwing away fruits and vegetables that they are required to take

(Jalonick 2014). At one elementary school after the implementation of the policy 45 percent of served food and beverages were discarded by students (Byker et al. 2014). However, Cohen et al. (2014) evaluated plate waste at several schools before and after the 2012 standards were implemented, and found substantial amounts of food waste both before and after the 2012 policy. Schwartz et al. (2015) found that the standard reduced plate waste in middle schools; so, it is unclear whether the standard causes increased food wastage. In 2014 a bill was proposed to ease the requirements of the meal standards, particularly regarding the amount of whole grains required in meals (Jalonick 2014).

The U.S. Food and Drug Administration sets federal calls for food safety, which are promulgated at the state and local levels as well. Food safety inspections or food labeling requirements mandate the disposal of food that is not allowed to be sold or consumed, such as food that is improperly labeled or inadequately stored. The USDA and the European Union (EU) have recognized that food safety policies contribute to waste, but consider human health protection the primary concern. Still, both have vowed to reduce food waste. The USDA is working to streamline donation procedures for wholesome misbranded or non-standard food that is fit for human consumption to redistribution agencies, and has spearheaded several food waste reduction initiatives, such as through tax incentives for donors and liability protection. These efforts include the Bill Emerson Good Samaritan Food Donation Act, U.S. Federal Food Donation Act of 2008, and Internal Revenue Code 170(e)(3).

5. Behaviors and Attitudes Leading to Residential, Institutional, and Commercial Food Wastage

Food wastage is not the result of a single behavior, but combinations of multiple behaviors (Quested et al. 2013). Cultural, political, economic, geographic, and socio-demographic drivers described in section 4 may cause the behaviors, but so can personal preference, values, and attitudes. There is no clear consensus on attitudes toward food waste, although food waste awareness has been shown to reduce waste (Parizeau et al. 2015). Some work has found a lack of concern and awareness regarding food waste (Buzby et al. 2011, Pearson et al. 2013) and a perception that food waste prevention is not a priority (Graham-Rowe et al. 2014). Neff et al. (2015), however, found widespread awareness of food waste among American consumers. Here specific residential, institutional, and commercial food wastage behaviors are described.

5.1 Institutional and Commercial Behaviors

At the retail and institutional levels, food is generally wasted due to choices regarding quantities of available food and visual qualities of food. Specific causes include (1) un-purchased specialty holiday food; (2) damaged packaging; (3) damaged or inadequately prepared items; (4) overstocking or over-preparation of food; (5) routine kitchen preparation waste; and (6) out-grading/quality control (Buzby and Hyman 2012). Appearance quality standards cause retailers, particularly supermarkets, to out grade foods due to rigorous quality standards concerning weight, shape, and appearance (Gustavsson et al. 2011). Many grocers take pride in beautiful food displays with uniform, flawless food, which require the culling of even slightly imperfect items. Overstocking also is an issue because retailers would rather put more stock out than run out of items and restaurants prefer to have a wide array of available menu options (Stuart 2009). Inaccurate forecasting of food needs also is a contributor to wastage (Mena et al. 2011). Although these factors may all contribute to food waste, the magnitude of wastage has been shown to vary across commodity types. Buzby et al. (2015) found that in U.S.

supermarkets, the percentage of fresh produce delivered to U.S. supermarkets that was not sold for any reason ranged from 2.2 (sweet corn) to 62.9 (turnip greens) percent; the range for fruits was smaller, ranging from 4.1 (bananas) to 43.1 (papaya) percent. These differences may be attributed to packaging differences, susceptibility to damage, and the public's knowledge and familiarity with certain foods.

In food service, plate waste is a significant contributor to food waste (NRDC 2012), and results from large portion sizes and undesired accompaniments. Portion sizes are increasing inside and outside the home in the developed world (Wansink and Payne 2009, Wansink and van Ittersum 2007, Wansink and Wansink 2010). Portion sizes began to rise in the 1970s, and then increased sharply in the 1980s and continued to climb in the 1990s. Portion increases have been seen in supermarkets, where the number of items in larger sizes has increased ten-fold between 1970 and 2000. The average sizes of certain foods, such as bagels and muffins, have increased significantly over the past 20 years. These large portions encourage both waste and obesity (Young and Nestle 2002). Kallbekken and Saelen (2013) found that reducing the physical size of plates in hotels reduced food waste by 19.5 percent.

5.2 Residential Behaviors

Consumer behavioral choices cause food wastage at the household level through the interaction of aspects of food's journey into and through the home: planning, shopping, storage, preparation and consumption (Quested et al. 2013). Poor planning at the shopping stage leads to over-provisioning and impulse or bulk purchases (Koivupuro et al. 2012), which are significant contributors to food waste (Pearson et al. 2013). Food is commonly purchased without much thought as to how it will be used (Gustavsson et al. 2011) which can contribute to wastage.

In the home, wastes may be generated due to preparing too much food (Koivupuro et al. 2012) or preparing food inadequately. People may lack the skills to prepare food well, or to reuse leftovers. In the U.K., 40 percent of household food waste was due to the preparation and serving of more food than could be consumed (Quested and Johnson 2009). Over-provisioning is both intentional and unintentional, as cooks may find it difficult to estimate how much to cook, but they also would rather prepare too much food than not enough (Pearson et al. 2013). Portion sizes in the home, as measured in the sizes of bowls, glasses, and dinner plates, and serving sizes as presented in cookbooks, have been increasing. The serving size of some entrees increased by as much as 42 percent in the 2006 *Joy of Cooking* cookbook from recipes in the first (1931) edition (Wansink and Payne 2009).

Food spoilage due to improper or suboptimal storage, poor visibility in refrigerators, and partially used ingredients, leads to wastage (NRDC 2012). A survey of U.K. households found 47 percent more fresh food was wasted compared to frozen foods because fresh food spoils faster (Martindale 2014). Another U.K. study found that more than half of food waste occurs because food was not used in time (Quested and Johnson 2009), possibly due to confusion over "use by", "sell by", "enjoy by", and "best by" date labeling (Quested and Johnson 2009, Van Garde and Woodburn 1987). In the U.S., there are no federal standards on the presentation and meaning of date labels on food. State rules vary in coverage and what the dates mean which leads to consumer confusion (Kosa et al. 2007), and often results in safe, edible food being thrown away. This confusion and general misconceptions about food safety and high sensitivities to food safety are contributors to food waste (Pearson et al. 2013).

6. Discussion: Policies for Food Waste Prevention

This paper demonstrated that food waste is a complex, interdisciplinary, and international issue which can have profound effects for global sustainability. Table 4 illustrated that large quantities of food is currently wasted, and food waste disposal has been shown to increase with time (Thyberg et al. 2015). Examination of the diverse range of food wastage drivers and behaviors provides insight into the best ways to achieve successful food waste prevention, which possibly can reverse the trend of increased food wastage. Currently in the U.S. there is no widespread or visible political or social momentum to prevent food waste (Buzby et al. 2014). Little research has directly addressed factors that motivate, enable or inhibit food waste prevention behaviors (Graham-Rowe et al. 2014). Here prevention policies are placed in the context of generation behaviors and attitudes; this context is valuable as we move forward with developing policies to sustainably manage food waste in the U.S. and abroad.

6.1 Policies to Prevent Food Waste

Waste prevention requires changes in people's behavior, both collectively (e.g., companies) and individually (BioIntelligence Service 2011, Wilson 1996). Sections 4 and 5 demonstrated that there are an array of attitudes, preferences, values, and behaviors toward food which contribute to the propensity to waste food at residential, institutional, and commercial sectors; these factors may differ from person to person. National circumstances and cultural norms have also been linked to food wastage (BioIntelligence Service 2011), so wastage patters may differ from region to region and country to country. This indicates that effective approaches to food waste prevention may also differ (Buzby et al. 2011). Table 7 describes prevention mechanisms which were developed based on behavioral and attitudinal factors that drive wastage from residential, institutional, and commercial sectors in developed countries.

Table 7. Mechanisms to Prevent Food Waste Based on Waste Generating Behaviors and Attitudes

Factor	Description	Mechanisms to Prevent Waste
Over Preparation/ Large Portion Sizes/Undesired Food	Excess food that is prepared but that is not consumed (includes plate waste)	1. Public/employee education regarding proper food preparation, portion sizes, and on importance of ordering flexibility to ensure people like the food they are served 2. Food redistribution policies for edible retail and commercial food (e.g., to a food bank)
Inadequate Food Preparation/Lack of Food Preparation Skill	Food that is prepared incorrectly (such as by burning) or poorly (such as food that does not taste good) which results in wasting; food that is wasted due to an inability to reuse excess food or incorporate left-overs into a new meal	Public/employee education regarding proper food preparation and reuse
Defects in Food or Food Packaging	Food that is disposed due to imperfect qualities of the food (such as bruising) or damaged food packaging (includes out-grading)	1. Logistic improvements (e.g., improved transportation that reduces food damage; improved food packaging) 2. Food redistribution/donation policies for edible retail and commercial food (e.g., to a food bank)
Over Stocking	Excess food that is purchased but not consumed /sold (either at consumer or retail levels)	1. Public/employee education regarding food purchasing and planning 2. Logistic improvements (e.g., stock management improvement for retailers)

Spoilage/Food Not Used in Time/Confusion Over Date Labels/High Sensitivity to Food Safety	Food that is allowed to spoil before it can be consumed/sold or food that is believed to be inadequate for consumption based on personal preferences, date labels, or conceptions about food safety	1. Public/employee education regarding food storage, food safety, and food planning 2. Improved, easily understandable food labeling systems 3. Logistic improvements (e.g., stock management improvement for retailers, improved product packaging)
Routine Kitchen Preparation Wastes	Non-edible food components that are disposed of as part of routine kitchen preparation (e.g., apple cores)	These wastes are hard to reduce completely; therefore, they are best targeted with policy options for MSW systems, such as food waste diversion policies (to AD or composting)
Lack of Awareness or Concern About Food Waste	Lack of awareness or concern about wasting food	Education regarding the issue of food waste, quantities generated, and why it is an environmental, economic, and social concern

6.2 A Multi-Faceted Policy Approach

Policies for food waste prevention should target the circumstances and actions that lead to food wastage and should be informed by motivations for waste production. Graham-Rowe et al. (2015) found that at the household level, survey participants were more likely to intend to reduce fruit and vegetable food wastage if they felt favorable about waste reduction, that others would approve of these behaviors, and confident in their ability to reduce waste. So, policy approaches should be multi-faceted and address attitudes and logistical aspects of waste prevention. There are a range of policy options to support food waste prevention (UNEP 2014) (Table 8). It is necessary to address multiple prevention mechanisms simultaneously because prevention is not created by one, but by many behaviors (Cox et al. 2010). Furthermore, by using multiple policy approaches, different parts of the population will be targeted, thus providing greater opportunities to engage more people (Quested et al. 2013). This is necessary because different populations will respond differently to prevention initiatives. For instance, Rispo et al. (2015) found that economically and socially deprived communities, particularly those in high-rise, high-density housing, will require exceptional efforts and additional resources to drive behavior changes to prevent food waste.

It can be concluded that a package of prevention policies are necessary to prevent food waste; they should encompass three key aspects: Values, Skills, and Logistics. The first aspect, Values, involves addressing values and perceptions which drive behavior. These values are grounded in the motivations for food waste prevention described in section 3. Values policy options should address identified concerns regarding food wastage, which include: (1) food waste is a waste of resources (money and edible food); (2) wasting food is wrong (WasteMinz 2014) and yields feelings of guilt (Graham-Rowe et al. 2014); and (3) food waste negatively impacts the environment (Doron 2013). An example of a Values policy is an educational campaign which teaches people about the importance of environmental and social altruism, and how preventing food waste can provide benefits (Wilson 1996). Another is one which emphasizes the economic impact of food wastage (Table 5); the concept of saving money has been found to be a powerful motivator to food waste prevention (Graham-Rowe et al. 2014, Quested et al. 2013, WasteMinz 2014). A means to support Value-driven behavior change is to provide the public with knowledge on food waste generation quantities. Miliute-Plepiene and Plepys (2015) found that improved awareness about food waste quantities spurred by the introduction of a food waste sorting program played an important role in food waste prevention in a Swedish municipality.

The next policy component, Skills, enables people to change their behaviors, such as by providing training on how to prevent food waste. Stefan et al. (2013) found that providing consumers with practical tools to improve their food planning and shopping routines could reduce waste. Graham-Rowe (2014) also determined that people should be trained in food management skills to empower them to reduce waste. Neff et al. (2015) found that concern for foodborne illness was the most common reason for discarding food by American consumers. Providing education training and skills to help people better understand food safety may be essential for waste prevention. At the retail level, Mena et al. (2011) found that a cause of food wastage was improper employee procedures for stocking, stock rotation, and other tasks. Better employee training could address this skill-deficit.

The final aspect of a policy package is Logistics which facilitates food waste prevention and minimizes inconvenience, both of which have been identified as key aspects of successful food waste prevention programs (Graham-Rowe et al. 2014). There are various logistical improvements which may prevent waste. At the retail level, a major cause of food wastage is poor forecasting regarding food needs. Improving forecasting practices and using up-to-date data mining models are examples of logistical improvements which can reduce forecast error and ultimately wastage (Mena et al. 2011). Other logistical based policies include those which provide incentives to businesses to use preferred product packaging or those which support research and development focused on improved packaging. Williams et al. (2012) determined that 20 to 25 percent of household food waste was due to packaging factors. So, improved food packaging can significantly prevent food waste. Packaging may be used to increase product protection, facilitate temperature control, or prevent damage during distribution (Verghese et al. 2015). Logistical improvements at the institutional level, particularly schools, which have been identified include enabling the storage of intact food for later use, modification of policies which encourage waste (e.g., mandating students take certain foods), and changes to daily operations (e.g., increasing time students have to eat) (Blondin et al. 2015). A final policy option targeting logistics are those that facilitate the redistribution of excess food to the needy. Logistical barriers to donation may be substantial (Schneider 2013b), but they be overcome to some degree with strong coordination efforts.

Table 8. Potential Food Waste Prevention Policies

Prevention Policy	**Description**	**Category**
Education to Promote the Importance of Food Waste Prevention in Terms of Environmental, Social, and Economic Impacts	Education campaigns addressing the issue of food waste, quantities generated, and why it is important to prevent food waste. These programs can focus on moral issues of wasting food and the potential to save money by preventing food waste. The campaigns may be done through various media outlets, including mailings, face-to-face training, email, and social media.	Values
Education to Promote Behavior Changes	Education campaigns focused on behavior changes can target a variety of audiences and focus on various aspects of food waste prevention. These aspects include proper food preparation, portion sizes, food reuse, ordering flexibility in restaurants, food purchasing, food storage, food safety, and meal planning. The campaigns may be done through various media outlets, including mailings, face-to-face training, email, and social media.	Skills
Encourage Food Redistribution/Donation Policies (for edible retail and commercial food)	Policies can encourage the redistribution of edible food for human consumption. Recovery policies may include tax incentives for donors, limited liability regulations for donors, programs to facilitate the	Logistics

	connection between donors and the needy, or may facilitate logistics of collection and transport.	
Promote Food Redistribution to Animal Feed	Policies can facilitate diversion of wasted food from retail and consumer sectors to animal feed, such as foods that were refused due to packaging errors or blemishes. Programs may facilitate the connection between donors and the needy, provide tax incentives to donors, or may facilitate logistics of collection and transport. Furthermore, at the household level, education can encourage people to feed excess food to pets instead of disposing it.	Logistics
Incentivize Food Waste Prevention	Policies can be enacted to incentivize prevention, such as rewarding companies that are able to significantly prevent food waste. Incentives can be financial, such as tax credits for those that prevent waste, or mandated higher costs for waste disposal (which should encourage reduction).	Logistics
Increase Research and Development	Policies to support research and development can contribute to innovations which may reduce food wastage. These include improved packaging that extends shelf life, improvements in food storage, or better tracking systems for stock management. Policies may include funding for research organizations or tax incentives.	Logistics
Improve Food Packaging	Policies can encourage reconfiguration of product packaging to prevent waste, such as packaging to extend shelf life or protect products. Policies may include financial incentives to businesses using preferred packaging.	Logistics
Improve Food Date Labeling	Policies to eliminate ambiguous food labeling include well-defined, clear, scientifically-sound date labeling systems for food.	Logistics
Change Waste Collection System Design	Policies to change the design of municipal waste collection systems can help prevent food waste. These include volume based systems for trash or reduced number of days that trash is collected.	Logistics
Change Treatment of Collected Wastes	Policies can reduce food waste by stipulating how it is to be treated. An example is legislation to ban landfilling of organics. Fiscal incentives, such as taxes, fees, or subsidies, can also dictate treatment methods.	Logistics
Mandate Targets for Prevention	Policies to mandate reporting of food waste statistics and achievement of specific prevention goals can encourage prevention.	Logistics

6.3 Selecting the Best Policy Approach

There are regulatory, social, and political obstacles to enacting food waste prevention policies. Thyberg and Tonjes (2015) outlined many of these challenges, including poor public participation, lack of efficient indicators to monitor performance, and uncertainty regarding policy outcomes. There is no one-size-fits-all solution to food waste; policy measures to address it should be custom tailored for each individual situation, integrate community needs, and involve a package of several measures addressing Values, Skills and Logistics. Holistic approaches which integrate education, financial aspects, and logistical improvements across food and waste systems are ideal.

It is unclear which combination of mechanisms to prevent food waste is most effective because evaluations of food waste prevention policies are scarce. Due to the inherent difficultly in studying and implementing waste prevention, there has been little quantitative work assessing its environmental impacts (Gentil et al. 2011). Moreover, it is difficult to demonstrate a consistent, direct link between specific policy mechanisms and measured waste prevention results (Cox et al. 2010). Further complicating food waste prevention is the fact that many food waste prevention initiatives are still in their early stages, so comprehensive data are not yet available (BioIntelligence Service 2011). Rather than struggle with the lack of existing data and concrete conclusions regarding the best policy means to prevent food waste, it is suggested that new, well-planned intervention campaigns be initiated, but with mandates for proper

monitoring and evaluation. These data can serve as critical resources for designing future waste prevention programs and improving existing programs (Thyberg and Tonjes 2015). Prevention initiatives targeting food loss (losses at production, post-harvest, and processing stages of the food supply chain) should parallel food waste prevention campaigns to address the issue from multiple angles.

Food waste prevention policies can substantially reduce the amount of food waste disposed, making it an effective alternative to collection and treatment of wastes economically, socially, and environmentally. However, even with rigorous prevention programs, food waste from residential, institutional, and commercial sectors will never be eliminated because some food waste is unavoidable (e.g., peels) (Schott et al. 2013), and redistribution of edible food to feed humans may be unfeasible due to food perishability and high transport or distribution costs (Buzby et al. 2014). Food also may not meet safety or quality requirements under food safety regulations (Salhofer et al. 2008). Furthermore, prevention activities may not broadly appeal to consumers and they may be costly (Buzby et al. 2011). Estimates of the proportion of food waste that is avoidable differ considerably across studies; estimates for the proportion of avoidable food waste are: 34 percent avoidable in Sweden (Schott et al. 2013); 47 percent avoidable and 18 percent partially avoidable in Germany (Kranert et al. 2012); 60 percent avoidable in the U.K. (WRAP 2013); and 54 percent avoidable and 12 percent partially avoidable in New Zealand (WasteMinz 2015). More studies documenting the proportion of disposed food waste that is avoidable would be beneficial, especially in the U.S. where data are lacking. Nevertheless, once prevention policies are enacted, recovery programs to encourage the capture of energy and nutrients from food waste should be pursued.

7. Conclusion

Increasingly citizens, scientists, businesses, institutions, and policy makers are realizing that the current food system is unsustainable and changes are required if the world will be able to support a population of over nine billion by 2050. Reducing food waste will become an increasingly important strategy to help feed this growing human population (Godfray et al. 2010). However, food waste prevention has not yet become mainstream in the U.S. or abroad. Wastage of food is a widespread phenomenon globally and it is likely that food waste generation will continue growing if not curbed by prevention policies. Waste prevention in general has frequently been ignored in waste management, as signaled by states that define waste goals in terms of recycling or diversion, rather than using indicators that capture prevention success. Understanding the implications of food waste and adjusting attitudes and behaviors toward food in order to prevent it should be an urgent priority. This paper deepened the understanding of food waste and highlighted that it is a complex issue involving numerous diverse actors across the globalized food chain. Policies to prevent food waste should address the range of behaviors and motivations for wastage. They should be multi-faceted so that they target people's values, provide them with skills to prevent waste, and facilitate logistical improvements to encourage prevention. Food wastage is an issue that demands attention, research, and action, particularly regarding ways to prevent food waste generation.

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