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Developing and Testing a Novel Intervention to Reduce Household Food Waste

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Abstract

The amount of food wasted is a topic of societal and academic interest. As academic research in this area is nascent, there are significant knowledge gaps, which this dissertation seeks to narrow, pertaining to: (1) the measurement of food waste; (2) the human behaviors that lead to wasting of food; and (3) the development of efficacious food waste reduction interventions.

A systematic literature review of 55 food waste estimates showed that on average 114.3 kg/capita/year is wasted from consumption (i.e., household) and 198.9 kg/capita/year across the entire food supply chain. There is considerable uncertainty with these data because of the different food waste measurements methodologies employed.

Household waste composition study data (2012-2015) from 9 Ontario municipalities, that used the same direct measurement methodology and included a single "food waste" category, were aggregated and analyzed to develop estimates of food waste in the garbage stream. This methodology, which showed households disposed 2.40 kg/week of food waste in the garbage, was used as the basis of a bespoke household food waste measurement methodology.

To better understand food wasting behavior and facilitate the development of an effective intervention the theory of planned behavior (TPB) was used to inform the development of a survey, which was administered to households in London, Ontario, Canada. Households (n=1,263) threw out avoidable food 4.8 times/week. Perceived behavioral control ($p<0.001$) and personal attitudes ($p<0.01$), in particular, were significantly associated with less food wasting behavior. Further, 58.9% selected reducing monetary loss as the primary motivator to reducing this behavior.

A "Reduce Food Waste, Save Money" household intervention, which combined elements of behavioral economics (nudging the desire to reduce monetary loss) and the TPB (strengthening perceived behavioral control), was developed, tested and assessed in a randomized control trial. Treatment total household food waste decreased by 31% and this was significantly greater ($p=0.02$) than for control households. Key determinants of

avoidable food waste reduction included personal attitudes, perceived behavioral control, the number of people in a household and the amount of garbage set out.

This research can contribute directly to food waste reduction policy in national, provincial, and municipal contexts.

Keywords: food waste, household food waste, theory of planned behavior, behavioral economics, waste characterization, intervention

Co-Authorship Statement

The following dissertation includes four integrated articles and a version of each article has already been (or will be) published in peer-reviewed journals. The co-authorship details of the integrated articles are presented below.

Chapter 2: van der Werf, P., Gilliland, J.A. (2017, May). A systematic review of food losses and food waste generation in developed countries. In *Proceedings of the Institution of Civil Engineers-Waste and Resource Management* (Vol. 170, No. 2, pp. 66-77). Thomas Telford Ltd. https://doi.org/10.1680/jwarm.16.00026

Chapter 2 was co-authored by Paul van der Werf and Jason Gilliland. Paul van der Werf is primary author of the article. The systematic review protocol was developed by van der Werf with input and supervision from Gilliland. The literature search, data extraction, and data synthesis were all conducted by van der Werf with input, resources and supervision from Gilliland. The original draft was written by van der Werf with review and editing by Gilliland.

Chapter 3: van der Werf, P., Seabrook, J. A., & Gilliland, J. A. (2018). The quantity of food waste in the garbage stream of southern Ontario, Canada households. *PloS one*, *13*(6), e0198470. https://doi.org/10.1371/journal.pone.0198470

Chapter 3 was written by Paul van der Werf with Jamie A. Seabrook and Jason A. Gilliland as co-authors. The study was conceptualized by van der Werf, who was also responsible for study methodology, data collection, data management, data analysis, and writing the original draft. Seabrook and Gilliland advised on data analysis and contributed to the writing through review and editing of subsequent drafts. Gilliland also contributed project supervision.

Chapter 4: van der Werf, P., Seabrook, J. A., & Gilliland, J. A. Food for Naught: Using the Theory of Planned Behavior to Better Understand Household Food Wasting Behavior. This has been accepted for publication in The Canadian Geographer.

Chapter 4 was written by Paul van der Werf with Jamie A. Seabrook and Jason A. Gilliland as co-authors. The study was conceived by van der Werf, who was also

responsible for data collection, data management, data analysis, and writing the original draft. Seabrook and Gilliland also contributed to the study design, analytical plan, and data analysis, as well as the writing through review and editing of subsequent drafts. Gilliland also contributed resources and project supervision.

Chapter 5: van der Werf, P., Seabrook, J. A., & Gilliland, J. A. "Reduce Food Waste, Save Money"- Testing a Novel Intervention to Reduce Household Food Waste

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Chapter 1

1 Introduction

1.1 Research background

Food waste is a global problem with substantial monetary, environmental, and societal impacts (Gustavsson et al., 2011). It can be considered 'avoidable' (i.e., at one-point edible) or 'unavoidable' (e.g., peels, bones, and other 'inedible waste by-products') (Beretta et al., 2013; Schneider, 2013; WRAP, 2009). International research has estimated that up to 50% of food available for consumption (i.e., avoidable) is wasted along the food supply chain (Gustavsson et al., 2011; Parfitt et al., 2010). In Canada, it is estimated that 40% of consumable food, worth $31 billion annually, is discarded as 'waste' and that almost 50% of that is generated by consumers, such as households (Abdulla et al., 2013; Gooch & Felfel, 2014). Its environmental impacts are considerable and include wasted energy (Cuéllar & Webber, 2010), wasted water (Lundqvist et al., 2008), and greenhouse gas generation from agricultural production, shipment to markets, and decomposition of food (Agriculture and Agrifood Canada, 2015; Weber & Matthews, 2008). Wasting food also has indirect social impacts. While wasted food cannot be conflated with food insecurity, it is ironic that while many households have so much food they can throw some of it out, an estimated 8% of Canadian adults live in food insecure households (i.e., they lack reliable access to a sufficient quantity of affordable, nutritious food) (Statistics Canada, 2015). If household food waste was reduced, its embodied monetary and other resources could, in part, be captured and redirected to the food insecure.

While there appears to be considerable interest in better managing food so that it does not become waste, there are three key gaps in knowledge: (1) the measurement of food waste; (2) the human behaviors that lead to wasting of food; and (3) the development of efficacious food waste reduction interventions.

This dissertation addresses these gaps at the household level. At this part of the food supply chain, food wasting is a behavioral issue rooted in consumer and other socially mediated household attitudes and actions. At its highest level, this dissertation examines

how to minimize household food waste from food management and waste management perspectives. Food always starts as food, but for biological reasons trends towards waste. So how do we better match household food management with food consumption to minimize its waste management?

1.1.1 What is waste?

As a starting point, it is useful to understand how any material becomes waste. At some point much of the material items we possess cross an invisible line, where its utility declines to the point where it has transformed into waste and is discarded. This loss of utility can be literal or actual, such as a chair with an unrepairable broken leg. Gregson and Crang (2010) describe waste as an innate characteristic of certain things; items that are deemed worthless or harmful; and things that need to be separated from people and managed. Waste can also be viewed as the end of the pipe and, in its most unsophisticated form, as items that are leftover, redundant and final by-products of cultural organization (Evans, 2014). This loss of utility can also be figurative or pejorative, such as culling a closet full of clothes to make more room. There is nothing wrong with the clothes; we have just decided we do not want some of them anymore. In this case, waste is used as a normative category of judgement (Hawkins, 2006), or pejoratively, as a quick way to describe the inefficient use of time or money (Schor, 1999). The transformation of food to waste follows a similar path.

Because food, in particular fresh food, is also a food source for microorganisms, it typically has a very finite utility window. When it has decayed to the point that it is unappealing or unhealthy to eat, it will be treated as waste. People's judgement will vary in this regard and what one person thinks is no longer edible and therefore waste, someone else may still consider edible. Munro and Marshall (1995) suggest food waste disposal is exclusion, viewable from various perspectives including with whom you eat, the physical act of eating, and the physical act of food disposal. It can be out of necessity, but regardless, this loss of utility has a strong pejorative aspect, or as they describe it "what is not dinner is dirt" (Munro & Marshall, 1995, p. 317). Put another way, the actual pejorative interface of food transformation to waste varies widely and therefore offers opportunities to educate consumers and households about how to reduce actual food waste and eliminate pejorative food waste (i.e., food that people think is no longer edible

but in fact is still edible). To address this issue of food waste there is a critical need to understand its quantity and nature.

1.1.2 Food waste measurement

How material items manifest as waste has long been an area of study. Researchers such as William Rathje and his team pioneered the physical examination of waste in the 1970s, by using archeological principles to examine wastes in landfills and pre-landfill waste streams, to better understand what people deem to be waste (Rathje & Murphy, 2001). It is this type of research that starts to get at the actual pejorative interface of waste generation. That is, does something become a waste because it is, or because we otherwise deem it so? As early as the mid-1970s, Rathje's team estimated that about 9.3% or 78kg of annual household food purchases, worth $90 (in 1974 US dollars), were wasted (Harrison et al., 1975).

The measurement of food waste can help provide accurate and precise data to estimate the extent of the problem, and repeated measures can help evaluate the impact of interventions. Unfortunately, due to the methodological limitations in many food waste measurement studies, existing estimates often lack accuracy and precision (van der Werf & Gilliland, 2017; van der Werf et al., 2018). Langley et al. (2009) concluded that estimating the amount of food waste in an area is difficult due to lack of sufficient available data. This is supported by the recommendations of others that further research is urgently needed to improve the methodologies used to create food waste estimates (Abdulla et al., 2013; Gustavsson et al., 2011). There are two main approaches to estimating the quantity and composition of household food waste: *indirect* (Gustavsson et al., 2013; Kreith & Tchobanoglous, 2002; Sharma & McBean, 2007) and *direct* measurement (ASTM, 2008; Klee & Carruth, 1970; Sharma & McBean, 2007; Stewardship Ontario, 2014; Waste Diversion Ontario, 2015).

A key issue with current estimates is that many have been made *indirectly* (Sharma and McBean (2007). Quantities of food are put into product categories and then waste is imputed through the use of waste factors (i.e., % of a product category assumed to become waste). Even though some of these estimates are stratified along the food supply chain (FSC), few offer any detailed insights into food waste generation as a result of

specific activities and/or locations (e.g., food waste generation at a household, grocery store or restaurant), although consumers, including households, have been identified as key food waste generators. While useful for estimates that have a broad geographic scope (e.g., countries), its key disadvantage is that it does not physically examine any waste streams. Referring to indirect methods that do not use original food waste data, Brautigam et al. (2014, p. 693) warn: "it has to be recognised that all calculation methods can only be seen as approximations, which barely reflect reality." There are three key reasons for this: (1) using indirect data provides at best surrogate estimates because food waste is not actually being measured; (2) using broad estimates erroneously pre-supposes that food waste generation is homogenous across populations; and (3) current food waste estimates provide little detail about the nature of food waste because they have not considered whether food is avoidable or unavoidable, or the nature of food waste (i.e., to what extent does it consist of various food types such bakery, dairy, meat, fruits and vegetables etc.).

Maystre and Viret (1995), Rugg (1997) and Abdulla et al. (2013) all recommend that *direct* measurement, which collects, sorts, weighs and statistically analyzes waste samples collected at the point of disposal, be used to provide more accurate and precise estimates of food waste. However, to date, there has been very little peer-reviewed food waste research that has directly examined the quantity and types of food wasted in household garbage bags or bins.

The current limited understanding of food waste quantity and composition also impairs the ability to accurately estimate the true monetary, environmental, and social impacts of food waste. It is the amelioration of these impacts that can potentially be used as food waste reduction intervention motivators and components. Therefore, the direct measurement of food waste (i.e., via waste characterization studies) can provide detailed and accurate data, which can contribute to the development of effective food waste reduction interventions. Further, researchers such as (Bulkeley & Gregson, 2009) call for greater engagement with households to inform waste policy, arguing that waste policy has to "open up the black box that is the household and engage with household practices" (p.4). This can be partially satisfied through the direct collection and measurement of household food waste samples. Therefore, to better quantify this household behavior, this

dissertation includes an improved methodology to collect and measure household food waste samples.

1.1.3 Why does food become waste?

It is helpful to have some understanding, from theoretical perspectives, of why food becomes waste. A number of researchers, including food geographers, have tried to explain the irony of simultaneous food excess and scarcity. More specifically, they have worked to better understand and explain food distribution inequity. Riches (2002, p. 650) ascribes food insecurity and the development of food banks to the "… the state's failure to 'respect, protect and fulfill' the right to food." He blames this on the dramatic shift in federal and provincial social policy towards market-driven, neoliberal concepts of state welfare. This is echoed by Warshawsky (2015), who conceptualized food systems and food waste as part of a political ecological approach to "theorize the urban environment," and this approach focuses on the "multi-scalar dimensions of environmental and social marginalization and uneven access to resources." (p.28). Warshawsky suggests that implementation of food waste policy has devolved to non-state, that is, neoliberal, actors who do not share the same motivations as state actors. Thus, opposition to neoliberalism essentially hypothesizes that government devolution of services and/or funding is a significant contributor to food waste, rescue, and more importantly, the need to rescue.

While there may be a political ecological aspect to why food is on the one hand wasted, and the on other hand, needs be rescued, one would think that there may be more reasons for this than just less government and more private sector involvement. This above noted supposition suggests a devolution of personal responsibility, to preferably state, and hopefully, not private sector actors. However, as individuals, we are presented with choices. In a consumer society, the purchase of goods plays a bigger role in defining oneself than what we produce (Gregory et al., 2011). Consumerism manifest as individual choice that results in a mismatch of food purchase and consumption, plays a role in the production of food waste, and the need for food rescue. However, there appears to be little academic support for ascribing personal or household responsibility, that is ensuring that the food at hand is consumed, in the decision-making processes that result in food becoming waste.

Munro and Marshall (1995) essentially assert that connecting food waste to the production and consumption of meals is an oversimplification, and that consumption is related to inclusion and disposal to exclusion. As well, Warshawsky disagrees with this assertion and suggests: “Food waste should not be thought of as the result of individual choices, personal responsibility, and community engagement at the local level, unrelated to global food flows or the political economy of food production. For these reasons, I would suggest that broader shifts in thinking are needed to conceptualize food waste beyond a local, consumer driven problem.” (D. Warshawsky, personal communication, 30 January 2017). Further, (Evans, 2011) aligns with Warshawsky, and puts forward that household food waste “cannot be conceptualized as a problem of individual consumer behavior” or blamed on a “throwaway society” (p. 429) or other moralizing (Evans, 2012). The groundwork of his thinking and ethnographic research is based on structuration theory (which looks at how systems are put together and how actors act within them) and practice theory (how social beings make and transform the world they live in) (Evans, 2011). Evans suggests that food wastage comes from pressure to eat properly (and buying more fresh food), the mismatch between food provisioning and consumption, and the mismatch between rhythms of everyday life and the temporalities of food (Evans, 2011, 2012; Evans, 2014). Evans advises that solving this problem starts with a fuller recognition of the ways in which other actors (e.g., retailers) shape the conditions under which food is at risk of wastage, and more generally, involve “a re-think of how the prevailing organization of food consumption (and production) shapes food waste. For example, do we need to re-think how, when and where we eat?” (D. Evans, personal communication 15 February 2017).

The foregoing views clearly have merit, but they overcomplicate the issue of food waste to the point where it becomes unsolvable. In this dissertation, a simpler view is adopted. It is possible to connect households to their food wasting behavior by directly communicating with them and encouraging them to take greater control over the behaviors they can change (i.e., personal responsibility), and worry less about food supply chain structural issues that may not be readily solvable.

Helping households to change requires an understanding of “why” households waste food and “how” to motivate behavior change. While there have been a number of studies

which have tried to ascertain “why” food is wasted and “what” would motivate its reduction (Parizeau et al., 2015; Visschers et al., 2016; WRAP, 2007b), household food wasting behavior is not fully understood. A better understanding of this behavior can contribute to intervention development.

1.1.4 Household food wasting behavior

Research suggests there are several reasons why household food is wasted, including spoilage (i.e., food that has decayed), fussy eaters in the household or being overly sensitive to high risk food spoilage (Cappellini, 2009; Göbel et al., 2015; Graham-Rowe et al., 2014; Halloran et al., 2014; Jorissen et al., 2015; Koivupuro et al., 2012; Thyberg et al., 2015; Williams et al., 2012; WRAP, 2014). Much of this behavior can be placed under the umbrella of poor ‘food literacy’, which can be defined as a lack of knowledge regarding the various aspects of household food provisioning (including planning, buying, preparing, serving, and storing). This includes confusion with regard to food labels such as: ‘best before’ and ‘use by’ dates (Porpino, 2016; Principato et al., 2015; WRAP, 2011, 2014); what to do with leftovers (Evans, 2012; Graham-Rowe et al., 2014; WRAP, 2013); inadequate meal planning and grocery shopping (Abeliotis, 2014; Pearson et al., 2013; WRAP, 2011); buying, preparing and serving too much food (Van Garde & Woodburn, 1987; Williams et al., 2012; WRAP, 2007a); and poor food storage (Aschemann-Witzel et al., 2015; BIO Intelligence Service, 2011; Koivupuro et al., 2012).

Sociodemographic determinants of avoidable food wasting include: age (especially households with younger children) (Fusions, 2014; Melbye et al., 2016; Tucker & Farrelly, 2016); household size and type (i.e., larger and with children) (Baker, 2009; Koivupuro et al., 2012; Neff, 2015; Parizeau et al., 2015); possibly household income (with higher income households wasting more) (Fusions, 2014; Neff, 2015; Stancu et al., 2016); and possibly gender (with males potentially wasting more than females) (Koivupuro et al., 2012; Secondi et al., 2015; Visschers et al., 2016). Very little information exists linking ethnicity and food waste (Fung & Rathje, 1982; Panizza et al., 2016).

Behavioral determinants include antecedents of intentions, as described in the theory of planned behavior (TPB) (Ajzen, 1991) (see Section 1.3), that inform people’s intentions

and ultimately their behaviors. With respect to wasting food, this includes factors such as attitude (Graham-Rowe et al., 2015; Quested et al., 2013; Stefan et al., 2013; Thyberg & Tonjes, 2016; Visschers et al., 2016), perceived behavioral control (Graham-Rowe et al., 2015; Stancu et al., 2016; Visschers et al., 2016), and social norms (Bernstad, 2014; Cappellini & Parsons, 2012; Graham-Rowe et al., 2015). Other behavioral determinants of note include self-identity and the good provider identity (Evans, 2011; Graham-Rowe et al., 2014; Visschers et al., 2016).

Effective food waste reduction interventions need to consider such determinants, but also what could motivate people to reduce their food waste. The strongest potential motivator appears to be saving money (Abeliotis, 2014; Porpino, 2016; Tucker & Farrelly, 2016) and moral values (Bolton, 2012; Graham-Rowe et al., 2014; Neff, 2015; Quested et al., 2013). Much weaker motivators appear to be concern about the environmental impact of food waste (BIO Intelligence Service, 2011; Neff, 2015; Tucker & Farrelly, 2016) and humanitarian or social concerns, such as hunger and poverty (Baker, 2009; Tucker & Farrelly, 2016; Watson & Meah, 2012). Stancu et al. (2016, p. 16) reported that people were more aware of the economic consequences than environmental and social consequences, suggesting that "people are motivated … by self-interest in their food waste behavior," and that they see food waste behavior as food-related behavior and much less so as an environmental behavior.

Inducing personal responsibility and participation in food waste reduction behavior – as introduced in Section 1.1.3 and which is essentially the approach taken in this dissertation – is not an easy task. This induction can emanate from sustainable waste management and food management fronts. One of the factors that positively influences participation in sustainable waste management is awareness of the problem (Jensen, 2002; Xiao et al., 2017). However, awareness or knowledge of a problem does not guarantee participation, as convenience and habitual behavior often take precedence. Jensen (2002) suggests that people really need to understand the problem, instead of just being aware of it. The real understanding of the problem is what ultimately leads to personal responsibility. Coad (2005) points out that in order for people to be motivated and to effectively participate in waste reduction, access to information 'how they can get involved' needs to be available. Further, Minn et al. (2010) emphasizes the idea that empowering people with knowledge

(to help them understand the problem) and motivation helps them to realize their responsibilities as it pertains to sustainable waste management.

Evans et al. (2017) reported food waste prevention seems to start with personal responsibility of individual consumers. Thus, inducing personal responsibility in household food waste reduction may be a viable approach. This can include working directly and continuously with households to empower them to understand the problem of food waste and provide necessary tools to effect its reduction. For instance, the United Kingdom reported a considerable reduction in avoidable household food waste disposal between 2007 and 2012, using this approach (WRAP, 2013a). Further, Evans et al. (2017) reported that showing the personal responsibility of individuals in food waste reduction led to more responsible behavior by food retailers (i.e., how food is sold to customers).

1.1.5 Purpose and objectives

The overarching **purpose** of this dissertation is to address the aforementioned knowledge gaps by developing, implementing, and evaluating a novel intervention aimed at reducing household food waste. This dissertation also aims to meet three specific **objectives**: (1) to refine existing waste characterization methodologies to develop better estimates of household food waste disposal and composition, as well as its monetary, environmental and social impacts; (2) to conduct a household survey to gain a better understanding of household food wasting behaviors and reduction motivators; and (3) to develop and implement an intervention comprised of presenting households with local food waste quantity and impact data (i.e., monetary, environmental and social), coupled with information to improve their food literacy, and to evaluate its effectiveness for motivating households to reduce their food waste disposal.

The **rationale** for this research is that without detailed, directly-collected, household food waste disposal, impact, and behavioral data, it is not possible to develop effective food waste interventions and properly evaluate their effectiveness. Researchers such as Brautigam et al. (2014) and Abdulla et al. (2013) suggest that there is considerable room to improve the measurement of food waste. Further, much of the current food waste behavioral research has taken place in Europe (European Commission, 2010; WRAP,

2007b) with few examples of Canadian research (Parizeau et al., 2015). This research represents the first attempt to develop, implement, and rigorously evaluate a theoretically informed household food waste reduction intervention in Canada.

Thus, the overarching **research question** of this dissertation is:

Can providing a household with local food waste quantity and impact data (e.g., monetary, environmental and social) coupled with information to improve their food literacy motivate them to reduce their food waste disposal?

The experimental component of this dissertation research has two overarching **hypotheses**:

H1: Providing households with local food waste quantity and impact data (e.g., monetary, environmental, and social) coupled with information to improve their food literacy will result in a reduction of food waste disposal.

H2: Reducing the monetary impact of food waste will be a key motivator as compared to reducing environmental and social impacts.

1.2 Geographic context

The content of this dissertation is germane to other developed countries, and more specifically to North American and possibly European households. The geographic context is described within each manuscript and summarized here.

Chapter 2 includes estimates of food waste generation at the country, region, state and municipal level in developed countries throughout the world. Chapter 3 includes an estimate of southern Ontario household food waste generation and the basis of a waste characterization methodology. The results and the approach used to collect these data are relevant specifically to southern Ontario municipalities, but are also readily applicable to northern Ontario municipalities, as well as other North American and possibly European municipalities.

Chapter 4 presents the results of a household food waste survey which was distributed throughout the city of London, Ontario. The survey was used to better understand self-

reported household food waste generation and its determinants. It was also used to recruit volunteer households to test an intervention and inform intervention development. Chapter 5 presents the results of an evaluation of a household food waste reduction intervention distributed to a diversity of households in London, Ontario. Although the research was limited to one city, the research presented in Chapters 4-5 can be considered a template which could be applied in other North American and possibly European municipalities.

1.3 Conceptual framework

Within the discipline of geography, this research is situated in Human Geography and specifically the sub-field of Food Geography. Food Geography examines topics related to food production and food consumption, including patterns and dynamics of relationships between food producers and food consumers on global and local scales (Barr et al., 2013). The entire food supply chain, including its production, processing, transportation, sale, and consumptions results in positive and negative monetary, environmental, and social impacts. In recent years it has received increased attention from the scientific community, international organizations, and policymakers because of its food security and environmental impacts (Schanes et al., 2018). Within food geography, household food wastage probably best fits under the umbrella of food security and more specifically food insecurity. The basic idea behind food security is having a sufficient amount of food to feed the population (Robinson, 2016) or where everyone at all times has access to sufficient, safe, nutritious food to keep an active and healthy lifestyle (McCarthy et al., 2018). Food security is a growing global issue and raises questions about the amount of food wasted and how it could have been used to feed people (Papargyropoulo et al., 2014). As human population continues to increase, the requirements for food increase with it. The problem of food waste and food security is a complex issue, which requires a multi-disciplinary approach (Schanes et al., 2018). There are two broad approaches that can be used to attempt to solve this issue. The first approach is to increase food production. This approach inevitably introduces additional challenges and issues, as increasing food production has monetary, environmental and social impacts. The second approach is to increase the efficiency of food production. Decreasing the amount of food produced that becomes waste can be an important contributor, in this regard.

Figure 1.1 presents a broad overview and theoretical context of this research. The theoretical framework guiding this research is built from three different, yet complementary, theoretical traditions: (1) Positivism; (2) Theory of Planned Behavior; and (3) Behavioral Economics. Within Figure 1.1, steps 1 and 2 of the research seek to quantify food waste and its impacts. Step 3 seeks to understand the reasons for food waste generation and whether presenting households with information about their food waste will motivate its reduction.

Despite criticisms, positivism remains strong within human geography (Kitchin, 2015). What it may lack in perceived epistemological sophistication, it makes up for in clear-cut empirical verification of the research questions and research objectives.

The TPB was designed to predict and explain human behavior (Ajzen, 2011, 2015); it has recently been used by consumer behavior researchers to help determine 'why' food becomes waste by asking households about their food wasting intentions and self-reported behaviors (Stancu et al., 2016; Visschers et al., 2016). The TPB was incorporated into the theoretical context of this dissertation as a model to help measure household food wasting intentions, its antecedents and its ultimate impact on behavior.

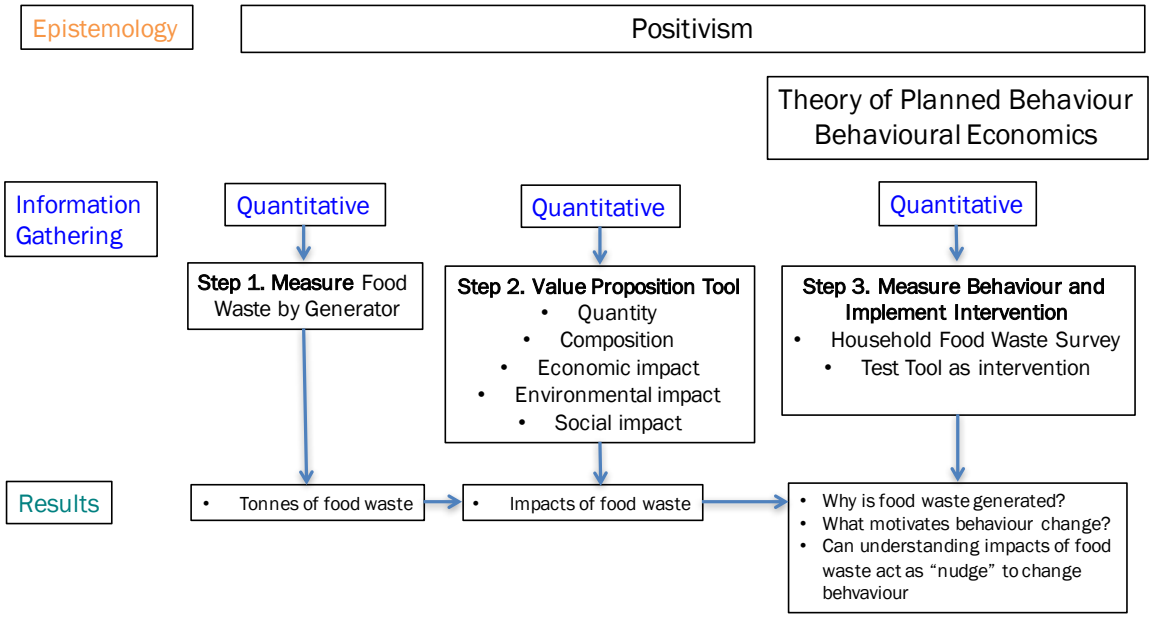

Figure 1.1 - Theoretical context

More simply TPB was used to help understand ‘why’ food is wasted and ‘what’ would motivate behavior change. As well, intention’s antecedents, attitude, social norms and perceived behavioral control represent the starting point of intervention development because it is one or all these that we are trying to positively influence. For this research, intervention development focused on influencing ‘perceived behavioral control’ using the monetary impacts of food waste disposal as a motivator, and the distribution of food literacy information as a change agent. This research strengthened the use of the TPB by including direct measurement of *actual* behavior (i.e., through collection and analysis of curbside waste samples) as opposed to self-reported behavior, as has been the case in previous studies (Stancu et al., 2016; Visschers et al., 2016).

This research also explores whether (food wasting) behavior is rational – while not specifically articulated, a frequent critique of the TPB – or could it be irrational, as suggested by behavioral economists (Camerer et al., 2003; Tversky & Kahneman, 1985). It is likely that to effect change across a broad swath of households, with differing interests and motivations, requires irrational or more automatic System 1 behavior, as described by behavioral economists (Kahneman, 2011; Thaler & Sunstein, 2009a). Further, behavioral economists, such as Thaler and Sunstein (2009a), argue that using positive reinforcement or indirect suggestions through ‘nudges’ to try to achieve non-forced compliance can influence intentions and decision making of households at least effectively, if not more effectively, than regulations (such as by-laws restricting waste bins). Therefore, aspects of behavioral economics were incorporated into this research. In particular, the monetary impact of food disposal, which was identified as the key food waste reduction motivator by survey respondents, was used in the intervention to ‘nudge’ households to change their behavior.

1.4 Dissertation format: Integrated article

This dissertation examines food waste disposal and reduction in five sequential steps: (1) develop an understanding of food waste disposal across the food supply chain; (2) develop an understanding of food waste disposal across southern Ontario households and determine if the methodology used to collect these data can be refined to collect more detailed household food waste data; (3) use waste characterization and other available data to estimate the monetary, environmental and social impacts of household food

waste; (4) develop an understanding of household food waste generation and behavioral determinants via a household survey; and (5) use data from points 3 and 4, and aspects of behavioral economics and the TPB, to develop and implement an intervention and evaluate its impact on food waste disposal through use of a refined household food waste methodology. This research is sufficiently segmented that it merits an integrated article format for this dissertation.

Figure 1.2 depicts a methodological framework. The first part of this research asks 'how much' food waste is being generated, what is its composition and how best to measure it at the household level. The second part of this research investigates 'why' food waste is produced, 'what' would motivate a household to reduce the amount of food that becomes waste, and whether an intervention that encompasses some of the foregoing data will result in a reduction of household food waste.

A version of the first manuscript (Chapter 2), "A Systematic Review of Food Loss and Food Waste Generation in Developed Countries", has been published in the *Proceedings of the Institution of Civil Engineers-Civil Engineering*. The primary research goal was to provide a comprehensive literature review of food loss and waste estimates across the food supply chain (FSC), how these estimates were made (i.e., through indirect or direct means), and identify improvements that are required to collect accurate and precise food waste generation data. To meet this goal, the following research questions were addressed:

a. How much food waste is generated at each stage of the FSC?
b. What variables contribute to food waste generation?
c. What are the issues with current food waste measurement methodologies?
d. What are the current data gaps?

Chapters 3-5 include relevant literature reviews on food waste quantification, household food wasting behaviors and food waste intervention development.

A version of the second manuscript (Chapter 3), "The Quantity of Food Waste in the Garbage Stream of Southern Ontario, Canada Households", was published in *PLOS One*. The primary research goal was to better understand the quantity of food waste disposed by southern Ontario households in the garbage stream and whether the current method

used could serve as the basis to examine food household food waste. To meet this goal, the following research questions were addressed:

a. How much food waste is disposed in the garbage stream by southern Ontario households?
b. How do these estimates compare to current estimates of household food waste disposal?
c. What is the difference in food waste disposal for urban versus rural neighbourhoods?
d. What is the impact of seasons, median household size and median household income on food waste disposal?

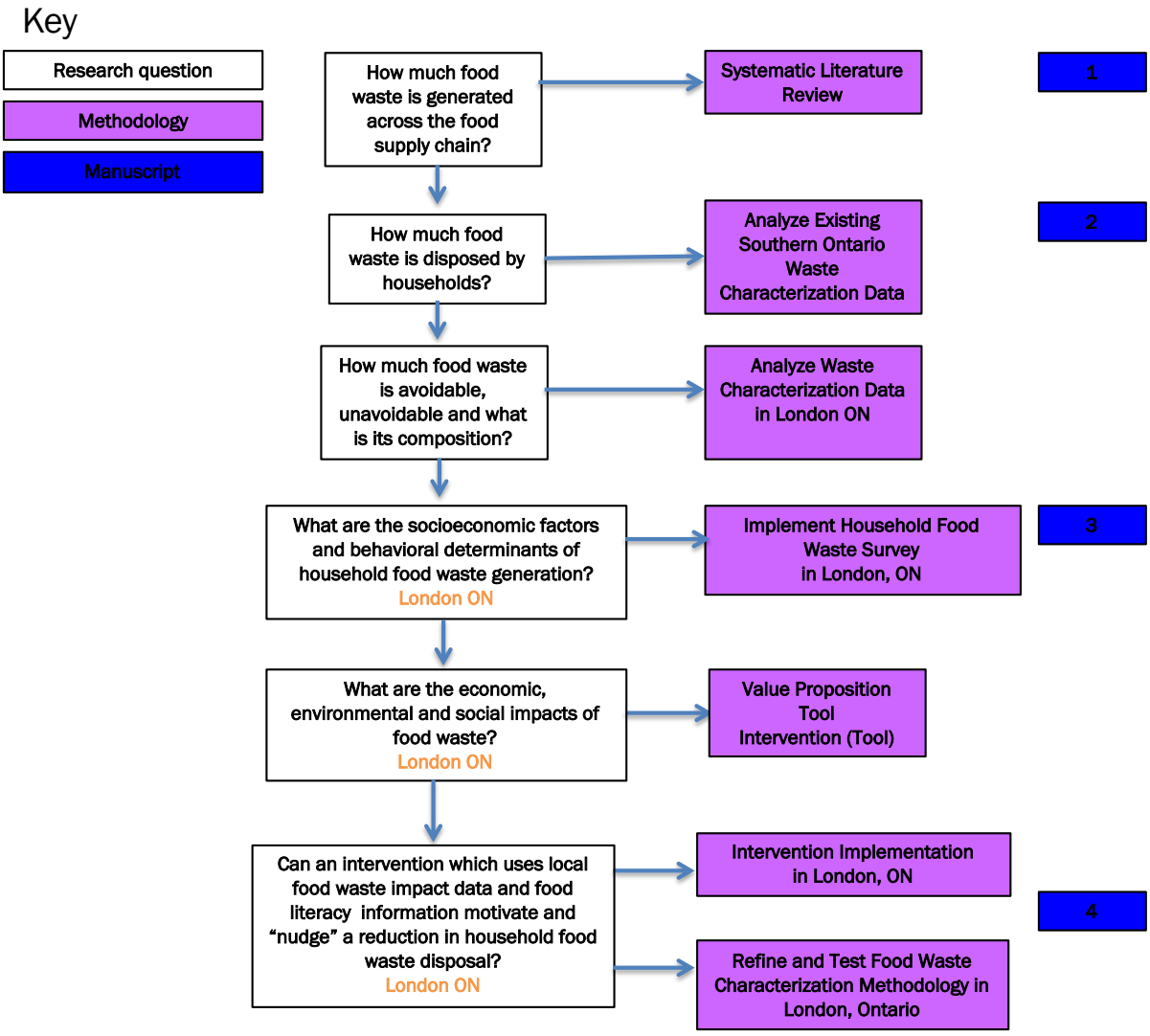

Figure 1.2 - Methodological framework

A version of the third manuscript (Chapter 4), "Food for Naught: Using the Theory of Planned Behavior to Better Understand Household Food Wasting Behavior", was submitted for consideration for publication in the journal *The Canadian Geographer*. The primary research goal was to better understand household food wasting behaviors. This was accomplished by administering a food waste survey that asked households to self-report food wasted and posed questions about food wasting behavioral determinants and possible food waste reduction motivators. To meet this goal, the following research questions were addressed:

a. Why do households waste food and what are their self-reported intentions and behaviors?
b. What impact or combination of impacts (i.e., monetary, environmental, social), if any, will motivate households to reduce food waste?

A version of the fourth manuscript (Chapter 5), "Pilot Testing a Novel Intervention to Reduce Household Food Waste", was submitted for consideration for publication in the journal *Environment and Behavior.* The primary research goal was to develop an intervention informed by local food waste disposal and impact data, the results of the household food waste survey, as well as behavioral economics and nudging. A secondary research goal was to use a refined waste characterization methodology to measure the impact of the aforementioned intervention, and it resulted in the collection of pre- and post-intervention garbage samples and manually sorting/weighing food waste. To meet these goals, the following research questions were addressed:

a. Can local food waste quantity and impact metrics (monetary, environmental and social impacts); household food waste survey data (i.e., motivators, behavioral determinants); and behavioral economics (i.e., nudging) be utilized to develop an efficacious household food waste reduction intervention?
b. Can a food waste reduction intervention motivate households to reduce their food waste in a measurable way?
c. Can a bespoke food waste characterization methodology be employed to measure the impact of the intervention?

1.5 Ethical considerations

Ethics approval for this was received from The University of Western Ontario Non-Medical Research Ethics Board, for Chapters 4 and 5 (REB #108899). The approval form is included in Appendix 1. Informed consent was obtained from on-line survey respondents by their participation in the survey. Further, informed consent was obtained from household volunteers to participate in further research (i.e., collect samples of garbage to measure food waste; additional survey), recruited from the aforementioned survey, by them answering affirmative to the call for volunteers and including their name and address.

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CHAPTER TWO

2 A Systematic Review of Food Losses and Food Waste Generation in Developed Countries

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Published in Proceedings of the Institution of Civil Engineers – Waste and Resource Management (Vol. 170, No. 2, pp. 66-77).

*Doctoral Candidate

2.1 Abstract

The objective of this systematic literature review was to compile and assess food losses and waste estimates, from developed countries, across the food supply chain. The methodology involved systematically identifying studies and extracting, compiling and analysing their estimates of food losses and waste. Of the 55 estimates extracted, from these studies, the most (43·6%) were from the consumption (average 114·3 (kg/capita)/year) part of the food supply chain. On average, total food losses and waste were 198·9 (kg/capita)/year. While this review revealed a high degree of variability of estimates and inconsistent trends for the independent variables: scope of food waste, geography and study methodologies; food waste generation, at the consumption part of the food supply chain, was significantly higher for North American compared with European estimates ($p = 0·003$); and significantly higher ($p = 0·030$) for indirect than direct estimates. Similarly, total food waste generation indirect estimates were significantly higher ($p = 0·035$) than directly measured estimates. To improve the accuracy and precision of food losses and waste estimates, additional research is required to develop and implement a bespoke, weight-based and statistically sound methodology for its direct measurement.

2.2 Introduction

World food production has increased substantially in the past century, as has calorie intake per capita (Nellemann et al., 2009). Nevertheless, food insecurity persists: according to the Food and Agriculture Organization (FAO) 795 million people are undernourished globally, including 15 million in developed regions (FAO et al., 2015).

The quantification of food losses and waste (FLW) is being used to draw attention to the poor use of food resources. According to Gustavsson et al. (2011) developed countries generate more FLW than developing countries. Its reduction presents opportunities to reduce its economic (e.g., wasting money), environmental (e.g., greenhouse gas generation) and social (e.g., food security) impacts. To develop effective FLW reduction interventions and measure their impact, it is essential to have a more precise understanding of its generation. Since a variety of methods have been used to collect FLW data, precise estimates have been elusive. The objective of this systematic literature review is to compile and critically assess current annual per capita weight based estimates of FLW along the various parts of the food supply chain (FSC) in developed countries.

Figure 2.1 depicts the various parts of the FSC which consists of *agricultural production*, *postharvest handling and storage*, processing and packaging, *distribution (i.e., retail sale)* and *consumption*. Our conceptualization incorporates system boundaries adapted

from Nahman and De Lange (2013); Parfitt et al. (2010) and Gustavvson et al. (2011). It highlights the progression of food from farmers to consumers. Each stage of the FSC is a FLW generation and intervention point.

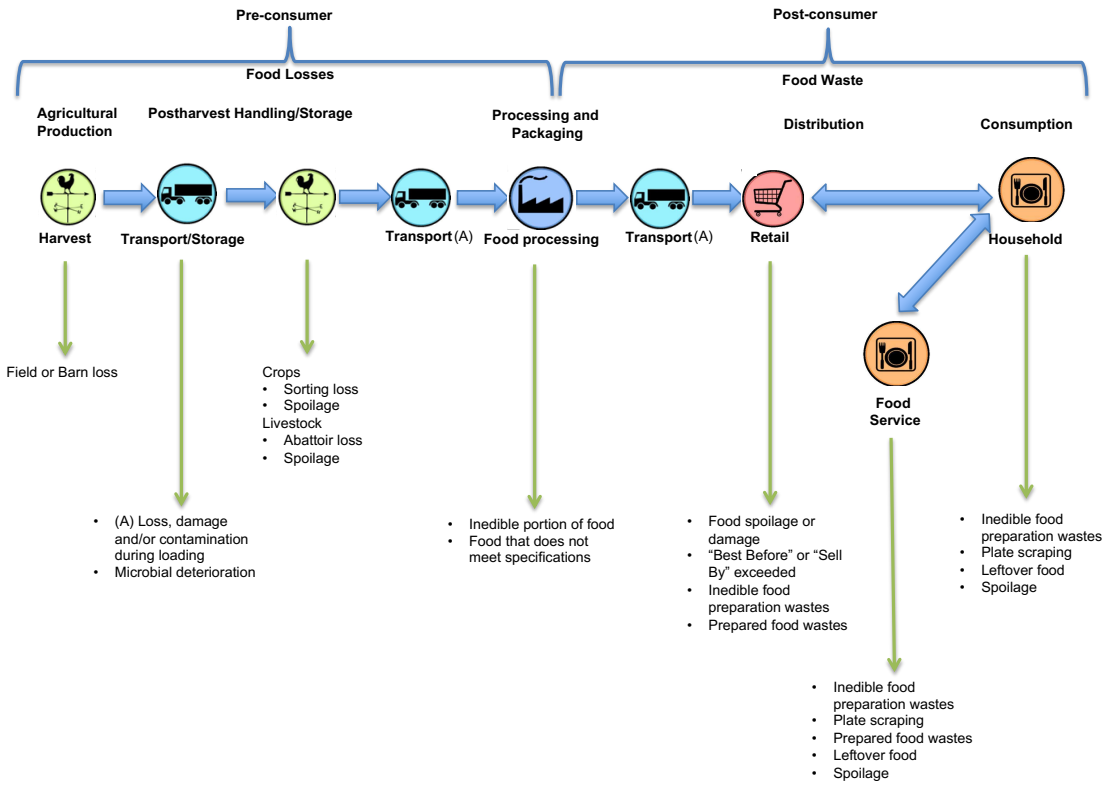

Figure 2.1 - Overview of food supply chain and food losses and food wastes

Schneider (2013) summarizes a number of definitions that have been applied to FLW. In this paper, the front part of the FSC (Figure 2.1) encompasses *agricultural production*, *postharvest handling/storage and processing*, with food that becomes unavailable for human consumption referred to as food losses (Gustavsson et. al., 2011; Kummu et al., 2012; Parfitt et. al., 2010). The back part of the FSC encompasses *distribution* and *consumption*, with food that becomes unavailable for human consumption referred to as food waste (Parfitt et. al., 2010). Food losses and waste are either deemed edible or inedible, which are referred by some as avoidable or unavoidable food waste, respectively. (Beretta, 2009; WRAP, 2009). Edible FLW is food that was at one point edible. Inedible FLW is food that was never edible (e.g., vegetable peels, egg shells, bones).

2.2.1 Annual food production, consumption and FLW generation

The total production of edible food has been estimated at about 900kg/capita/year in North America and Europe (Gustavvson et al., 2011). Meanwhile, estimates of total food available for consumption vary considerably: total food consumption in the developed world has been estimated at 1,006kg/capita/year (Alexandratos and Bruinsma, 2012). Per country food consumption estimates include 779kg/capita/year in Canada (Abdulla et al., 2013); 500kg/capita/year in the United States (Kantor et al., 1997), 500-600kg/capita/year of food purchased for consumption in Finland (Tike, 2010; Viinisalo et al., 2008), and 687kg/capita/year food consumption, at the retail level in Switzerland (Beretta et al., 2013).

Parfitt et. al. (2010) reported that there is no consensus on the amount of global food production that is lost, with ranges of 10-40% and up to 50%. Gustavsson et. al. (2011) estimated that 1/3 of the food produced for human consumption, or about 1.3 billion tons/year is lost or wasted annually, but because many assumptions had to be made to develop these estimates, they note that the results must be interpreted with great caution. It was estimated that developed regions (Europe and North America) generate 95-115 kg/capita/year FLW, which is considerably higher than for developing regions (sub-Saharan Africa and South/Southeast Asia), which generate 6-11 kg/capita/year. Abdulla et. al. (2013), using Statistics Canada and World Bank data (1961-2009), estimated that the amount of FLW in Canada averaged 40% of food available for consumption and that in 2009 approximately 7.3 million tonnes was wasted in Canada. Agriculture and Agrifood Canada (2015) reported there were approximately 6 million tonnes/year of FLW from retail and household consumption.

2.2.2 Data gaps

There is some agreement among researchers about the state of FLW estimates. According to Parfitt et al. (2010), there is no consensus on the amount of FLW due to data gaps and uncertainties. Furthermore, many existing estimates link back to the same limited primary datasets, with much of the published data originating from fieldwork undertaken in the 1970s and 1980s. Langley et al. (2009) concluded that calculating and estimating the amount of food waste is a difficult issue due to a lack of real and meaningful data.

Indeed, a number of researchers have identified that there are major data gaps in the knowledge of global FLW, that necessitates using secondary (i.e., indirect) rather than primary datasets, and that further research is urgently required to improve FLW estimates (Abdulla et. al., 2013, Gustavsson et. al, 2011). It is clear that there are some challenges with the available FLW estimates, including how these estimates are gathered and their precision.

Koester (2013) questions how FLW quantities have been calculated and suggests that current estimates are inflated. In questioning the results of Buzby and Hyman (2012), he suggests that rather than summing food losses, calorific values should be presented, although even this approach would result in an overestimation because in some cases "food loss could have been economically rational" (p. 64). Elaborating on these assertions, Koester (2014) posits that the current definition of FLW is inadequate and not suitable for developing policies that contribute to food security, or improve efficiency of resource use and contribute to a sustainable environment. The foremost need is to develop appropriate measures, perhaps using multiple methods, for aggregating FLW across the FSC. Koester's (2013) arguments are echoed by Buzby et al. (2014), who note that FLW is becoming an increasingly important topic both domestically and internationally. Better estimates of the amount and value of FLW could help serve as quantitative baselines to develop interventions to reduce FLW generation.

2.3 Methods

A systematic literature review was performed by adapting methods described in Petticrew and Roberts (2006) and PRISMA guidelines (Liberati et al., 2009). This method, which is widely used in medical and social science fields, has been applied to this review to facilitate a systematic retrieval of relevant research papers. The purpose is to impart additional rigour to the literature review process. This was accomplished by collaboratively developing all search terms, identifying databases to be used and identifying inclusion/exclusion criteria in advance of starting the review.

2.3.1 Search strategy

Studies that examined the amount of FLW generated along the FSC were identified through searching the following databases: Scopus; Geobase; and Web of Science. The

search included articles published between 1 January 1985 and 15 October 2015. The following search terms were used: “Food” AND “Waste” AND Quant*; “Food Waste” AND Quant*; “Food Waste” AND “Characterization”; "Food Waste" AND "Cost"; "Food Loss"; "Food Losses"; "Food Waste" AND "Composition"; "Food Waste" AND "Measure*; "Food Waste" AND Agri* AND Quant*; "Food Waste" AND Household* AND Quant*; "Food Waste" AND Food Process* AND Quant*; "Food Waste" AND "Supply Chain" AND Quant*; “Waste” AND “Characterization” AND “Food”; "Waste Characterization" AND Method*; "Waste Characterization" AND "Food"; “Waste Audit” AND Method*; and “Waste Audit” AND “Food”.

The inclusion/exclusion criteria for studies included: (1) Detailing research between 1985 and 2015; (2) English language; (3) Quantitative and qualitative studies; (4) Results of food waste quantification by weight; and (5) Research conducted in developed countries.

Relevant studies were identified first through title screening and then abstract reviews of titles that passed first screening. Studies remaining after abstract screening were subject to full text screening and a final decision on relevance for inclusion in the review. Paper relevance was determined through the application of the inclusion/exclusion criteria. Studies from which weight-based FLW quantities could be extracted and normalized on a per capita basis were selected. This was confirmed by both authors.

Data points were extracted from studies and grouped by their respective part(s) of the FSC. Data points were normalized, where necessary, to kg/capita/year by dividing the annual weight of food waste generated by the appropriate population. The number of data points per part of the FSC were counted and averaged. The following independent variables were identified: (1)

Scope of FLW (inedible/edible or edible); (2) Geography (Europe or North America); and (3) Study Methodologies (direct or indirect measurement). Statistical analysis of the data was undertaken by establishing null hypotheses that each independent variable had no impact on the amount of FLW generated for the dependent variables: *distribution*,

consumption and *total* FLW; which were chosen because they had the most FLW data points. This was assessed using an independent samples T-test.

2.4 Results

Figure 2.2 depicts the results of the systematic review. After the database search and initial title screening, the authors screened the remaining abstracts of all articles in the reference list, using the inclusion/exclusion criteria. This resulted in a final reference list of 135 papers for full-text review.

The multi-staged search strategy with full-text review yielded 30 papers that met the inclusion criteria for final consideration in this review. The 30 papers included 17 papers that were found directly through the full-text review process and another 13 papers that were identified from a title review of the reference lists of these papers, as well as a scoping review of the grey literature.

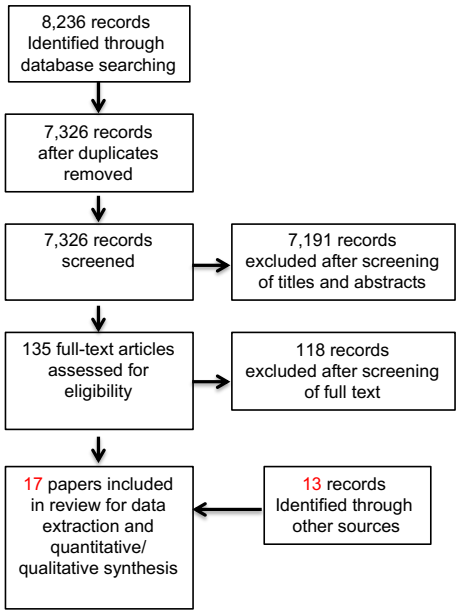

Figure 2.2 - Flow diagram of the systematic review

2.4.1 Results of individual studies and study characteristics

Table 2.1 presents summaries of each of the selected studies. Essentially all the studies were North American (United States and Canada) and European (European Union and

Scandinavian countries). Almost all studies were undertaken and published after 2005 and include both edible and inedible FLW in their estimates, rather than segmenting out just the edible fraction of FLW. The studies included: regional estimates (e.g., Europe, North America and Oceania- Gustavsson, 2011); countrywide estimates (e.g., Canada- Abdulla et al., 2013; United States- Buzby and Hyman, 2012, 2014); statewide estimates (e.g. Hawaii- Okazaki et al., 2008), county estimates (Griffin et al., 2009); and neighbourhood estimates (e.g., Malmo, Sweden- Bernstad et al., 2012 and 2013). Few studies provided estimates of FLW across each part of the FSC. Quantitative research included mostly uncontrolled studies that combined and extrapolated existing data sets to develop estimates, or the studies of weight based waste composition measurements. Research studies also included surveys and diaries.

Table 2.1 - Overview of systematic review results

Author	Year(s)	Country	State of Food	Method	Study Methodology	Food Supply Chain					
						Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
						kg/capita/year					
Abdulla et. al., 2013	2009	Canada	Edible and Inedible	Used secondary Statistics Canada data, which in turn used U.S. Department of Agriculture (USDA) "waste factors", and World Bank data to develop estimates.	Indirect					308.2	
Agriculture and Agrifood Canada, 2015	2010	Canada	Edible and Inedible	Used Statistics Canada and USDA data to develop estimate.	Indirect				54.5	121.5	
Bernstad et al., 2012	2008	Sweden	Edible and Inedible	Weighing all waste leaving the study area and repeated waste composition analyses of large samples from all fractions.	Direct					95.7	
Bernstad et al., 2013	2009	Sweden	Edible and Inedible	Weighing of all waste fractions, repeated waste composition analyses of disposed waste and a questionnaire.	Direct					68.8	
Brautigam et al., 2014	2006	EU	Edible and Inedible	Calculations are based on a FAO mass flow methodology (based on Food Balance Sheets, described in Gustavsson et al., 2011, 2013).	Indirect	95.2	30.6	33.5	14.4	114.8	288.5

Table 2.1 - Overview of systematic review results- continued

Author	Year(s)	Country	State of Food	Method	Study Methodology	Food Supply Chain: Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
						kg/capita/year					
Buzby and Hyman, 2012	2008	US	Edible	Compiled estimates of food loss using the US Department of Agriculture's Economic Research Service's Loss-Adjusted Food Availability (LAFA) data.	Indirect					188	
Buzby et al., 2014	2010	US	Edible	Compiled estimates of food loss using the US Department of Agriculture's Economic Research Service's Loss-Adjusted Food Availability (LAFA) data.	Indirect				63	195	
Defra, 2010	2007	England	Edible and Inedible	The results from various curbside and recycling depot waste audits were summarized to develop an estimate of waste quantity and composition, including food waste.	Direct					83.2	
EC, 2010	2006	EU	Edible and Inedible	Used 2006 Eurostat data and various national sources to compile total food waste per country.	Indirect			70.0	33.9	75.9	179.8
Edjabou et al., 2015	2013	Denmark	Edible and Inedible	A waste auditing methodology was developed and used to estimate the composition, including food waste, of curbside single family and multi residential waste.	Direct					86.6	

Table 2.1 - Overview of systematic review results- continued

Author	Year(s)	Country	State of Food	Method	Study Methodology	Food Supply Chain					
						Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
						kg/capita/year					
Edjabou et al., 2015	2013	Denmark	Edible and Inedible	A waste auditing methodology was developed and used to estimate the composition, including food waste, of curbside single family and multi residential waste.	Direct					75.3	
Garrone et al., 2014	not provided	Italy	Edible and Inedible	Case studies were used to develop an extrapolated estimate of the amount of food waste generated from food processing and distribution/retail sales in Italy.	Indirect			3.0	13.0		
Griffin et al., 2009	1999	US	Edible and Inedible	A case study was conducted in a single upper New York State County to estimate food waste generation along the food supply chain. Information was gathered through interviews and from published county, state and national sources.	Indirect	19.3		1.2	17.6	57.6	95.6
Gustavsson et al., 2011	2007	North America and Oceania	Edible	Used FAO datasets and assumptions to address data gaps to develop estimates of FLW along the FSC.	Indirect					115	300
Gustavsson et al., 2011	2007	Europe	Edible	Used FAO datasets and assumptions to address data gaps to develop estimates of FLW along the FSC.	Indirect					95	280

Table 2.1 - Overview of systematic review results- continued

Author	Year(s)	Country	State of Food	Method	Study Methodology	Food Supply Chain					
						Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
						kg/capita/year					
Hodges et al., 2010	2008	US	Edible	Used data from United States Department of Agriculture, Economic Research Service, 2010 to develop an estimate of food waste.	Indirect				64.0	123.8	
Jones 2006	not provided	US	Edible and Inedible	No explanation of methods.						213.6	
Jones, 2005	not provided	US	Edible and Inedible	No explanation of methods.					106.4		296
Kantor et al., 1997	1995	US	Edible and Inedible	The United States Department of Agriculture (USDA) Economic Research Service developed preliminary estimates of food waste generation by retail, food service and consumer sectors. Many of the studies on which these estimates are based date from the mid-1970's or before.	Indirect				9.3	155.0	266.3

Table 2.1 - Overview of systematic review results- continued

Author	Year(s)	Country	State of Food	Method	Study Methodology	Food Supply Chain					
						Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
						kg/capita/year					
Katajajuuri et al., 2014 and Silvennoinen et al., 2014	2010	Finland	Edible	Household food waste data was collected through a diary study. Food service sector data was collected via on site (i.e. weighing of food waste along various parts of food service chain- e.g. cooking, serving, customer leftovers). Retail sector and industry data was collected via interviews of various parties in the supply chain.	Direct			14-26	26-30	23	
Langley et al., 2010	not provided	UK	Edible and Inedible	Tested a method of quantifying (self weighing) and estimating the composition (through use of a diary) of food waste disposed by households.	Direct					72.6	
Lebersorger et al. 2011	2009	Austria	Edible and Inedible	Calculated the number (n) of urban and rural waste samples to collect and sort on the basis of a 95% confidence level, using mean and standard deviation data from previous waste analyses.	Direct					49.6	

Table 2.1 - Overview of systematic review results- continued

Author	Year(s)	Country	State of Food	Method	Study Methodology	Food Supply Chain					
						Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
						kg/capita/year					
Lebersorger et al., 2011	2009	Austria	Edible and Inedible	Calculated the number (n) of urban and rural waste samples to collect and sort on the basis of a 95% confidence level, using mean and standard deviation data from previous waste analyses.	Direct					18.8	
Matsuto and Ham, 1990	1989	US	Edible and Inedible	Waste samples collected from curb in Madison, Wisconsin and Sapporo, Japan and manually sorted into a number of categories, including food waste.	Direct					65.3	
Matsuto and Ham, 1990	1988	Japan	Edible and Inedible	Waste samples collected from curb in Madison, Wisconsin and Sapporo, Japan and manually sorted into a number of categories, including food waste.	Direct					123.0	
Okazaki et al., 2008	2005	US Hawaii	Edible and Inedible	Information collected on food establishments and their practices came from the State of Hawaii Department of Health (DOH) list of permitted food establishments and a food waste recycling survey was developed and distributed to all permit holders.	Direct				240.9		

Table 2.1 - Overview of systematic review results- continued

Author	Year(s)	Country	State of Food	Method	Study Methodology	Food Supply Chain					
						Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
						kg/capita/year					
Parizeau et al., 2015	2015	Canada	Edible and Inedible	Data from green bin only and did not include household garbage destined for landfill. Also allowable green bin items include other items besides food waste.	Direct					217.4	
USDA ERS, 2014	2010	US	Edible and Inedible	Compiled estimates of food loss using the US Department of Agriculture's Economic Research Service's Loss-Adjusted Food Availability (LAFA) data.	Indirect						194.9
USEPA, 2009	2008	US	Edible and Inedible	USEPA collects and reports on waste generation and disposal data in the US and has done so for the last 30 years. Municipal solid waste (MSW) includes household, commercial and institutional waste.	Indirect						104.5
USEPA, 2014	2012	US	Edible and Inedible	USEPA collects and reports on waste generation and disposal data in the US and has done so for the last 30 years. Municipal solid waste (MSW) includes household, commercial and institutional waste.	Indirect						116.0

Table 2.1 - Overview of systematic review results- continued

Author	Year(s)	Country	State of Food	Method	Study Methodology	Food Supply Chain					
						Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
						kg/capita/year					
WRAP, 2009	2007	UK	Edible and Inedible	Estimates of solid and liquid food waste were derived from annual waste generation totals obtained from municipalities, waste composition studies and diary research.	Direct						134.3
WRAP, 2013b	2011	UK	Edible and Inedible	Gathered production and retail data and applied estimates of food waste to develop estimates. Developed a mass balance to estimate food waste types and how are they are managed.	Direct			61.7	7.1		
WRAP, 2013a	2012	UK	Edible and Inedible	The estimates for household food and drink waste were derived from a summary of waste audits and kitchen diary research.	Direct						130.3

2.4.2 Review of results by position on FSC

Figure 2.3 depicts all of the FLW data points by position on the FSC. It is clear that most of the research in these studies was focused on the *consumption* part of the FSC, followed by studies that provided a *total* estimate or *distribution* estimate. Table 2.2 presents an overview of the FLW weight data points across the FSC, along with the results of a descriptive statistical analysis. There is a high degree of variability in the estimates across all parts of the FSC.

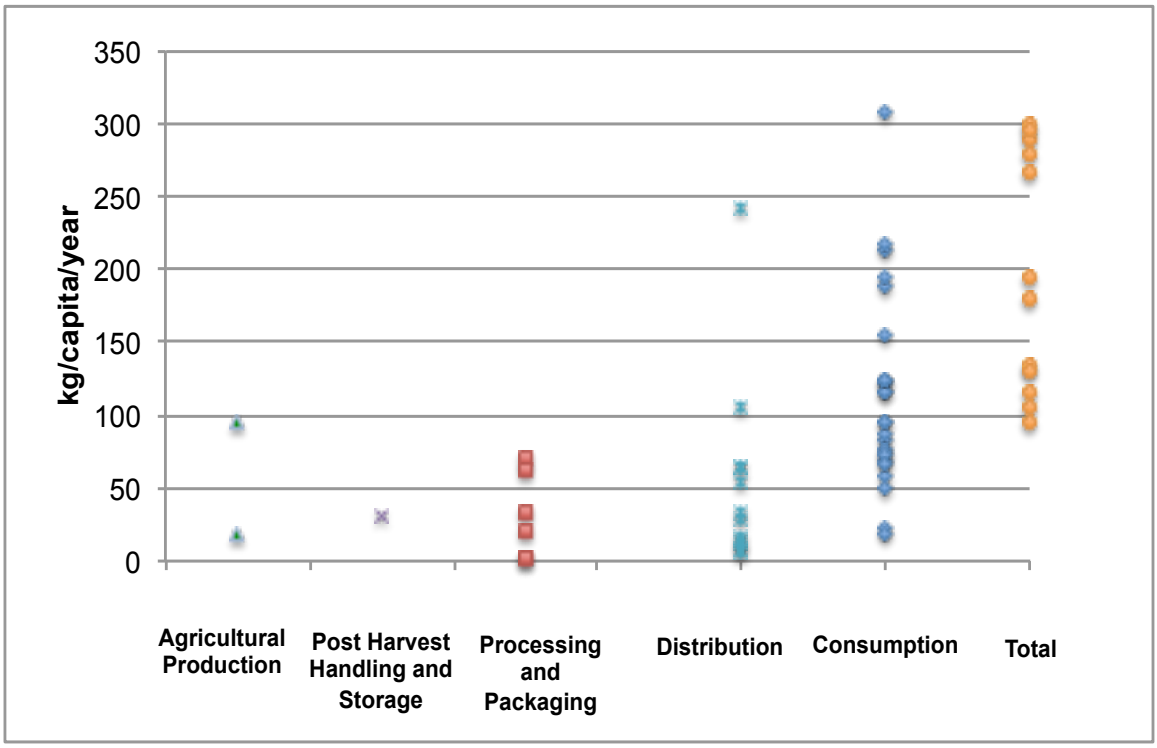

Figure 2.3 - Detail of FLW weight data points across FSC

Table 2.2 - Summary of FLW weight data points across FSC (kg/capita/year)

	Agricultural Production	Post Harvest Handling and Storage	Processing and Packaging	Distribution	Consumption	Total
n=	2	1	5	11	24	12
Min	19.3	30.6	1.2	7.1	18.8	95.6
Max	95.2	30.6	70.0	240.9	308.2	300.0
Average	57.2	30.6	33.9	56.7	116.3	198.9
Standard Deviation	53.7		32.0	68.5	68.0	82.3

Agricultural Production and Postharvest Handling and Storage

There were three studies that developed estimates for these two parts of the FSC. Brautigam et al. (2014) adopted multipliers developed by Gustavvson (2011) to estimate FLW and used them to develop a European Union (EU)-wide estimate of 125.8 kg/capita/year for these two parts of the FSC, which represented 44% of their overall estimate of EU FLW.

Processing and Packaging

The lower FLW estimates (1.2-3.0 kg/capita/year) (both generated using case studies) were from a single upstate New York State county (Griffin et al., 2009) and from a single country (Italy) (Garonne et al., 2014). The highest estimate (70.0 kg/capita/year) (based on Eurostat data and data from national sources) was from the European Union (EU) (European Commission, 2010) and was similar to a UK wide estimate (61.7 kg/capita/year), which used food production data to develop an estimate of FLW (WRAP, 2013b).

Distribution

The lower estimates of FLW were from the UK (WRAP, 2013b) (7.1 kg/capita/year). Estimates for the United States (Kantor et al., 1997) were calculated using US Department of Agriculture-Economic Research Service (USDA-ERS) data and previous studies that estimated FLW generation. The higher estimates identified in the review were from the US state of Hawaii (Okasaki et al, 2008) (240.9 kg/capita/year) (survey). The *agricultural production* to *distribution* parts of the FSC represent pre-consumer

FLW estimates. Estimates ranged from 173.7 to 185.0 kg/capita/year (Brautigam et al., 2014; Gustavsson et al., 2011).

Consumption

In this review, the most data points and highest average annual per capita FLW generation (114.3 kg/capita/year), are found within the *consumption* part of the FSC. The lower estimates came from a rural area (Lebersorger et al., 2011) (18.8 kg/capita/year) (based on waste audit of curbside waste samples) and Finland (Katajajuuri et al., 2014 and Silvennionen et al., 2014) (23 kg/capita/year) (based on diary study that measured edible food waste only). The highest estimate came from Canada (308 kg/capita) (Abdulla et al., 2013) (using Statistics Canada and World Bank data and applying USDA waste factors).

Total

In some cases, estimates of *total* FLW included the sum of FLW estimates from the different parts of the FSC, but in most cases this was characterized by standalone estimates of all FLW generated. On average, it was estimated that 198.9kg/capita/year of FLW is generated. The lower estimates came from a single upstate New York State county (Griffin et al., 2009) (95.6 kg/capita/year) (case study) and the United States (USEPA, 2014) (116 kg/capita/year). The highest estimate was based on studies of North America and Oceania (300 kg/capita/year) (Gustavvson et al., 2011).

2.4.3 Review of independent variables

Table 2.3 presents a summary of average FLW for the independent variables: (1) scope of FLW (inedible/edible or edible); (2). geography (Europe or North America); and (3) study methodologies (direct or indirect measurement), for the dependent variables: *distribution*; *consumption* and *total*. The FLW differences of greatest magnitude were related to the variables geography and study methodologies. For Geography, the average FLW estimates for *distribution* were higher and *consumption* significantly higher ($p=0.003$) for North America than Europe although for *total* they were similar.

Table 2.3 - Summary of independent variables and FLW weight data points (kg/capita/year) for the dependent variables: distribution, consumption and total

	Scope of FLW		Geography		Study Methodologies	
	Inedible/ Edible	Edible	Europe	North America	Indirect	Direct
Distribution						
n=	9	3	5	7	8	3
Average	55.2	51.7	19.3	79.4	33.7	92.0
S.D.	76.9	20.5	11.2	78.2	23.5	129.4
p=	0.940		0.123		0.517	
Consumption						
n=	18	6	12	11	11	12
Average	111.0	123.3	71.6	160.0	140.9	81.6
S.D.	71.7	63.6	28.7	73.8	69.7	51.6
p=	0.719		0.003		0.030	
Total						
n=	10	2	5	7	9	2
Average	180.6	290.0	202.6	196.2	202.9	132.3
S.D.	77.7	14.1	77.1	91.8	83.7	2.8
p=	0.085		0.902		0.035	

For Study Methodologies, direct measurement methods (n=3) resulted in higher FLW estimates for *distribution*. Indirect measurements resulted in significantly higher FLW estimates for *consumption* (p=0.030) and *total* (p=0.035*)*, although it should be noted that for there were only two studies that employed direct study methodologies to estimate *total* FLW.

2.4.4 Risk of bias within and across studies

The main risk of bias within the studies reviewed relates to how data were collected and analyzed. For studies using indirect measurement, the risk of bias relates to what is actually being measured. The general approach is to use estimates of the amount of food that is produced and apply estimates of FLW along the various parts of the FSC. These estimates are generally old (some date to the mid-1970s) and it is not clear how they were developed. The risk of bias, across studies, occurs when this same methodology or variation thereof is used by a number of researchers. Any under or over-estimation could also be manifested in these studies.

For studies using direct measurements involving the collection and sorting of waste samples, the risk of bias relates to the representativeness of the samples (e.g., number and

location of households from which waste is collected for composition analysis) and the meaningfulness of resultant extrapolations. For direct food waste measurements that involve self-reporting (e.g., using diaries), the risk of bias relates to the lack of blinding. Mindful that different interventions are not being assessed in these studies; bias can be manifest as performance and detection bias. There appeared to be little risk of bias across these studies because the methodologies did not appear to be shared.

2.5 Discussion

The results showed that there is a greater tendency to measure FLW at or just before it gets to the consumer and that these yield the highest estimates; that there is considerable variability in the data; that North American estimates are generally higher that European ones; and that indirect measurements generally result in higher FLW estimates. The results are far from unequivocal and this exercise confirms the noted concerns about the current state of FLW data and methodological issues (Abudulla et al., 2013, Gustavvson et al., 2011, Langley et al., 2009, Parfitt et al., 2010).

2.5.1 Methodological issues

A key methodological issue is that FLW estimates are derived both indirectly and directly, yielding results that are difficult to compare. Furthermore, current estimates do not always differentiate edible from inedible FLW or offer much detail on its composition. Indirect estimates are often used to develop global, continent or country wide estimates whereas direct measurements are used for smaller geographic units such as a City or a region (Table 2.1). Table 2.4 summarizes the differences between indirect and direct FLW measurement.

Table 2.4 - Comparison of indirect and direct measurement of FLW

	Indirect Measurement	Direct Measurement
General approach	Mass flows model used to estimate FLW along each part of the FSC	Direct collection of waste samples to estimate FLW at a specific FSC position(s)
Steps to calculate FLW	FLW estimated using five step process: Estimate production volumes (typically national or transnational) per commodity Estimate food loss coefficient per commodity Calculate the product of the production volume and food loss coefficient per commodity Allocate FLW across the FSC per commodity Sum per commodity FLW to develop total per FSC position FLW	FLW estimated using six step process: Scope, by position on FSC, where waste samples will be collected Scope by geography (e.g., City) Scope FLW sorting categories (e.g., avoidable and unavoidable) Collect representative samples of FLW Manually sort and weigh FLW into selected categories Extrapolate FLW by scoped position(s) on the FSC, geography and sorting categories
Output	Results in general national and transnational FLW estimates	Results in specific and scoped geographically local FLW estimates
Use of output data	Identifies and estimates extent of FLW but offers little *empirical* evidence on where to possibly implement interventions	Identifies and estimates extent of local FLW and offers *empirical* evidence on where to possibly implement interventions

2.5.1.1 Indirect measurement

Indirect estimates have been derived from estimates of how much food is available to be consumed and applying waste factors.

2.5.1.1.1 Worldwide estimates

In their widely cited paper, Gustavsson et al. (2011) present global and regional (Europe, North America and Oceania, Industrialized Asia, Sub-Saharan Africa, North Africa, West

and Central Asia, South and Southeast Asia and Latin America) FLW estimates on behalf of the Food and Agriculture Organization (FAO). A mass flows model was used to estimate FLW along each part of the FSC. The production volumes for all commodities were collected from the 2009 FAO Statistical Yearbook (FAOSTAT, 2010a) and the 2007 FAO Food Balance datasheets (FAOSTAT, 2010b). Allocation and conversion factors were applied to determine food available for human consumption. The authors made assumptions and estimates based on FLW in similar regions and other factors where there were data gaps. There is insufficient data presented on how estimated/assumed FLW percentages across the FSC of each region were derived.

2.5.1.1.2 United States estimates

Countrywide estimates of American FLW data were developed by the U.S Department of Agricultural - Economic Research Service (USDA-ERS) starting with Kantor et al. (1997 to the most recent estimates by Buzby et al. (2014). USDA-ERS, 2014 provides some insights into how these estimates were developed, how they have been improved, as well as their limitations. The basis of these estimates were derived from the ERS' Loss-Adjusted Food Availability (LAFA) Data series. It uses ERS's food availability data, which estimates the annual production of more than 200 foods and then adjusts for food spoilage, plate waste, and other losses at different stages along the food supply and consumption chain, to more closely approximate actual consumption. Food loss coefficients were gathered from published reports and discussions with commodity experts. Loss assumptions were based on data and studies from the mid-1970s onwards.

As described in USDA-ERS (2014), attempts have been made to improve the underlying assumptions used to make estimates of FLW. Estimates of primary level (i.e., farm to retail weight) FLW were updated through industry interviews and research. Some retail FLW estimates were updated by comparing supplier shipment data with point of sales data at large national supermarket chains and supplemented with qualitative information from retail contacts. Consumer-level loss estimates for cooking loss and food loss from edible food were updated through: (1) a review of the literature, (2) a small set of restaurant interviews, (3) a numerical estimation method to calculate consumer-level food loss estimates using Nielsen Homescan data (food purchase data) and (4), the dietary intake component of the National Health and Nutrition Examination Survey (NHANES)

(food consumption data). In 2012 ERS used the "best estimate" of these consumer FLW estimates, but continued to use the LAFA dataset when updated data were unavailable.

The LAFA dataset does not measure actual consumption or quantities ingested because it is not based on direct observations of individual intake. Furthermore, LAFA does not identify where, along the FSC, FLW is created. Ultimately these estimates function as a proxy of per capita consumption and FLW generation along the FSC.

2.5.1.1.3 Canadian estimates

Abdulla et al. (2013) used reports published from Statistics Canada and the World Bank to calculate FLW from food available for consumption. Statistics Canada used "waste factors" provided by the USDA (Statistics Canada, 2010) to estimate FLW at the *consumption* part of the FSC. Canada does not have the data required to empirically quantify FLW at each point in the FSC. Abdulla et al. (2013) recommends launching a replicable pilot study in an area or region to measure FLW across the FSC and then replicate elsewhere in Canada.

2.5.1.2 Direct measurement

Direct measurements of FLW are taken where it is possible to collect and sort waste samples. To date, this has tended to occur with post-consumer waste and specifically at the *consumption* part of the FSC.

2.5.1.2.1 United Kingdom

The UK's Waste Reduction Action Programme (WRAP) has developed a number of solid and liquid *consumption* estimates of FLW (WRAP 2009, WRAP 2013a, WRAP 2013b). This relies on waste management tonnage data collected by local authorities, the results of waste composition analysis (i.e., waste audits), and the use of kitchen diaries (i.e., FLW tracking by residents). It multiplies the percentage of FLW in the waste stream with the total amount of waste generated and supplements this with waste composition data and with kitchen diary data (i.e., which also included detail on pet feeding or home composting of FLW).

Processing & packaging and *distribution* data were obtained from various industry

surveys (i.e., by the Environment Agency, Department for Environment, Food and Rural Affairs (Defra), Food and Drink Federation), business reports on waste (to satisfy permitting requirements) and using business register data to estimate and extrapolate waste generation. FLW estimates were developed from a variety of datasets, because individual datasets did not provide a complete set of information.

2.5.1.2.2 Other

Some studies used direct measurement to either estimate and/or test methods to estimate FLW generation (Katajajuuri et al., 2014; Langley et al., 2010; Lebersorger et al., 2011, Okazaki et al., 2008, Parizeau et al., 2015, Silvennoinen et al., 2014) or to assess the impacts of FLW reduction interventions (Bernstad et al., 2012, 2013). Studies typically included a weight-based assessment of FLW and in some cases included diary studies or surveys. For other studies, the focus was on estimating the composition of the overall waste stream of which FLW was a component (Defra, 2010; Edjabou et al., 2015; Matsuto and Ham, 1990). The challenge with the direct measurement of FLW is the ability to extrapolate the resultant data. WRAP (2009; 2013a; 2013b) and Defra (2010) have demonstrated a possible methodological approach.

2.5.2 Additional research

Given the challenges described for using indirect sampling, it is difficult to envision its use for developing anything more than a general picture of the current situation, but not to inform the development of interventions in any meaningful way. Direct measurement of FLW, from collected waste samples, should result in more precise estimates of FLW, at least for the geographic area in which they were completed. These data can be used to inform intervention development and importantly can subsequently be re-measured to assess the efficacy of the intervention.

Additional research is required to better understand FLW generation across all parts of the FSC. To date, FLW estimates have focused on *consumption* and to a lesser extent *distribution* and *total* estimates. Additional FLW estimates are required for *agricultural production*, *postharvest handling/storage* and *processing and packaging*. Although challenging, particularly for *agricultural production*, where in-field or in-barn measurements would be necessary, direct measurements should be taken to develop these

estimates. Furthermore, FLW estimates from *agricultural production* require a more precise definition to determine when food becomes FLW.

For instance, there may be in-field sorting of a crop whereby a portion of the crop is left behind in the field. While this could be construed to be FLW, it could also be considered as a source of organic matter necessary to maintain soil tilth.

Additional methodological development to directly measure FLW across the FSC are required as initiated by Langley et al. (2010) and Lebersorger et al. (2011) with the possible enhancement of these estimates through mathematical methods (Langley et al., 2009). The basis of these methods should focus on statistically sound weight-based assessment of waste samples, through waste auditing, but, should also provide additional detail on the various food fractions (e.g., bakery, meat) that comprise FLW. As well, it should include consideration of edible versus inedible FLW because this can help establish the net amount that is recoverable for human consumption. These methods should be tested and refined in small geographic areas (e.g., Cities and Towns). Ultimately, the results of FLW estimates from small geographic areas can be assembled and extrapolated to develop broader regional (e.g., province) or countrywide FLW estimates.

Efforts to add more rigour to FLW measurement are underway and includes *The Food Loss and Waste Accounting and Reporting Standard* (FLW Protocol, 2016). Although largely neutral on indirect and direct methods, it presents a detailed and systematic framework on how to approach FLW measurement, so that it meets the needs to those measuring FLW and facilitates potential comparison of results.

2.5.3 Limitations

This review focused on weight based FLW estimates and did not consider greenhouse gas (GHG), calorie or dollar based FLW estimates for two reasons. Firstly, this was the most common FLW estimation approach, by far. Secondly, these other metrics are largely inferred from weight based estimates and given the above noted FLW estimation challenges this was deemed to be of limited value.

2.5.4 Conclusions

Based on this systematic review of the literature *total* average FLW in developed countries is estimated to be 198.9 kg/capita/year, while average *consumption* related FLW is estimated to be on average, 114.3 kg/capita/year. There is considerable variability in the various FLW estimates and this is a function of how these data have been collected, and in particular, if the data was collected indirectly or directly. While indirect measurements can provide an overview of the current situation, direct measurements are needed to develop more accurate and precise estimates of FLW, as well as its composition. Ultimately what is required is the development and testing of a bespoke and statistically sound methodology to directly measure FLW. This method should be developed so that it is replicable and usable in a variety of geographic contexts (e.g., city, region). While global or countrywide FLW estimates developed through indirect data collection are interesting, more scoped estimates will provide improved data from which purpose-built interventions to reduce FLW can be developed and implemented.

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CHAPTER THREE

3 The quantity of food waste in the garbage stream of southern Ontario, Canada households

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3.1 Abstract

There is little consensus on the amount of worldwide food waste generation because many current estimates are indirect and link back to the same limited primary datasets, with much of the data originating from fieldwork undertaken in the 1970s and 1980s. Direct measurement of waste streams, through waste composition studies, can be used to develop accurate estimates of food waste disposal. In Ontario, Canada, municipalities that undertake household waste composition studies all use a common direct measurement methodology that includes a broad range of waste categories, including food waste. The purpose of this research was to estimate the quantity of food waste disposed, in the garbage stream, by households in southern Ontario, Canada, and determine if this common methodology could be expanded and serve as the basis of a standardized and rigorous household food waste measurement methodology. Household waste composition study data (2012-2015), including a single "food waste" category, were gathered from 9 Ontario municipalities, aggregated and analyzed to develop estimates of food waste in the garbage stream. On average, households disposed 2.40 kg/week of food waste in the garbage, which comprised 35.4% of this waste stream. This does not include any food waste otherwise disposed (e.g., sink) or recycled (e.g., composted). Urban households disposed significantly greater amounts of food waste compared to rural households in the spring ($p=0.01$) and summer ($p=0.02$). Households with access to a green bin program disposed significantly less food waste than those with no access to a green bin program in the spring ($p=0.03$) and summer ($p<0.01$). The common methodology used to develop these estimates shows promise as the basis of a household food waste measurement methodology. This future methodology would include dividing food waste into avoidable and unavoidable food waste categories, as well as adding subcategories (e.g., avoidable fruits and vegetables).

3.2 Introduction

Given humanity's biological nature, the procurement, preparation, eating and wasting of food has been a constant feature of our history. This wasting of food represents lost utility and ultimately, inefficiency. It is ironic, however, that food waste and food insecurity co-exist. On the one hand, Gustavsson et al. (2011) estimates that one-third and Parfitt et al. (2010) suggests up to one-half of annual food production is wasted, while on the other hand, up to 795 million people are undernourished globally, including 15 million in developed regions (FAO IFAD and WFP, 2015). Reducing the amount of food that becomes waste can help ameliorate this social issue, as well as presenting opportunities to reduce its monetary (e.g., wasting money) and environmental (e.g., greenhouse gas generation) impacts.

The European Commission (2010, p. 24) defines food waste as "waste composed of raw or cooked food materials, and includes food discarded at any time between farm and fork; in households relating to food waste generated before, during or after food preparation, such as vegetable peelings, meat trimmings, and spoiled or excess ingredients or prepared food." WRAP (2009) and Beretta et al. (2013) sub-categorize food waste into three categories: (1) Avoidable: Edible food that was thrown away because it was no longer wanted; (2) Possibly avoidable: Food that some people eat but others do not (e.g., apple peels); may be eaten depending on how it is prepared (e.g., potato skins); or that is thrown out due to a specific criterion (e.g., bent carrots); and (3) Unavoidable: Food that is normally not edible (e.g., banana skin, coffee grounds, inedible slaughter house waste). This also includes losses/wastes from harvesting, storing, transporting and processing that are unavoidable with the best available technologies. In this paper, food waste is either avoidable (i.e., food that was edible at one point) or unavoidable (i.e., food that was never edible).

Since the 1970s, a few researchers have investigated food waste disposal and behaviour (Harrison et al., 1975; Munro & Marshall, 1995; Van Garde & Woodburn, 1987; Wenlock et al., 1980), but this did not coalesce beyond these disparate pockets of research. More recently, due perhaps to the juxtaposition of a rapidly growing population and our improved ability to grow food with ongoing food insecurity, there is a developing critical mass of academic research interest, and government intervention and policy development related to reducing food waste. Underlying this interest is the recognition that it is essential to have an accurate and precise understanding of food waste generation. Current food waste generation estimates, across the food supply chain of developed countries, vary widely (Abdulla et al., 2013; Brautigam et al., 2014; European Commission, 2010; Gustavsson et al., 2011; USDA-ERS, 2014; USEPA, 2009, 2014) ranging from 96kg/capita/year in a single upstate New York State county (Griffin et al., 2009) to 300 kg/capita/year in North America and Oceania (Gustavsson et al., 2011). Much of this food waste is generated by consumers/households and estimates vary widely (Abdulla et al., 2013; Bernstad et al., 2012; Buzby & Hyman, 2012; Edjabou et al., 2015; Hodges et al., 2010; Langley et al., 2010; Lebersorger & Schneider, 2011; WRAP, 2009, 2013), ranging from 19 kg/capita/year in a rural area in Austria (Lebersorger & Schneider, 2011) to 308 kg/capita/year in Canada. (Abdulla et al., 2013). The large

variability in estimates is a function of geographic differences but is also due to the method used to collect food waste data (e.g., waste audits, diary studies and surveys), the scale of measurement (household, city, national average) and whether the estimate includes avoidable and/or unavoidable food waste.

There is some agreement among researchers about the inadequate state of food waste estimates and that further research is required to improve its measurement (Langley et al., 2009; Parfitt et al., 2010; Porpino, 2016; van der Werf & Gilliland, 2017). There are a number of reasons for these current data gaps. An overarching reason is that there is no international standard, with methods "usually rooted and used regionally or nationally" (Dahlén & Lagerkvist, 2008), meaning that studies are not very comparable (Lebersorger & Schneider, 2011). This is starting to change with the recent development of a food loss and waste accounting and reporting protocol (FLW Protocol, 2016). Secondly, van der Werf and Gilliland (2017) found that there is a high degree of variability of food waste quantity estimates across all parts of the food supply chain. They suggested that there are challenges with the veracity and comparability of these data because of the indirect and direct approaches deployed in its measurement and because the scope of food waste, in current research, varies to include avoidable, unavoidable or both of these food waste streams. These data gaps can be overcome through the development and application of methodological improvements to the measurement of food waste (van der Werf & Gilliland, 2017).

It is the rationalizing and selecting between the indirect and direct measurement approaches that is central to the required methodological improvements. Most simply, as described by Sharma and McBean (2007), indirect methods estimate quantities of food (i.e., domestic food production and imported food) by product categories, and then waste quantities are imputed through the use of waste factors (i.e., percent of a product category that is assumed to become waste). Other indirect measurement methods include statistical estimation due to economic activity (Reynolds et al., 2016). The main advantage of this method is that it is useful for estimates that have a broad geographic scope (e.g., countries); its key disadvantage is that it does not physically examine any waste streams. A discrediting factor is that many of these indirect estimates originate from fieldwork undertaken in the 1970s and 1980s (Parfitt et al., 2010). The two-fold challenges of

collecting data this way are the age of factors used to make these estimates and the fact that no actual food waste was measured to make these estimates. Referring to the indirect collection of food waste data, Brautigam et al. (2014) warns: “it has to be recognised that all calculation methods can only be seen as approximations, which barely reflect reality.” Maystre and Viret (1995), Rugg (1997), Abdulla et al. (2013) and van der Werf and Gilliland (2017) all recommend that *direct* measurement be used to estimate food waste.

Direct methods are used to collect, sort, weigh and statistically analyze waste samples collected at the point of generation or just prior to disposal. Its advantage is that actual waste streams are being physically examined. Its disadvantages are that it can be costly and vulnerable to demographic bias (i.e., samples collected not representative) (Sharma & McBean, 2007). The main approach to the direct measurement of household food waste, typically referred to as waste characterization studies (Gay, 1993; Newenhouse & Schmit, 2000) or waste composition studies (Edjabou et al., 2015; Sahimaa et al., 2015), involves the curbside collection of household waste samples on their waste collection day. The waste samples typically represent a 1-2-week generation period. Collected waste samples are then taken to a location to be sorted and weighed. Waste samples typically include the garbage stream and may also include green bin (i.e., a separate bin to collect food and other organic waste) and blue box (i.e., a separate bin to collect recyclables) streams.

Key strata used to measure household waste include: geographic location, household type (single family, multi-residential households), waste management system (e.g., bagged waste versus automated collection), housing type, urban/rural areas, socio-demographic differences, and season (Burnley et al., 2007; Dahlén & Lagerkvist, 2008; Eriksson et al., 2012; European Commission, 2004; Parfitt & Flowerdew, 1997; Sahimaa et al., 2015; Sharma & McBean, 2007). Ideally, representative sampling areas are randomly selected, although constrained for the above noted factors (Burnley et al., 2007). To date, direct method studies have examined food waste as part of overall waste composition measurement (DEFRA, 2010; Edjabou et al., 2015; Matsuto & Ham, 1990), although there are a growing number of studies that focused exclusively on food waste (Bernstad et al., 2013; Bernstad et al., 2012; Lebersorger & Schneider, 2011; Parizeau et al., 2015).

The focus of this study was to develop a better understanding of how to directly measure household food waste. There has been little research to specifically measure household food waste in the province of Ontario, Canada. However, many southern Ontario (360,000 km^2; population of approximately 12 million) municipalities routinely undertake household waste composition studies, using a common methodology (Stewardship Ontario, 2005, 2014; Waste Diversion Ontario, 2002, 2015) that typically includes "food" as a sorting category. The first objective of this study was to develop an estimate of the amount of food waste disposed, in the garbage stream, by southern Ontario single-family households using 2012-2015 waste composition study results, collected using this common methodology. A second objective was to determine if this methodology could be adapted and expanded as the basis of the suggested "bespoke and statistically sound methodology" (van der Werf & Gilliland, 2017) to directly measure household food waste. Both of these study objectives were met.

3.3 Material and methods

3.3.1 Data collection

Twenty-eight single-family household waste composition datasets, from nine different southern Ontario municipalities (with a population of approximately 2.2 million inhabitants), were gathered, aggregated and analyzed to estimate single family (i.e., detached, or semi-detached homes) food waste disposal, in the garbage stream. The nine municipalities included a range of large and medium urban (e.g., Greater Toronto Area, southwestern and eastern Ontario) and rural (e.g., central, and southwestern Ontario) municipalities. The datasets, generated from 2012-2015, used a common waste composition study methodology, which is described in (Stewardship Ontario, 2005, 2014; Waste Diversion Ontario, 2002, 2015). This methodology was developed in 2002 and with some refinements has been in use since that time.

Each of the 28 datasets consisted of waste composition study data from 100 households. Typically, each sample of 100 households was compiled from 10 sampling areas of 10 consecutive homes strategically selected by the respective municipality to function as a

representative sample. One municipality was represented by five sampling areas of 20 homes. Therefore, there were a total of 85 sampling areas across the nine municipalities. Each municipality selects their different sampling areas based on factors, such as housing type (e.g., older homes, newer homes) and neighbourhood socio-economic status. The sampling areas are spread out over weekly waste collection days and typically 2 to 4 sampling areas are collected per week day. Waste samples are collected from sampling areas on their waste collection day and are intercepted at the curb prior to municipal collection. The samples are taken to a sorting area and are sorted into as many as 120 sorting categories, including a single "food waste" category. The sorted food waste is weighed and documented. Collection and sorting of wastes was undertaken by waste auditors (i.e., companies that provide professional waste composition study services to municipalities). Each waste composition study was repeated twice over two consecutive weeks for the same households. Thus, two weekly data points (i.e., week 1 and week 2) made up the average of each sampling area's seasonal data point. Waste composition studies are repeated up to 4 times per year (i.e., to encompass each of the four seasons) for the same sampling areas and households.

Three of the nine municipalities (one large urban, one medium urban, and one rural) divided food waste into avoidable and unavoidable streams, and included the results from ten (i.e., sub-set of the 28 waste composition studies) two-week seasonal waste composition studies. This sub-set of waste composition studies was also analyzed separately to develop an estimate of avoidable and unavoidable food waste in the disposal stream.

Furthermore, we compiled data on several variables that could potentially influence the estimates of food waste disposal for inclusion as independent variables in statistical models. For each of the samples, we recorded the waste auditor, season of each study (i.e., winter, spring, summer, fall), sampling area type (i.e., urban, or rural), and household access to food waste diversion programs (i.e., green bin program for collecting food wastes at the curb). In addition, estimates of the number of people per household and median household income (Canadian dollars) were compiled for each sample area using data from the 2011 Canadian census (Statistics Canada, 2017) at the dissemination area level, which is the smallest area unit for which Statistics Canada releases

demographic data and is a reliable proxy for each sampling area (Healy & Gilliland, 2012).

3.3.2 Statistical analysis

Data were analyzed using SPSS version 22 (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.). An average of food waste disposal was developed by averaging all weekly data points from each sampling area. Paired data (i.e., from week 1 and week 2) were used to develop seasonal averages. If there was a missing weekly data point from a sampling area (e.g., if a waste sample was collected by the municipal waste contractor before the waste composition study crew arrived on site), then the other weekly data point was not used to develop the seasonal average. This occurred for 8 of 229 paired data points.

Continuous variables were reported as means and standard deviations, whereas categorical variables were summarized as percentages. The independent samples t-test was used to compare differences in means between two groups, and the paired t-test compared mean differences between food waste disposal estimates across the four seasons. The repeated measures analysis of variance (RMANOVA) assessed differences in the mean food waste per season and by whether homes had green bins. The strength and direction of the associations between two continuous variables were measured using the Pearson correlation coefficient. A multiple regression model was used to assess the influence of urban households, access to a green bin program, and number of people per household on disposal of food waste during the spring and summer months. A 2-sided p value <0.05 was considered statistically significant.

3.4 Results

Fig. 1 depicts the average waste composition from the 28, two-week single-family household waste composition studies. On average, 35.4% of the disposal (i.e., garbage) stream consisted of food waste (range 27.2%-45.6%). The mean food waste disposal of these households was 2.40 kg/household/week (SD= 1.07) or 124.80 kg/household/year (Table 1). This does not include food waste otherwise disposed (e.g., sink) or recycled (e.g., composted). The range per municipality (n=9) was 1.78-3.10 kg/ household /week and per waste composition study (n=28) was 1.41-3.31 kg/ household /week. Furthermore, the per sampling area (n=85) range was 0.00-4.04 kg/ household /week,

with the low part of this range coming from sampling areas with seasonal populations (e.g., summer cottage residents). Variability is based on a neighbourhood basis, but not on a household basis.

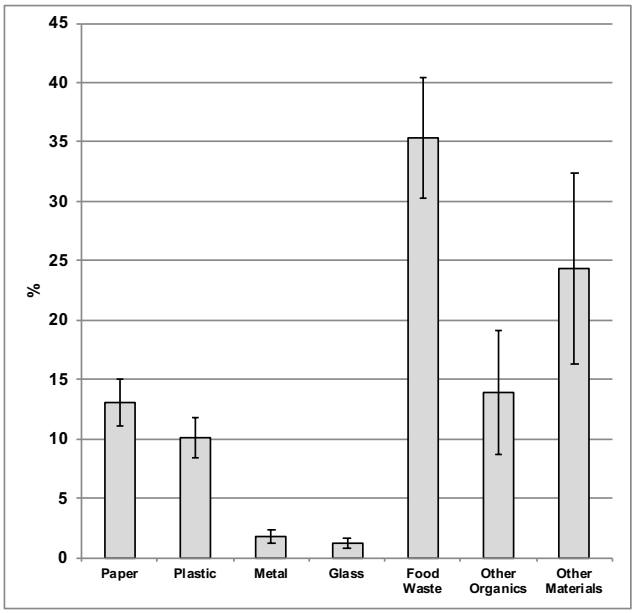

Figure 3.1 - Overall waste composition

Table 3.1 summarizes the impact of the independent variables on food waste disposal. There were no differences in food waste disposal as measured by two different waste auditors. Urban households disposed more food waste than rural households; households with access to a green bin program disposed less food waste than households without access to a green bin program; and food waste disposal was marginally higher in the summer and fall. None of these differences, however, were statistically significant.

Table 3.1 - Average weekly food waste disposal for southern Ontario households and impact of waste auditor, sampling area type, access to food waste diversion programs and season

	n	Mean	SD	p-value
		kg/household/week		
Food Waste	85	2.40	1.07	
Independent Variables				
Waste Auditor				
Waste Auditor 1	35	2.42	1.04	0.91
Waste Auditor 2	50	2.39	1.10	
Sampling Area Type				
Rural	50	2.32	0.98	0.37
Urban	35	2.53	1.19	
Food Waste Diversion Program				
Green Bin	55	2.28	1.13	0.15
No Green Bin	30	2.63	0.92	
Season				
Winter	75	2.33	1.26	
Spring	55	2.30	1.30	
Summer	55	2.39	1.10	
Fall	75	2.36	1.34	

There was a weak positive correlation (r=0.29, p=0.01) between food waste disposal and the number of people living in a household. Weak positive correlations were also found between the number of people in a household and winter disposal (r=0.21, p=0.07), spring disposal (r=0.37, p=0.01), summer disposal (r=0.24, p=0.08), and fall disposal (r=0.26, p=0.02). There was no association (r=-0.11, p=0.34) between food waste disposal and median income, and no relationship between median income and seasonal food waste disposal (r= -0.01 to -0.17).

The relationship between seasonal urban and rural food waste disposal, the impact of having access to a green bin program, and the number of people per household was also assessed. Urban households disposed significantly greater amounts of food waste compared to rural households in the spring (p=0.01) and summer (p=0.02) (Table 3.2).

Table 3.2 - Food waste disposal by season and sampling area type

		n	Mean	SD	p-value
			kg/household/week		
Winter	Rural	50	2.25	1.12	0.42
	Urban	25	2.50	1.51	
Spring	Rural	40	2.01	1.17	0.01
	Urban	15	3.06	1.36	
Summer	Rural	40	2.17	0.99	0.02
	Urban	15	2.96	1.19	
Fall	Rural	40	2.22	1.43	0.34
	Urban	35	2.52	1.24	

Finally, using multiple regression models it was determined that in the spring (Table 3.3) and summer (Table 3.4), urban households disposed significantly more food waste in both seasons, controlling for the number of people in the household. Furthermore, households with access to a green bin program disposed of significantly less food waste than those with no access to a green bin program in the spring ($p=0.03$) and summer ($p<0.01$).

Table 3.3 - Multiple regression on Spring food waste disposal (kg/household/week)

	B	**SE**	**p-value**
Urban household	20.11	8.88	0.03
People per Household	21.68	12.16	0.08
Access to a green bin program	16.23	12.16	0.03
Constant	-28.14	34.92	
Adjusted R^2	0.20		

Table 3.4 - Multiple regression on Summer food waste disposal (kg/household/week)

	B	**SE**	**p-value**
Urban household	22.32	7.25	<0.01
People per Household	10.67	9.86	0.28
Access to a green bin program	20.41	6.11	<0.01
Constant	2.72	28.32	
Adjusted R^2	0.24		

Three of the nine municipalities (one large urban, one medium urban and one rural) divided food waste into avoidable and unavoidable streams and included the results from ten (i.e., sub-set of the 28 datasets) two-week seasonal waste composition studies. Food waste averaged 36.1%. As described in Table 3.5, avoidable food waste was slightly more than one-half of all food waste.

Table 3.5 - Avoidable and Unavoidable Food Waste Disposal

	N	**Mean**	**SD**	
		kg/household/week		**%**
Avoidable Food Waste	10	1.3	0.18	52.5
Unavoidable Food Waste	10	1.1	0.60	47.5
Total	**10**	**2.4**	**0.62**	**100.0**

3.5 Discussion

This study developed an estimate of the amount of food waste disposed, in the garbage stream, by southern Ontario single-family households using a common methodology, and assessed whether this methodology could be adapted and expanded to directly measure household food waste.

This research represents one of the first attempts to use direct at the curb measurement of food waste to measure household food waste in a geographic region, and to examine the influence of various independent variables (e.g., waste auditor, sample area type, food

waste diversion program, seasons, number of people per household, and median household income) on the quantity of food waste disposal.

As summarized in van der Werf and Gilliland (2017), consumers/households in developed countries dispose 18.8-308.2 kg/capita/year of food waste, with an average of 114.3 kg/capita/year (n=24; SD=68.0). In our study, there was an average of 2.9 residents per household and average food waste disposal was 43.0 kg/capita/year. Mindful that our results only encompass food waste disposed in the household garbage stream, this estimate is at the lower end of that range and well below the average. In a recent waste composition study from Guelph, Ontario, it was estimated that households disposed 4.2 kg/capita/week or 217.4 kg/capita/yr of organic waste (i.e., predominantly food waste, and also includes some non-food but compostable items) in their green bin (Parizeau et al., 2015). The amount of food waste in the garbage stream was not included in their estimate. Parizeau et al. (2015) estimate is considerably higher than the above noted estimates. It is suggested that the variability between these estimates is a result of different methodological approaches and actual differences. At this point, the various methodological approaches employed constrain the parsing out of actual differences in household food waste disposal between the results reported in this paper and other studies.

The lack of significant differences between food waste disposal estimates measured by two different waste auditors is an important finding and suggests that this common methodology is reliable and repeatable. The lack of overall seasonal significant differences also suggests that there may be year-round food waste disposal consistency. Additionally, the overall lack of significant differences of food waste disposal, in the garbage stream, between municipalities with and without access to green bin programs is an important finding and suggests that households with access to green bin programs may in fact dispose more food waste than households without this access (i.e., because green bin food waste disposal was not measured). This would need to be confirmed by the future simultaneous measurement of food waste in garbage and green bin disposal streams. While there was no green bin waste composition data for these households, from 2012-2015 all Ontario households with access to a green bin program, diverted a mean of

2.4kg/household/week (SD=0.1) (RPRA, 2018). The green bin is primarily for wasted food but also includes non-recyclable paper (e.g., paper towels) and contamination.

The foregoing, however, is tempered somewhat by Spring and Summer findings in which households without green bins disposed of significantly more food waste than households with green bins. Overall, the common methodology employed could form the basis of a more comprehensive household food waste measurement methodology.

Our study is not without limitations. Due to data availability, we only examined food waste disposed in the garbage stream. Our results, therefore, do not encompass any food waste directed to the green bin or informal methods such as backyard composters, feeding to pets, and disposal down the drain. The amount of food waste managed via informal methods can be considerable. For instance, in an Australian study, Reynolds et al. (Reynolds, 2014) found that households generated a mean of 2.60 kg/week (SD=2.34) of informal household food waste.

As such, our estimates represent the minimum food waste disposed by households. These partial estimates do, however, address a key household waste stream and can be used to estimate environmental impacts, such as greenhouse gases from landfilled food waste. Further, the results only go marginally beyond "food waste" as a waste composition study sorting category and offer little detailed information on the composition of this food waste. Finally, the common methodology is used to collect data at the neighbourhood level (i.e., 10 consecutive households) so we can only be certain of the average of that neighbourhood, but not household-level characteristics of food waste disposal on a house-by-house basis. That is, the common methodology does not measure the variability of food waste generation between individual households. However, to facilitate municipality-level data extrapolation the common methodology includes instructions on how to select up to ten representative sampling areas (i.e., neighbourhoods) (Stewardship Ontario, 2005, 2014; Waste Diversion Ontario, 2002, 2015). Municipalities scale up the results from these neighbourhoods to develop an estimate of the amount of different waste types, including food waste, that go to landfill. Partially assuaging this limitation is that municipalities typically develop interventions on a neighbourhood basis, not at the household level.

Additional research is needed to take this common methodology and use it to develop and test a household food waste measurement methodology that includes: avoidable and unavoidable food waste sorting categories, as well as additional food waste sub-categories (e.g., avoidable fruit and vegetable waste); that measures the food waste in all waste streams (e.g., garbage, green bin); and is capable of elucidating the impact of the green bin on food waste disposal, and whether or not households with access to green bins dispose more food waste than households without access to green bins. Further, this refined methodology should be expanded to move beyond presenting municipality specific and largely descriptive data and incorporate inferential capabilities, so that it can be used to develop regional and possibly country-wide estimates. This research should consider and build on methodology development undertaken in other jurisdictions. For instance, the UK's Waste Reduction Action Programme (WRAP) has developed a number of solid and liquid food waste estimates (WRAP, 2009, 2013, 2013b, 2013c) using waste management tonnage data collected by local authorities, the results of waste audits and from kitchen diaries (i.e., food waste tracking by residents). Further, this research demonstrated a possible methodological approach to extrapolating these data. Aspects of the aforementioned research and other approaches have been used in other European and North American countries (Katajajuuri et al., 2014; Langley et al., 2010; Lebersorger & Schneider, 2011; Okazaki et al., 2008; Parizeau et al., 2015; Silvennoinen et al., 2014) with the focus on using a weight-based assessment of food waste and in some cases including diary studies or surveys.

Understanding food wasting behaviour can inform reduction interventions, and several largely qualitative studies have attempted to develop a better understanding of food wasting behaviours. Food appears to be wasted for various reasons including the pressure to eat properly and provisioning challenges (Evans, 2011); ingrained household routines leading to a pattern of overprovisioning and inflexibility in meal preparation, which are exacerbated by the sometimes unpredictability of daily life (Evans, 2012); food safety (Watson & Meah, 2012); lack of planning (for food purchase and preparation) (Aschemann-Witzel et al., 2015); and social factors (e.g., household type) and intractable consumer food expectations (e.g., freshness, variety) (Fusions, 2014). The direct quantitative estimation of food waste can build on and transcend qualitative data to confirm and track this behaviour.

Bulkeley and Gregson (2009, p. 4) call for greater engagement with households to inform waste policy, arguing that waste policy must "open up the black box that is the household and engage with household practices". Barr et al. (2013) contend that when moving up the waste hierarchy towards reduction means engaging with households "in ways that move beyond the simple disposal of things" (p. 67). To date, many household food waste estimates have been derived using indirect measurements (van der Werf & Gilliland, 2017) that do not engage households. Our study builds on other direct household food waste studies (Bernstad et al., 2013; Bernstad et al., 2012; Lebersorger & Schneider, 2011; Parizeau et al., 2015; WRAP, 2009, 2013c, 2014), more fully opening the Bulkeley and Gregson (2009) "black box" to compare food waste disposal across municipalities based on data collected using the same waste composition study methodology. This, however, is an intermediate step, and consideration should be given to ensuring that the household food waste measurement methodology can be used to measure food waste at the household level, and couple this with direct household interaction to measure the how and why of food wasting behaviour.

3.6 Conclusions

Based on available waste composition study data, households in nine southern Ontario municipalities dispose, on average, 2.4kg/ household /week of food waste in the garbage stream. The common methodology used to develop these estimates shows promise as the basis of a household food waste measurement methodology. Expanding this methodology to encompass greater disposal and composition detail can be used to produce more accurate municipal, regional and possibly country-wide household food waste estimates that can be used to develop sound food waste reduction policy and interventions.

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CHAPTER FOUR

4 Food for Naught: Using the Theory of Planned Behavior to Better Understand Household Food Wasting Behavior

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4.1 Abstract

It is estimated that the average North American disposes 160 kg of food waste annually. To better understand food wasting behavior, the theory of planned behavior was used to inform the development of a survey that was administered to households in London, Ontario, Canada. Respondent households (n=1,263) threw out avoidable food 4.8 times/week (SD=4.8, Mdn=4.0) and 5.9 food portions/week (SD=5.7, Mdn=4.0). When asked to choose one of three possible motivators to reduce food wasting behavior, 58.9% selected reducing monetary loss as their first choice, versus 23.9% reducing environmental impact and 17.2% reducing social impacts. Perceived behavioral control (r_s=0.57, p=0.01) and personal norms (r_s=0.54, p=0.01) were strongly correlated with intention to avoid food waste. A linear hierarchical regression analysis (R^2=0.30, p<0.001) on intention to avoid food waste further demonstrated that perceived behavioral control (p<0.001) and personal norms (p<0.001) had the greatest positive impact on intention. The intention to avoid food waste (r_s=-0.51, p=0.01) and perceived behavioral control (r_s=-0.57, p=0.01) were strongly negatively correlated with self-reported food wasting behavior. A linear hierarchical regression analysis (R^2=0.32, p<0.001) on self-reported food behavior showed that perceived behavioral control (p<0.001) and personal attitudes (p<0.01) resulted in less food wasting behavior, while more children in a household (p<0.01) resulted in more food wasting behavior. Interventions that seek to strengthen perceived behavioral control and convey the monetary impact of food waste could help reduce its disposal.

4.2 Introduction

An unintended consequence of our biological necessity to procure, prepare and eat food to survive is that a portion of food intended for consumption becomes waste. Food waste represents lost utility and food management inefficiency, which is manifest in negative economic, environmental and social impacts. Obversely, ameliorating this inefficiency can convert these impacts into possible societal benefits. In a systematic review of food waste quantification, van der Werf and Gilliland (2017) reported that food waste generation across the food supply chain, of developed countries, was on average 198.9 kg/capita/year and that each member of North American households generate an average of 160.0 kg/capita/year. Changing this human behavior has recently become an area of significant academic and societal interest, with research focused on improving food waste measurement and better understanding why food is wasted, particularly at the household level.

Households represent the endpoint of the profit-driven food supply chain and present a complex set of food management behaviors. A better understanding of these behaviors can be used to help maximize efficiency of household food management and reduce food waste. Research to date has

identified food literacy and socio-demographic factors as key behavioral determinants of household food waste generation.

4.2.1 Behavioral determinants of household food waste generation

4.2.1.1 Poor food literacy

People throw out food when it has spoiled or is otherwise unappealing (Halloran et al., 2014; Thyberg et al., 2015; Williams et al., 2012; WRAP, 2014). This is an outcome of poor food literacy, which can be defined as a lack of knowledge regarding food provisioning, storage, preparation and serving. For instance, many households inadequately plan meals (as it relates to food provisioning) and grocery shopping (Barilla Center for Food and Nutrition, 2012; BIO Intelligence Service, 2011; Romani et al., 2018; WRAP, 2011). This poor planning can lead to the over purchase, over preparation and over serving of food (Munro & Marshall, 1995; Pearson et al., 2013; Porpino, 2016; WRAP, 2014). At the retail level, households can inadvertently purchase packages containing too much food (so that some of it spoils) or from which it is difficult to extract food, ultimately leading to food waste generation (Bolton, 2012; Göbel et al., 2015; Halloran et al., 2014; WRAP, 2007b). Further, after food purchase, not knowing how and where (e.g., counter, fridge, freezer) to store food can lead to its premature spoilage and wastage (Göbel et al., 2015; Jorissen et al., 2015; Principato et al., 2015). Finally, some people have particular dietary habits that result in food waste, such as aversion to leftovers, intolerances for certain elements of a set meal, or, as is often the case for children, general fussiness (Evans, 2012; Neff, 2015; Porpino, 2016).

There is considerable confusion regarding food labelling. If consumers do not understand the meaning of food labels such as “best before” and “use by” dates, they tend to err on the side of caution, throwing away food before it is unsafe to eat (Aschemann-Witzel et al., 2015; BIO Intelligence Service, 2011; Pearson et al., 2013). Consumers can be overly sensitive to high health-risk foods, such as fresh meats, and they often discard them before their “use by” date (Evans, 2011; Fusions, 2014; Porpino, 2016).

4.2.1.2 Socio-demographic factors

Socio-demographic factors are key determinants of household food wasting behavior. Gender may be a determinant of food waste generation (Koivupuro et al., 2012; Secondi et al., 2015; Visschers et al., 2016), with males generally wasting more food than females. Age appears to be

a strong determinant of food waste generation; children tend to waste more and seniors tend to waste less food (Melbye et al., 2016; Quested et al., 2013; Visschers et al., 2016). Age also determines many responsibilities in the household, such as grocery shopping and meal preparation. Older people seem to be more food literate and have better grocery shopping planning, meal preparation, and/or reuse of leftovers skills than younger people.

Household composition (size and type) is another strong food waste determinant (Koivupuro et al., 2012; Parizeau et al., 2015; Tucker & Farrelly, 2016; Visschers et al., 2016). Not surprisingly, larger households, which often include children, generate more total food waste. However, smaller households appear to waste more food per capita than larger households. Household income may have some impact on food waste generation, although results have been inconsistent (Jorissen et al., 2015; Neff, 2015; Van Garde & Woodburn, 1987).

4.2.2 Modelling household food wasting behavior using the theory of planned behavior

The theory of planned behavior (TPB), which is designed to "predict and explain human behavior in specific contexts" (Ajzen, 1991, p. 181) has been used to model household food wasting behavior (Graham-Rowe et al., 2015; Stancu et al., 2016; Stefan et al., 2013; Visschers et al., 2016). The TPB posits that, if volitional, "people's intentions and behaviors follow reasonably and consistently from their beliefs no matter how these beliefs were formed" (Ajzen, 2015, p. 127). A key premise is that volitional behavior is largely predicated on one's intention to perform a given behavior, and that one's intention embodies an individual's motivation and the amount of effort they are willing to expend to effect a particular behavior (Ajzen, 1991). The TPB posits that there are three conceptually independent antecedents or determinants of intention: attitude, subjective norms and perceived behavioral control. The strength of each of these antecedents coalesce into part of a person's intention to perform a certain behavior.

Attitude is informed by a person's opinion, whether that be favourable or unfavourable about a given behavior and is really a mindset. In the case of wasting food, it is about whether people think it is an important issue and worthy of reduction efforts. It appears to be one of the strongest determinants identified in the literature, whether that be in the context of the TPB (Graham-Rowe et al., 2015; Stefan et al., 2013; Visschers et al., 2016) or through other research (Abeliotis, 2014; Baker, 2009; Brennan, 2007; Koivupuro et al., 2012; Quested et al., 2013;

Secondi et al., 2015; Thyberg et al., 2015). Studies suggest that consumers feel "bad" and are concerned about throwing away food, and this informs a negative attitude towards this behavior (Abeliotis, 2014; Evans, 2012; Graham-Rowe et al., 2014; Watson & Meah, 2012).

Subjective norms refer to the social pressure a person feels to complete (or not complete) a given behavior. That is, people's behaviors can potentially be influenced by society's expected behavior or subjective norms, whether in the context of TPB (Graham-Rowe et al., 2015) or otherwise (Bernstad, 2014; Cappellini, 2009; Cappellini & Parsons, 2012). This can extend to personal norms, or expectations people hold for themselves, and can be driven by moral values (Principato et al., 2015; Secondi et al., 2015; Watson & Meah, 2012; WRAP, 2011) or guilt (Graham-Rowe et al., 2014; Parizeau et al., 2015; Quested et al., 2013; Watson & Meah, 2012), environmental and civic concerns (Melbye et al., 2016; Principato et al., 2015; Williams et al., 2012) or anticipated regret (Graham-Rowe et al., 2015). However, the wasting of food is a behavior that is generally only seen by the generator, and Graham-Rowe et al. (2014) and Stefan et al. (2013) reported that subjective norms were unrelated to food wasting behavior and only modestly influenced intention.

Finally, people's perceived behavioral control, or their belief in their ability to behave one way or another, is a TPB antecedent that may influence food wasting intention and behavior (Graham-Rowe et al., 2015; Stancu et al., 2016; Stefan et al., 2013; Visschers et al., 2016). Perceived behavioral control has impacts on intention related to situations such as the conflict between food provisioning and fussy eaters, unexpected meals outside the home and large food packaging sizes (Evans, 2012; Williams et al., 2012). The amount of this perceived control had ancillary impacts on the intention to reduce food waste (Graham-Rowe et al., 2014) and greater impacts on planning or shopping for food (i.e., planning for and purchase of food) (Stefan et al, 2013).

Researchers have added other possible behavioral antecedents to the TPB model, such as self-identity (Aschemann-Witzel et al., 2015; Graham-Rowe et al., 2015), which can be viewed as "the extent to which the individual sees him/herself as the sort of person who would be willing to engage in the behavior in question" (Graham-Rowe et al., 2015, p. 195); personal norms, a measure of personal morality (Visschers et al., 2016); the good provider identity, which can be manifest by needing to have plenty of food on hand for various expected and unexpected

situations (Evans, 2011; Graham-Rowe et al., 2014; Visschers et al., 2016) and household planning habits (Visschers et al., 2016).

4.2.3 Study Rationale and Objectives

The rationale of our study was to build on existing research and expand our understanding of food wasting behavior in a North American context, where little such research has been undertaken. We focused on avoidable food waste (WRAP, 2009), that is, food that was at one point edible (e.g., an apple, slice of bread), and which is henceforth referred to as food waste. The primary objective of this study was to model household food wasting behavior in the city of London, Ontario, Canada using the TPB and other determinants. To meet this objective, we used a survey to measure: household food wasting behavioral determinants; self-reported weekly frequency and portions of food waste for six food types; the reasons why each food type was wasted; and the rank households assign to food waste reduction motivators. Additionally, we explicitly replicated the same approach used in a study of household food wasting in Switzerland by Visschers et al. (2016), to facilitate comparison of findings from two contrasting geographical contexts.

We hypothesized that the results of behavioral antecedents and determinants would be similar in a North American city and Switzerland (Hypothesis 1), but, based on data presented in van der Werf and Gilliland (2017), that self-reported food wasting quantities would be higher in the North American city (Hypothesis 2). As noted in Visschers et al. (2016), even though respondents reported throwing out an average of 5.33 (SD=15.40, Mdn=1.09) portions of food per week, respondent intention to not waste food was very high and was deemed the most important predictor of self-reported food waste. On that basis, we hypothesized that intention to not waste food would be the most important predictor of self-reported food wasting behavior (Hypothesis 3). Visschers et al. (2016) reported that financial attitudes positively and significantly impacted the intention not to waste food and negatively and significantly impact self-reported food waste; we therefore also hypothesized that reducing monetary impacts would be the predominant food waste reduction motivator among our survey respondents in London, Ontario (Hypothesis 4).

4.3 Methodology

Research was undertaken in London, Ontario, a mid-sized Canadian city of approximately 390,000 inhabitants (Statistics Canada, 2016). London has a six-business day curbside waste collection system for single family households that includes garbage and recyclables. Waste collection, disposal and diversion are undertaken by a combination of municipal and contracted private sector teams. There is currently no curbside program to separately remove food wastes, although approximately 60,000 backyard composters have been distributed throughout the City in the last 25 years (J. Stanford, personal communication, 15 May 2017).

4.3.1 Survey design

Using TPB as a conceptual framework (Ajzen, 1991), we developed a survey with 71-items, including questions from previously-validated and well-used household/consumer food waste surveys primarily from Visschers et al. (2016) but also from (Stancu et al., 2016; WRAP, 2007a, 2007a). The survey was administered online using Qualtrics survey software.
The survey introduction collected socio-demographic information (e.g., age, housing tenure, employment status, household income) and respondent responsibility related to food shopping and food preparation (adapted from WRAP (2007a)), as well as taking out waste and recycling on waste collection day. A question on the frequency of backyard composter usage was used as a proxy for pro-environmental behavior.

Using an approach similar to Visschers et al. (2016), respondents were asked to self-report the estimated frequency and portions (i.e., handfuls) of edible (i.e., avoidable) food waste thrown out (for any reason) over the past week by six food types (i.e., bread and baked goods, meat and fish, dairy, fruit and vegetables, dried food and other food). Respondents could select from 8 options (i.e., 0, 1, 2, 3, 4, 5, 6, 7+ times per week). A follow-up question asked respondents to provide the most common reason (e.g., purchased too much) their household throws out food for each of the six food types. A second follow-up question asked respondents to rank three possible food waste reduction motivators: reduce amount of money wasted, reduce environmental impact of wasting food (e.g., climate change), and reduce social impact of wasting food (e.g., hunger).

The remainder of the survey used the TPB model (Ajzen, 1991, 2006a, 2006b, 2015) to ask questions about food wasting intentions, intention's antecedents including attitudes (personal

attitudes, financial attitudes, environmental attitudes, perceived health risk), subjective norms and perceived behavioral control, as well as non-TPB food wasting determinants (personal norms, good provider identity and household planning habits) (Figure 4.1). Questions about food wasting intentions, its antecedents and other possible determinants, except for environmental attitudes, were directly adapted from Visschers et al. (2016, p. 77). A 7-point Likert scale was used, with higher scores representing greater agreement with a given question. These questions are included in the Appendix (Table A.4.10).

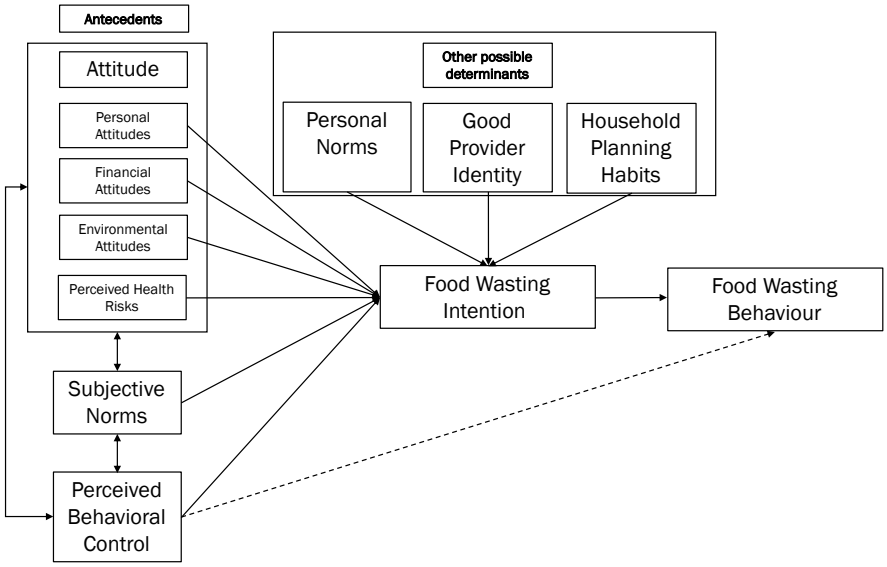

Figure 4.1 - Theory of planned behavior and other possible determinants model (after Ajzen, 1991; Visschers et al., 2016)

4.3.2 Survey dissemination and sample

An online Household Food Waste Survey was available for completion between 23 May and 8 July 2017. An accompanying letter of information and consent explaining the study was also provided. An opportunistic survey approach and concomitant comprehensive survey dissemination strategy was deployed to inform the entire city about this survey and encourage city-wide responses. This differed from Visschers et al. (2016), who sent their survey to randomly selected households. Various efforts were made to disseminate information about the survey as widely as possible to, in effect, give all households the opportunity to respond. A print and digital flyer served as the key vehicle to present uniform information to potential respondents. It served as a call to action and directed respondents to a website where they could

complete the survey. An extensive social media campaign was launched that included sustained dissemination via the City of London's and authors' various social media platforms including Facebook, Twitter and Instagram. A terrestrial media campaign included print and radio advertisements. Email contact was made to the chairpersons of all community associations within the city (n=25) with a request to distribute survey information to their members via email or their social media platforms. Survey information (>500 flyers) was also distributed at various neighbourhood festivals and events throughout the city. The authors tracked and mapped survey responses across the city on a weekly basis, and this resulted in hand delivery of flyers in underrepresented areas across the City (ca. 1,000 flyers).

Survey respondent inclusion criteria included: 1) London households only, assessed by postal code; and 2) Respondent completed the survey as presented in Qualtrics survey response output. This resulted in n=1,263 survey responses. The socio-demographic profile of the survey respondents and the City of London census metropolitan area (CMA) (Statistics Canada, 2016) population average is presented in Table 4.1. Respondents were largely female, with few children, employed, and living in a detached or semi-detached house. Survey respondents included more women and were younger than the population average. Further, our respondents included more 2-4 person and fewer one-person households; more people living in detached or semi-detached homes and fewer in apartments; and fewer low-income households and slightly more households from all other income brackets, except greater than $100,000 households, when compared to census data (Statistics Canada, 2016).

Table 4.1 - Socio-demographic profile (%) of survey respondents (S) (n=1,263) and city population (P)

Gender	S	P	People in Household	S	P	Household Income	S	P	Housing Type	S	P
Female	79.9	51.5	1	15.6	30.1	<40,000	21.5	29.0	Apartment	16.6	29.4
Male	19.4	48.5	2	41.0	34.8	$40-60,000	19.3	17.3	Detached/Semi-detached	70.5	59.7
Other	0.7	-	3	16.5	14.8	$60-80,000	17.8	14.0	Townhouse	9.2	10.5
			4	18.8	13.1	$80-$100,000	13.7	11.2	Other	3.7	0.4
			5	6.5	7.2	>$100,000	27.7	28.4			
			6+	1.6							
Age			**Children in Household**			**Employment Status**			**Housing Tenure**		
18-24	5.7	9.5	0	67.4	60.6	Unemployed	3.4	-	Live Rent Free	3.3	-
25-34	23.6	17.1	1	12.4	17.9	Student	5.5	-	Pay Rent	25.4	-
35-44	21.1	15.8	2	15.1	14.9	Stay at home parent	4.8	-	Pay Mortgage	45.8	-
45-54	18.4	18.2	3	4	6.6	Work part time	12.9	-	Own Home Outright	24.9	-
55-64	18.7	17.5	4	0.7		Work full time	55.2	-	Other	0.6	-
65+	12.5	22.0	5+	0.3		Retired	18.2	-			-

4.3.3 Statistical analysis

Data were analyzed using IBM SPSS Statistics version 25. The mean, standard deviation and interquartile range (IQR) were calculated for self-reported food wasting frequency and portions, by food type and by the total amount of food. Response scores per psychological construct were summed into a single index. For instance, the responses to the four questions on intention to avoid food waste were summed into a single intention index (Appendix, Table A.4.10). Cronbach's alpha was used to measure the internal reliability of the scales used to assess the psychological constructs of intention, attitudes, subjective norms, perceived behavioral control, personal norms, good provider identity and household planning habits. If the internal reliability was greater than 0.6 (i.e., reasonable), the mean was calculated and used in subsequent analyses.

The Spearman rank correlation coefficient was used to assess the bivariate strength and direction of the association between psychological constructs and total food wasting frequency. Per Cohen

et al. (2013) correlations are small (>0.1), medium (>0.3) or large (>0.5). The Friedman's test was used to assess differences in the medians of the ordinal variable food waste reduction motivators rank (i.e., 1-3). The Wilcoxon test for two related samples was used to determine the location of any significant rank differences. Two-step multiple regression models were developed to assess the relative effects of various predictors (i.e., Step 1 Sociodemographic factors, Step 2 Psychological factors) on intention to avoid food waste and perceived behavioral control. The same approach was used for the frequency of food wasting behavior, except that a Step 3 was added to the model and this included the non-TPB psychological constructs (i.e., personal norms, good provider identity and household planning habits). A 2-sided p value <0.05 was considered statistically significant.

4.4 Results

4.4.1 Descriptive results

As depicted in Table 4.2, households reported that they threw out avoidable food waste a mean of 4.77 times (SD=4.81) and 5.89 portions (SD=5.66) in the week prior to completing the survey. The frequency and portions of food wasted were strongly correlated by food type (r_s=0.78-0.85) and overall (r_s=0.85). Fruits and vegetables, followed by other food and bread and baked goods were the most common foods thrown out, with dried food the least common. Eleven percent of households reported throwing out no food waste and this ranged from 26% for fruit and vegetables and 81% for dried food.

Table 4.2 - Self-reported frequency and portions of food wasted, by food type (n=1,263)

self-reported frequency and portions of food wasted, by food type (n=1,263)

	Frequency/household/week					Portions/household/week				
	M	SD	Mdn	IQR	Households Reporting no Food Waste	M	SD	Mdn	IQR	Spearma Rank Correlatio
Bread and Baked Goods	0.79	1.09	0.00	1.00	636	1.17	1.64	1.00	2.00	0.83
Meat and Fish	0.63	1.07	0.00	1.00	787	0.76	1.22	0.00	1.00	0.85
Dairy (e.g. milk, cheese and yoghurt)	0.51	0.92	0.00	1.00	840	0.72	1.28	0.00	1.00	0.84
Fruit and Vegetables	1.58	1.49	1.00	2.00	324	1.91	1.85	2.00	3.00	0.78
Dried Food (e.g. cereal)	0.33	0.86	0.00	0.00	1,023	0.38	1.00	0.00	0.00	0.80
Other Food	0.95	1.27	1.00	2.00	620	1.01	1.44	0.00	2.00	0.83
Total	4.77	4.81	4.00	4.00	139	5.89	5.66	4.00	6.00	0.85

Survey respondents reported on why different food types were thrown out (Table 4.3). Buying too much was the leading reason for bread and baked goods, dairy, fruit and vegetables, and other food, while for meat and fish it was because it was past its best before date, and for dried food because it was spoiled. The mean was calculated across all food types and showed that the primary reasons for throwing out food were from buying too much, food spoilage, and food that is past its best before date. The amount of food never thrown out ranged between 13.7% for fruit and vegetables to 60.3% for dried food.

Table 4.3 - Reasons why various food types were thrown out

		Reason					
		Bought too much	Spoiled	Past Best Before	Leftover/Made too much	Other	Never throw out
	n	%					
Bread and Baked Goods	1,253	52.9	8.9	4.2	6.2	4.2	23.6
Meat and Fish	1,241	23.5	8.4	26.3	5.6	1.7	34.5
Dairy	1,249	37.0	24.5	2.1	3.8	1.5	31.1
Fruit and Vegetables	1,250	69.0	1.8	3.0	4.6	8.0	13.7
Dried Food	1,239	10.0	13.9	5.3	8.1	2.4	60.3
Other	1,216	23.4	11.4	15.4	12.8	3.5	33.6
M		36.0	11.5	9.4	6.9	3.6	32.8
SD		21.8	7.6	9.6	3.3	2.4	15.6

Survey respondents were asked to rank three possible food waste reduction motivators. Reducing the amount of money wasted appeared to be the key motivator (Table 4.4) and this was significantly higher than reducing both environmental and social impacts. Reducing environmental impact was significantly higher than reducing social impacts.

Table 4.4 - Ranking of food waste reduction motivators (n=1,228)

Motivator	**n**	**%**
Reduce amount of money wasted	723	58.9[a]
Reduce environmental impact (climate change)	294	23.9[b]
Reduce social impact (e.g., hunger)	211	17.2[c]
Total	1228	100

Values with different superscripts are significantly different (P<0.001)

Using a 7-point Likert scale, survey respondents indicated a high intention to not waste food (Appendix, Table A.4.10). Further, they had moderate-high negative attitudes about wasting food, from personal, financial and environmental perspectives with their subjective norms also

opposed to wasting food. Respondents did not appear overly concerned about or perceive health risks from eating leftovers or foods past their best before dates. Respondents perceived that they had a moderate level of control over food wasting in their households. The respondents had average household planning habits, in terms of planning meals, making grocery lists and sticking to them.

There were many significant bivariate Spearman rank correlations between self-reported food wasting frequency and the TPB, and other psychological constructs included in our survey (Table 4.5). In particular, the frequency of food wasting was strongly and negatively correlated with perceived behavioral control and intention to avoid food waste. Intention had a strong positive correlation with perceived behavioral control and personal norms. Perceived behavioral control was also moderately and positively correlated with subjective norms, personal norms, the good provider identity and household planning habits.

Table 4.5 - Spearman rank correlations between psychological constructs related to household food waste (n=1,263)

		1	2	3	4	5	6	7	8	9	10	11
1	**Frequency of food wasting per household**	1										
2	**Intention to avoid food waste**	-.509**	1									
3	**Personal attitudes**	-.371**	.486**	1								
4	**Financial attitudes**	-.131**	.270**	.294**	1							
5	**Environmental attitudes**	-.063*	.224**	.308**	.244**	1						
6	**Perceived health risks**	.289**	-.297**	-.226**	-.070*	-.132**	1					
7	**Perceived behavioral control**	-.566**	.566**	.382**	.146**	.186**	-.274**	1				
8	**Subjective norms**	-.217**	.224**	.111**	.121**	.064*	-.138**	.394**	1			
9	**Personal norms**	-.359**	.536**	.643**	.358**	.337**	-.266**	.390**	.126**	1		
10	**Good provider identity**	.236**	-.225**	-.061*	-.070*	-.120**	.168**	-.331**	-.161**	-.108**	1	
11	**Household planning habits**	-.220**	.355**	.328**	.183**	.171**	-.077**	.311**	.115**	.329**	-.114**	1

**p<.05, **p<.01*

4.4.2 Multiple linear regression

Model 1 of the linear regression on intention to avoid food waste resulted in a low model fit and showed that older age and backyard composter usage had a positive and significant impact on the intention to not waste food, while income had a negative and significant impact (Table 4.6). The addition of TPB and non- TPB constructs, as part of Model 2, improved model fit considerably. In particular, greater perceived behavioral control, stronger personal norms and household planning habits were positively associated with intention. Age, while still significantly related to intention, was a more moderately related variable, as were personal attitudes, financial attitudes

(positive), and perceived health risks (negative). Backyard composter usage was no longer significantly related to intention. The Model 2 explained variance was considerably higher than for Model 1(R^2=0.30 vs. R^2=0.04).

Table 4.6 - Hierarchical linear regression analysis on intention to avoid household food waste.

	Model 1			Model 2		
	B	SE	β	B	SE	β
(Constant)	22.778	0.854		8.751	1.53	
Age	0.587	0.134	0.16***	0.238	0.124	0.065*
Housing tenure	-0.14	0.238	-0.021	-0.104	0.217	-0.016
Number in household	0.157	0.205	0.036	0.206	0.184	0.047
Number of children in household	-0.433	0.256	-0.077	-0.153	0.225	-0.028
Employment status	-0.034	0.148	-0.007	-0.106	0.132	-0.024
Income	-0.333	0.113	-0.094**	-0.022	0.104	-0.006
Back yard composter use	0.343	0.099	0.103**	0.01	0.091	0.003
Personal Attitudes				0.097	0.047	0.073*
Financial attitudes				0.073	0.034	0.062*
Environmental attitudes				0.022	0.056	0.011
Perceived health risks				-0.093	0.029	-0.085**
Perceived behavioural control				0.178	0.027	0.218***
Subjective norms				0.024	0.049	0.013
Personal norms				0.24	0.04	0.218***
Good provider identity				-0.023	0.025	-0.025
Household planning habits				0.133	0.027	0.139***
Model statistics	R^2=0.04, F (7,1187)=8.86, p<0.001			R^2=0.30, F (16,1072)=29.89, p<0.001		

**p<0.05, **p<0.01, ***p<0.001*

The Model 1 results of the linear regression on perceived behavioral control resulted in a low model fit and showed that older age, backyard composter use and respondent responsibility for food purchase had a positive and significant impact, and the number of people in a household and higher income had a negative and significant impact on perceived behavioral control (Table 4.7). As with intention, the addition of TPB and non-TPB constructs, as part of Model 2,

improved model fit considerably. In particular, subjective norms, intention and personal norms had the strongest significant positive impact, while the good provider identity, perceived health risks, and number of people in a household had a significant negative impact on perceived behavioral control. The Model 2 explained variance was considerably higher (R^2=0.44 vs. R^2=0.13, respectively) than for Model 1.

Table 4.7 - Hierarchical linear regression analysis on perceived behavioral control to avoid household food waste.

	Model 1			Model 2		
	B	SE	*β*	B	SE	*β*
(Constant)	26.426	3.761		11.876	3.42	
Age	0.777	0.159	0.174***	0.428	0.137	0.096***
Housing tenure	0.128	0.278	0.016	0.023	0.239	0.003
Number in household	-0.717	0.259	-0.134**	-0.517	0.219	-0.097*
Number of children in household	-0.424	0.31	-0.062	-0.402	0.259	-0.06
Employment status	0.298	0.172	0.054	0.349	0.145	0.064*
Income	-0.283	0.132	-0.065*	-0.053	0.115	-0.012
Responsibility for food shopping	0.588	0.252	0.088*	0.283	0.21	0.043
Responsibility for food preparation	-0.293	0.254	-0.045	-0.086	0.212	-0.013
Responsibility for waste management	-0.176	0.159	-0.033	-0.166	0.132	-0.031
Back yard composter use	0.741	0.115	0.184***	0.357	0.099	0.089***
Intention				0.215	0.033	0.176***
Personal Attitudes				0.163	0.051	0.1***
Financial attitudes				-0.052	0.038	-0.036
Environmental attitudes				0.111	0.061	0.044
Perceived health risks				-0.124	0.032	-0.093***
Subjective norms				0.565	0.051	0.261***
Personal norms				0.11	0.044	0.081*
Good provider identity				-0.248	0.027	-0.22***
Household planning habits				0.112	0.03	0.095***
Model statistics	R^2=0.13, F (10,1173)=19.04, p<0.001			R^2=0.44, F (19,1069)=45.18, p<0.001		

**p<0.05, **p<0.01, ***p<0.001*

The Model 1 results of the linear regression show that a lower age, a greater number of people in the household, a greater number of children in the household, not using a backyard composter, and to a lesser extent housing type (i.e., townhouses significantly greater than apartments and other housing) and income, were significantly related to more self-reported food wasting (Table 4.8). The second model, which included TPB constructs, considerably improved the model's fit and increased the explained variance (R^2=0.32 vs. R^2=0.14 respectively). Perceived behavioral control and more positive personal attitudes were significantly and negatively related, and the number of children and environmental attitudes were positively associated with food wasting frequency. Non-TPB constructs and intention were added in the Model 3 but did not change the model's explained variance. Intention was negatively related, while back yard composter use was no longer significantly related to food wasting frequency.

Six food waste type linear regression models were all significant, with a range of explained model variances (R^2=0.12-0.21) (Table 4.9). Perceived behavioral control appeared to be the most consistent predictor of food wasting frequency for all six food types. The number of children in a household were significantly related to higher food wasting frequency of four food types including: bread and baked goods, meat and fish, dried food, and other food. Further, personal attitude was significantly related to lower food wasting frequency of four food types including: bread and baked goods, fruit and vegetables, dried food and other food. The frequency of fruit and vegetable

Table 4.8 - Hierarchical linear regression analysis on self-reported household food wasting frequency

	Model 1			Model 2			Model 3		
	B	SE	*β*	B	SE	*β*	B	SE	*β*
(Constant)	5.919	2.805		12.909	2.819		12.973	2.911	
Gender	-0.684	0.373	-0.055	-0.597	0.351	-0.048	-0.537	0.359	-0.043
Age	-0.457	0.118	-0.138***	-0.121	0.113	-0.036	-0.11	0.116	-0.032
Housing type	0.438	0.222	0.057*	0.518	0.209	0.066*	0.517	0.211	0.066*
Housing tenure	-0.226	0.213	-0.038	-0.225	0.202	-0.037	-0.22	0.205	-0.036
Number in household	0.417	0.197	0.105*	0.242	0.185	0.06	0.281	0.187	0.069
Number of children in household	0.826	0.234	0.162***	0.71	0.217	0.139**	0.683	0.219	0.134**
Employment status	0.073	0.129	0.018	0.177	0.12	0.043	0.182	0.123	0.044
Income	0.291	0.1	0.09**	0.114	0.097	0.035	0.098	0.098	0.03
Back yard composter use	-0.422	0.086	-0.141***	-0.165	0.083	-0.055*	-0.159	0.084	-0.052
Responsibility for food preparation	-0.064	0.156	-0.013	-0.072	0.144	-0.015	-0.064	0.147	-0.013
Responsibility for waste management	-0.018	0.127	-0.005	-0.041	0.117	-0.01	-0.035	0.119	-0.009
Personal Attitudes				-0.158	0.043	-0.128***	-0.15	0.044	-0.121**
Financial attitudes				-0.01	0.031	-0.009	-0.002	0.032	-0.002
Environmental attitudes				0.156	0.051	0.083**	0.161	0.052	0.084**
Perceived health risks				0.083	0.027	0.083**	0.074	0.027	0.073**
Perceived behavioural control				-0.266	0.024	-0.353***	-0.247	0.026	-0.325***
Subjective norms				0.011	0.045	0.007	0.017	0.046	0.01
Personal norms				-0.051	0.036	-0.05	-0.03	0.038	-0.029
Intention							-0.091	0.029	-0.096**
Good provider identity							0.017	0.024	0.02
Household planning habits							0.009	0.025	0.01
Model statistics	R^2=0.14, F (11,1147)=18.02, p<0.001			R^2=0.32, F (18,1052)=28.43, p<0.001			R^2=0.32, F (21,1033)=24.63, p<0.001		

**p<0.05, **p<0.01, ***p<0.001*

wasting

Table 4.9 - Linear regression analysis on self-reported household food waste for six food type

	Bread and Baked Goods			Meat and Fish			Dairy			Fruit and Vegetables			Dried Food			Other		
	B	SE	β	B	SE	β	B	SE	β	B	SE	β	B	SE	β	B	SE	β
	2.182	0.7		1.522	0.683		1.49	0.609		4.021	0.954		0.73	0.597		3.445	0.838	
Gender	-0.118	0.086	-0.042	-0.051	0.084	-0.019	-0.08	0.075	-0.034	-0.207	0.118	-0.054	0.047	0.074	0.021	-0.149	0.103	-0.045
Age	0.045	0.028	0.059	0.007	0.027	0.01	-0.049	0.024	-0.076*	-0.105	0.038	-0.101**	0	0.024	0	-0.036	0.034	-0.041
Housing type	0.052	0.051	0.029	0.142	0.05	0.083**	0.091	0.044	0.061*	0.025	0.069	0.01	0.079	0.043	0.056	0.09	0.061	0.043
Housing tenure	-0.028	0.05	-0.02	-0.024	0.048	-0.018	-0.038	0.043	-0.033	-0.055	0.068	-0.029	-0.033	0.042	-0.029	-0.017	0.059	-0.01
Number in household	0.068	0.045	0.074	0.038	0.043	0.043	-0.032	0.039	-0.042	0.114	0.061	0.092	0.052	0.038	0.07	0.064	0.054	0.06
Number of children in household	0.196	0.052	0.17***	0.119	0.051	0.107*	0.053	0.046	0.054	0.014	0.071	0.009	0.14	0.045	0.152**	0.168	0.063	0.125**
Employment status	0.02	0.03	0.021	0.016	0.029	0.018	0.011	0.026	0.014	0.06	0.04	0.047	0.024	0.025	0.032	0.045	0.035	0.042
Income	0.026	0.024	0.036	0.034	0.023	0.047	0.039	0.02	0.063	0.055	0.032	0.055	-0.007	0.02	-0.012	-0.028	0.028	-0.032
Back yard composter use	-0.013	0.02	-0.019	-0.007	0.02	-0.011	-0.024	0.018	-0.042	-0.053	0.028	-0.057	-0.007	0.017	-0.013	-0.059	0.024	-0.074
Responsibility for food preparation	-0.012	0.035	-0.011	-0.016	0.034	-0.015	-0.002	0.031	-0.003	0.023	0.048	0.015	0.005	0.03	0.006	-0.065	0.042	-0.05
Responsibility for waste management	-0.003	0.029	-0.003	0.041	0.028	0.046	-0.01	0.025	-0.013	-0.046	0.039	-0.037	0.012	0.024	0.017	0.003	0.034	0.002
Personal attitudes	-0.031	0.011	-0.11***	-0.009	0.01	-0.032	-0.01	0.009	-0.044	-0.043	0.014	-0.113**	-0.019	0.009	-0.083*	-0.031	0.013	-0.096*
Financial attitudes	0.004	0.008	0.016	0.002	0.007	0.008	0.007	0.007	0.036	-0.001	0.01	-0.004	0.003	0.007	0.013	-0.02	0.009	-0.072*
Environmental attitudes	0.023	0.013	0.052	0.021	0.012	0.05	0.028	0.011	0.077*	0.019	0.017	0.032	0.019	0.011	0.055	0.039	0.015	0.078*
Perceived health risks	0.013	0.007	0.057*	0.025	0.006	0.113***	0.007	0.006	0.037	-0.001	0.009	-0.004	0.009	0.006	0.048	0.015	0.008	0.058
Perceived behavioral control	-0.046	0.006	-0.267***	-0.043	0.006	-0.264***	-0.029	0.005	-0.204***	-0.063	0.009	-0.269***	-0.024	0.005	-0.172***	-0.05	0.008	-0.251***
Subjective norms	0.007	0.011	0.02	-0.006	0.011	-0.018	0.01	0.01	0.033	0.009	0.015	0.018	-0.004	0.009	-0.012	0.008	0.013	0.017
Personal norms	0.002	0.009	0.009	-0.015	0.009	-0.07	-0.012	0.008	-0.062	-0.017	0.012	-0.055	-0.002	0.008	-0.012	0.01	0.011	0.037
Intention	-0.018	0.007	-0.086***	-0.011	0.007	-0.053	-0.02	0.006	-0.115***	-0.013	0.009	-0.044	-0.009	0.006	-0.054	-0.014	0.008	-0.055
Good provider identity	-0.003	0.006	-0.016	0.003	0.006	0.018	0.012	0.005	0.076*	0.006	0.008	0.021	-0.005	0.005	-0.033	-0.003	0.007	-0.011
Household planning habits	-0.007	0.006	-0.033	0.003	0.006	0.016	0	0.005	0.001	0.005	0.008	0.02	0	0.005	-0.001	0.006	0.007	0.027
	R^2=0.21, F (21,1059)=14.92, p<0.001			R^2=0.19, F (21,1055)=13.15, p<0.001			R^2=0.15, F (21,1056)=10.25, p<0.001			R^2=0.20, F (21,1057)=14.17, p<0.001			R^2=0.12, F (21,1052)=7.655, p<0.001			R^2=0.17, F (21,1048)=11.30, p<0.001		

*$p<0.05$, **$p<0.01$, ***$p<0.001$*

appeared to decline with age, while perceived health risks had the largest impact on meat and fish wasting.

4.5 Discussion

We were able to meet our objectives by successfully replicating a similar methodology deployed by Visschers et al. (2016) to model household food wasting behavior in London, Ontario. In the following sections, we compare and discuss our results with studies by Visschers et al. (2016) and other researchers to identify how to strengthen the use of the TPB to measure household food wasting behaviors and which psychological construct(s) should be considered when developing food waste reduction interventions. We explored the TPB intention:behavior relationship and whether perceived behavioral control is better suited to be the key predictor of food wasting behavior.

4.5.1 Comparison of food waste predictors with Visschers et al. (2016)

The amount of self-reported food waste portions in our findings (Table 4.2) was marginally higher than in Visschers et al. (2016), confirming Hypothesis 2. The mean of many psychological constructs including intention, personal attitudes, perceived health risk, perceived behavioral control, social norms and personal norms were higher in Visschers et al. (2016), suggesting more strongly held views than in our findings (Appendix, Table A.4.11). Conversely, mean survey responses in our study were higher for financial attitudes and marginally higher for good provider identity and household planning habits. However, the rank of the various common constructs, including high-ranking ones such as intention, personal norms and social norms were quite similar, and low-ranking ones, including good provider identity, household planning habits and perceived health risks, were identical. The key difference was personal attitudes, which had a higher mean and ranked much higher in Visschers et al. (2016), while financial attitudes had a higher mean and ranked higher in our findings. The foregoing suggests that while the means were different, relative respondent opinions were similar between the two studies, confirming Hypothesis 1.

Comparing bivariate relationships between self-reported food wasting behavior and psychological constructs, we found the same four constructs (intention, personal norms,

personal attitude and perceived behavioral control) had significant negative moderate-to-strong relationships, as in the study by Visschers et al., 2016. Nevertheless, our findings diverged somewhat from Visschers et al. (2016), with the strongest relationships being between perceived behavioral control and closely after that intention, rather than the other way around. Our findings indicate that perceived behavioral control may be as strong a predictor as intention, if not stronger.

The results of regression analyses were also compared with Visschers et al. (2016). Socio-demographic variables had a modest impact on the intention to not waste food, in both studies. These variables offered more robust predictive capacity for food wasting behavior in Visschers et al. (2016) than our findings, with age, gender and education having significant impacts, although children in the household was a common and significant positive predictor in both studies. For intention to not waste food, the three highest significant predictors in both studies included perceived behavioral control and personal norms, whereas financial attitudes were higher in (Visschers et al., 2016) and household planning habits higher in our study. The three highest significant predictors of self-reported food wasting behavior were perceived behavioral control, number of children in the household, and personal attitude in our study, but intention, perceived behavioral control and good provider identity in Visschers et al. (2016). This comparison re-iterates the divergence between the two studies, identified in bivariate relationships, suggesting that Hypothesis 3 was not met. Further, in our study, perceived behavioral control was the most significant predictor of self-reported food wasting behavior for each food waste type, whereas it was intention in Visschers et al. (2016). This finding indicates that in our study, perceived behavioral control is a more important predictor of food wasting behavior than intention.

Thus, the key difference between our study and Visschers et al. (2016) appears to be related to the greater strength of perceived behavioral control as a predictor of both intention and self-reported food wasting behavior. This was further supported by the linear hierarchal regression on perceived behavioral control in which more of the variance was explained than for intention. This speaks to a potential weakness of only using intention as a predictor of self-reported household behavior. Arguably, no one intends to deliberately dispose of food and this was manifest as the highest psychological construct mean in both studies.

Perceived behavioral control may function as a survey respondent proxy for household (i.e., group) intention and/or behavioral efficacy, and therefore may serve as a better predictor of this behavior.

4.5.2 Food waste predictors in other studies

The TPB has also been used in other studies to model food wasting behavior, and the results generally concur with the violability of this intention:behavior relationship. Stefan et al. (2013) used a modified TPB survey to ask Romanian consumers about their food wasting habits and found that it did not explain survey respondent food wasting behaviors well. While moral attitude had a significant positive impact, and lack of concern a significant negative impact on intention to not waste food, subjective norms and perceived behavioral control had no impact. Their results showed that planning, and especially shopping routines, explain most of the variance in food wasting behavior, while intention to not waste food, the lynchpin of the TPB, did not have a significant impact on reported food waste. Stefan et al. (2013, p. 379) explain this by suggesting that food waste is embedded in food provisioning routines and not "driven by conscious intentions". Graham-Rowe et al. (2015) used an extended TPB model in surveys that measured intention and behavior to reduce household fruit and vegetable waste. In the baseline survey, demographics, TPB and additional predictors (self-identify, anticipated regret, moral norm and descriptive norm) explained up to 73% of the variance in intention to reduce fruit and vegetable waste. Intention, but not perceived behavioral control, was a significant predictor of behavior, although the amount of variance explained was quite low (5%). They suggested the additional predictors augment the predictive capabilities of the TPB. Stancu et al. (2016) used an extended TPB in a survey to predict intention to not waste food and food wasting behavior. The additional predictors used were related to various food planning and procurement routines and household food-related skills. Their model explained 45% of the variance of intention to not waste food and 43% of food wasting behavior. Attitudes and injunctive norms explained most of the variance of intention, while moral norms and perceived behavioral control had no impact. Perceived behavioral control, leftover use routines and shopping routines explained most of the variance of food wasting behavior, with intention making a low contribution.

In the context of our study, the foregoing research shows that intention has a limited impact on predicting food wasting behavior and that personal attitudes, personal and subjective norms, and food management predictors such as household planning habits and good provider identity are better predictors of this behavior. All of these predictors were significant antecedents of perceived behavioral control in our study (Table 4.7).

4.5.3 Implications for intervention development

Visschers et al. (2016) suggested that food waste reduction interventions should concentrate on intention, perceived behavioral control, and the good provider identity; whereas Stefan et al. (2013) and Romani et al. (2018) recommended they be built around consumer food planning and shopping routines, while also attempting to integrate a change in consumer attitudes. Our findings generally concur, although we suggest that perceived behavioral control could potentially be exchanged with intention as the key TPB determinant of behavior, and that intervention development focus on strengthening its significant antecedents. What this means is developing interventions that seek to bolster subjective and personal norms as well as personal attitudes that wasting food is not right and needs to be curtailed. It also means raising people's food literacy by providing them with information that would allow them to improve their household planning habits. This would, in turn, help them reduce the over-purchase of food that is in part embodied by the good provider identity.

Reducing monetary impact was significantly and clearly the preferred food waste reduction motivator for most survey respondents, confirming Hypothesis 4. There is some evidence of a disconnection between selecting this motivator and respondent financial attitudes. In bivariate analyses, financial attitudes were only moderately related to personal norms; and in regression analyses only modestly, but significantly, related to intention; not at all with perceived behavioral control, self-reported food wasting frequency, or food wasting frequency by food type. Respondents generally reported "bought too much" as the key reason why the six food types are thrown out. Re-establishing this connection should be an integral part of intervention development. It means educating people about the value of their household food waste and using this information to prime innate personal and subjective norms to not waste money. This can be complemented by providing clear and actionable food literacy information that is focussed on saving money by not wasting food.

4.5.4 Limitations

There are two key limitations of our study. Firstly, our survey was opportunistic and not a randomly selected sub-set of the population. However, we argue that only people who want to complete surveys will, and that transcends the approach used to elicit respondents. We used a comprehensive and multi-faceted approach to attract a diversity of respondents and were successful in that regard. Secondly, we relied on self-reported food wasting behavior. This is fraught with challenges, such as observer bias, because it does not measure actual behavior, but rather a survey respondent's assessment of their household's behavior. This can be overcome by collecting curbside household waste samples on their waste collection day, and manually sorting out and weighing food waste. Indeed, future research should compare actual behavior with self-reported behavior and further assess the impacts on TPB constructs on actual behavior.

4.6 Conclusions

We successfully modelled household food wasting behavior in London, Ontario, Canada. Perceived behavioral control appeared to be the dominant predictor of self-reported food wasting behavior in this study and interventions should focus on strengthening this determinant.

This can be accomplished through further activation of personal attitudes, personal and subjective norms, as well as food literacy that focusses on managing the good provider identity and enhancing household planning habits. While much of the behavior that leads to food wasting is arguably rational, priming the irrational and innate behavior to save money can be a powerful tool to motivate households to reduce their food waste.

4.7 Appendix

Table A.4.10 Appendix- Survey items per construct, including mean, standard deviation, corrected item-total correlation (r pbis) per item, as well as internal reliability (Cronbach's α)

Questions per construct	M	SD	Cronbach's α	M	SD	r_{pbis}
Intentions	**5.99**	**1.48**	**0.94**			
I try to waste no food at all.				6.13	1.43	0.86
I always try to eat all purchased foods.				6.02	1.45	0.87
I try to produce only very little food waste.				5.86	1.51	0.85
I aim to use all leftovers.				5.95	1.52	0.81
Attitudes						
Personal attitudes	**5.30**	**1.71**	**0.76**			
It is unnecessary to waste food: it can always be used in some way.				5.15	1.66	0.60
It is immoral to discard foods while other people in the world are starving.				4.81	1.83	0.64
It upsets me when unused products end up in the waste bin or garburator.				5.93	1.41	0.57
Financial attitudes	**5.54**	**1.79**	**0.61**			
I think that wasting food is a waste of money.				6.47	0.96	0.30
I cannot afford to pay for foods that are then discarded.				4.81	1.93	0.37
Saving money does not motivate me to discard less food.*				5.34	1.89	0.41
I rarely think about money when I throw away food.*				5.51	1.79	0.52
Environmental attitudes	**5.81**	**1.66**	**0.6**			
Throwing out food does not have an environmental impact.*				6.25	1.34	0.45

I rarely think about the environment when I throw away food.*				5.37	1.82	0.45
Food safety attitudes	**2.83**	**1.88**	**0.64**			
I believe that the risk of becoming ill as a result of eating food past its "best before" date is high.				3.53	1.80	0.41
I am not worried that eating leftovers results in health damage.*				3.14	2.19	0.38
I think that consuming leftovers is harmless.*				1.98	1.43	0.42
I think that one can perfectly safely eat food products whose "best before" dates expired a few days.*				2.68	1.64	0.53
Perceived behavioral control	**5.24**	**1.83**	**0.78**			
I find it difficult to prepare a new meal from leftovers.*				5.39	1.77	0.48
I find it difficult to make sure that only small amounts of food are discarded in my household.*				4.97	1.83	0.62
I find it difficult to plan my food shopping in such a way that all the food I purchase is eaten.*				4.88	1.95	0.62
I have the feeling that I cannot do anything about the food wasted in my household.*				5.74	1.52	0.51
Other household members make it impossible for me to reduce the amount of food wasted in my household.*				5.23	1.90	0.53
Subjective norms	**5.68**	**1.64**	**0.83**			
People who are important to me find my attempts to reduce the amount of food wasted unnecessary.*				5.51	1.76	0.72
People who are important to me disagree when I try to reduce my food waste.*				5.85	1.50	0.72
Personal norms	**5.77**	**1.46**	**0.87**			
I feel bad when I throw food away.				6.17	1.27	0.60

I feel obliged not to waste any food.				5.73	1.45	0.80
It is contrary to my principles when I have to discard food.				5.60	1.52	0.79
I have been raised to believe that food should not be wasted and I still live according to this principle.				5.59	1.54	0.71
Good provider identify	**3.51**	**1.94**	**0.63**			
It would be embarrassing to me if my guests ate all the food I had prepared for them. They would probably have liked to eat more.				2.95	1.90	0.27
I regularly buy many fresh products although I know that not all of them will be eaten.				3.14	1.89	0.29
I like to provide a large variety of foods at shared mealtimes so that everyone can have something he or she likes.				3.68	1.84	0.47
I always have fresh products available to be prepared for unexpected guests or events (e.g., illness).				3.17	1.79	0.36
When I am expecting guests, I like to buy more food than is necessary because I am a generous host.				4.60	1.80	0.53
Household Planning Habits	**4.36**	**1.88**	**0.79**			
When I have made a shopping list, I always keep strictly to it.				3.88	1.82	0.56
I am a person who likes to plan things.				5.32	1.61	0.54
Before I prepare food, I always consider precisely how much I need to prepare and what I will do with the left overs.				4.51	1.82	0.63
I always plan the meals in my household ahead and I keep to this plan.				3.71	1.82	0.68

*Item was reverse coded. A 7 point Lickert scale was used, with higher values corresponding to greater agreement with the statement.

Table A.4.11 Appendix-Comparison and ranking of respondent scores on the various psychological constructs

	City N=1,263			Visschers et al. (2016) N=796		
Construct	Rank	M	SD	Rank	M	SD
Intention	1	5.99	1.48	1	6.57	0.78
Personal Attitudes	5	5.30	1.71	2	6.22	1.04
Financial Attitudes	4	5.54	1.79	6	4.64	1.49
Environmental attitudes	-	5.81	1.66	-	-	-
Perceived health risks	9	2.83	1.88	9	2.56	1.21
Perceived behavioral control	6	5.24	1.83	5	5.68	1.05
Subjective norms	3	5.68	1.64	3	6.09	1.27
Personal norms	2	5.77	1.46	4	5.96	1.16
Good provider identity	8	3.51	1.94	8	3.44	1.27
Household planning habits	7	4.36	1.88	7	4.32	1.40

4.8 References

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CHAPTER FIVE

5 “Reduce Food Waste, Save Money”- Testing a Novel Intervention to Reduce Household Food Waste

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5.1 Abstract

An intervention, which combined elements of behavioral economics (nudging) and the theory of planned behavior, was developed and tested in a randomized control trial (RCT) involving households in the city of London, Ontario, Canada. A bespoke methodology involving the direct collection and measurement of food waste within curbside garbage samples of control (n=58) and treatment households (n=54) was used to evaluate the effectiveness of the intervention. A comparison of garbage samples before and after the intervention revealed that total food waste in treatment households decreased by 31% after the intervention and the decrease was significantly greater (p=0.02) than for control households. Similarly, avoidable food waste decreased by 30% in treatment households and was also significantly greater (p=0.05) than for control households. Key determinants of treatment household avoidable food waste reduction included personal attitudes, perceived behavioral control, the number of people in a household and the amount of garbage set out.

5.2 Introduction

Wasting food results in a confluence of negative monetary, environmental and social impacts. There is substantial academic and societal interest in finding ways to intervene to reduce food wasting, particularly at the household level. This interest has largely focused on avoidable food waste, which is defined as food that was, at one point, edible, as opposed to unavoidable food waste (e.g., vegetable peels, bones) (Beretta et al., 2013; WRAP, 2009). Despite the growing interest in this area, knowledge gaps exist in our understanding of what drives food wasting behavior (Schanes et al., 2018; Visschers et al., 2016), how to develop effective policies and programs to reduce household food wasting (Hebrok & Boks, 2017; Schanes et al., 2018), and how to adequately evaluate interventions (Hoj, 2012) . The overarching purpose of this study was to develop and pilot test a theoretically-informed intervention to reduce household food wasting and to evaluate its effectiveness through a randomized controlled trial.

5.2.1 The impacts and determinants of household food wasting

It is estimated that up to 50% of food available for consumption (i.e., avoidable) is wasted along the food supply chain (Gustavsson et al., 2011; Parfitt et al., 2010). As described in a recent systematic review of food waste quantities in developed countries, an estimated 198.9kg/capita/year (SD=82.3) of food waste is generated across the food supply chain, with 114.3 kg/capita/year (SD=68.7) generated at the consumer or household level (van der Werf & Gilliland, 2017). In the United States, the monetary impacts of food waste across the food supply chain are estimated to be $166 billion annually; this includes an estimated loss of about 10% of

household food expenditures (Buzby & Hyman, 2012). Further, the municipal collection and disposal of household food waste also represents an unnecessary cost. Food waste's environmental impacts are considerable and include wasted energy (Cuéllar & Webber, 2010), wasted water (Lundqvist et al., 2008), and greenhouse gas generation from agricultural production and shipment to markets (Agriculture and Agrifood Canada, 2015; Weber & Matthews, 2008). Wasting food also has indirect social impacts. At the same time that many households throw out food, 14.7 million people in developed countries are undernourished (FAO IFAD and WFP, 2015). In Canada, 8% of adults live in food insecure households (Statistics Canada, 2015).

The development of successful food waste reduction interventions at the household level needs to begin with an understanding of who wastes food and why. Researchers have identified socio-demographic determinants, including age (especially households with younger children) (Fusions, 2014; Melbye et al., 2016; Tucker & Farrelly, 2016); household size and type (i.e., larger and with children) (Baker, 2009; Koivupuro et al., 2012; Neff, 2015; Parizeau et al., 2015), higher household income (Fusions, 2014; Neff, 2015; Stancu et al., 2016); and gender (with males potentially wasting more than females) (Koivupuro et al., 2012; Secondi et al., 2015; Visschers et al., 2016).

Research has identified several other reasons why household food is wasted, including spoilage (i.e., food that has decayed), fussy eaters in the household or being overly sensitive to high-risk food spoilage (Göbel et al., 2015; Halloran et al., 2014; Jorissen et al., 2015; Thyberg et al., 2015). These determinants can be placed under the umbrella of poor "food literacy", which is defined as a lack of knowledge regarding the various aspects of household food management, which encompasses the planning, buying, preparing, serving, and storing of food. Food literacy also includes confusion regarding food labels such as "best before" and "use by" dates (Porpino, 2016; Principato et al., 2015; WRAP, 2011, 2014); inadequate meal planning and grocery shopping (Abeliotis, 2014; Pearson et al., 2013; WRAP, 2011); buying, preparing and serving too much food (Van Garde & Woodburn, 1987; Williams et al., 2012; WRAP, 2007a); poor food storage (Aschemann-Witzel et al., 2015; BIO Intelligence Service, 2011; Koivupuro et al., 2012); and lack of knowledge about what to do with leftovers (Evans, 2012; Graham-Rowe et al., 2014; WRAP, 2013).

5.2.2 Intervention development prerequisites

The development of an effective intervention needs to not only consider the key determinants of household food wasting, such as household sociodemographic characteristics and food literacy, but also needs to incorporate an understanding of what factors might motivate households to reduce food waste, as well as both rational and irrational determinants of this behavior.

5.2.2.1 Food waste reduction motivators.

The strongest potential food waste reduction motivators appear to be saving money (Abeliotis, 2014; Porpino, 2016; Tucker & Farrelly, 2016), and moral values (Bolton, 2012; Graham-Rowe et al., 2014; Neff, 2015; Quested et al., 2013). For instance, the financial impacts of purchasing too much food is a driver that can reduce food waste (Graham-Rowe et al., 2014; Quested et al., 2013; Williams et al., 2012). Much weaker motivators appear to be concern about the environmental impact of food waste (BIO Intelligence Service, 2011; Neff, 2015; Quested et al., 2013; Tucker & Farrelly, 2016; Watson & Meah, 2012) and humanitarian (i.e., social) concerns, such as hunger and poverty (Baker, 2009; Tucker & Farrelly, 2016; Watson & Meah, 2012). Health-conscious consumers appear to be motivated to reduce food waste (Quested et al., 2013), although these consumers typically buy more perishable commodities, some of which were ultimately discarded (Evans, 2011; Graham-Rowe et al., 2014). Stancu et al. (2016) reported that people were more aware of the economic consequences than environmental and social consequences, suggesting that "people are motivated … by self-interest in their food waste behavior" (p.16) and that they see food waste behavior as food-related behavior, and much less so as an environmental behavior.

5.2.2.2 Rational food waste behavioral determinants.

Several studies of the behavioral determinants of food wasting have used the theory of planned behavior (TPB) (Ajzen, 1991) for a conceptual framework and have focused on the key antecedents of intention, subjective norms, attitudes, and perceived behavioral control, and how intention influences behavior. Studies by Graham-Rowe et al. (2015) and Stefan et al. (2013) both reported that subjective norms were unrelated to food wasting behavior and only modestly influenced intention. This may be because the wasting of food is a behavior that is generally only seen by the generator. Consumers feel "bad" or were otherwise concerned about throwing away food and this informs a negative attitude towards this behavior (Abeliotis, 2014; Evans, 2012;

Graham-Rowe et al., 2014, 2015; Thyberg & Tonjes, 2016; Watson & Meah, 2012). Financial, environmental, social and health attitudes also influence food wasting behaviour, possibly functioning as motivators. Perceived behavioral control, or people's sense of their ability to perform a certain behavior (Ajzen, 1991), has impacts on intention related to situations, such as the conflict between food provisioning and fussy eaters, unexpected meals outside the home, and large food packaging sizes (Evans, 2012; Williams et al., 2012). Perceived behavioral control can function as a strong (Graham-Rowe et al., 2015) or weak (Stancu et al., 2016; Stefan et al., 2013) antecedent of intention, but also a similar, if not stronger, determinant of food wasting behavior (Stancu et al., 2016; Stefan et al., 2013; Visschers et al., 2016). Researchers have also explored other food wasting determinants, such as personal norms, household planning habits and the good provider identity, which can be manifest by needing to have plenty of food on hand for various expected and unexpected situations (Evans, 2011; Visschers et al., 2016).

There have also been some challenges with the ability of intention to strongly predict food wasting behavior (Russell et al., 2017; Stancu et al., 2016; Stefan et al., 2013), which may speak to a potential disconnect between people's intention to not waste food and the amount of food they actually waste. A possible reason is that people do not purchase food with the intention of throwing it out, and this is reflected in typically strong survey responses related to the intention to not waste food (Visschers et al., 2016). Thus, perceived behavioral control may be a better predictor of food wasting behavior and/or it strengthens the efficacy of the intention: behavior relationship (Graham-Rowe et al., 2015; Schanes et al., 2018; Stancu et al., 2016). Therefore, strengthening perceived behavioral control should be a critical component of intervention development.

5.2.2.3 Possible irrational food waste reduction determinants.

Research to date has predominantly focused on rational behaviors. The rationalist approach used to frame human behavior has been challenged in recent years by several behavioral economists (Camerer et al., 2003; Kahneman, 2011; Sunstein & Thaler, 2008; Thaler & Sunstein, 2009b; Tversky & Kahneman, 1992). A revised framing sees humans as "… less than perfect decision makers driven by cognitive short cuts and social norms and pressures" (Moseley & Stoker, 2013, p. 5). In a similar vein, Kahneman (2011) describes human behavior as being divided between two systems. System 1 "operates systematically and quickly, with little or no effort and no sense

of voluntary control", whereas System 2 "allocates attention to the effortful mental activities that demand it, including complex computation" (pp. 20-21).

Nudging, an application derived from behavioral economics, is an output of this thinking. The term, coined by Thaler and Sunstein (2009b), uses "libertarian paternalism", which refers to steering individuals to decisions that promote their well-being, while at the same time maintaining their right to choose, as its starting point. It has been used to help policy makers systematically integrate behavioral insights into various interventions (Lehner et al., 2015). Nudging is not meant to replace rational choice perspectives (Moseley & Stoker, 2013; Sunstein, 2015), but to build on it by including the cognitive, social and moral factors that are a part of our decision making (Moseley & Stoker, 2013). Behavioral economics and nudges have been used to promote more sustainable consumption behaviors (Sunstein, 2015), and can, in theory, be used to reduce household food waste. Porpino (2016) notes that consideration should be given to expanding and integrating theoretical models, such as the TPB with behavioral economics. This can extend to intervention development.

5.2.3 Previous food waste reduction interventions

In an extensive review of research on household food waste and intervention points, Hebrok and Boks (2017, p. 390) noted that "food waste can be seen as process where food turns to waste, within a web of interrelated practices, tools, concerns, skills, knowledge and anxieties." They identify information and awareness, technology and planning, leftovers and portioning, storage, packaging, food risk and policy and regulation as possible interventions and/or intervention insertion points. Still, the development of household food waste reduction interventions is relatively new and the best approach(es) continue to evolve.

Household food waste reduction can be physically and/or technologically facilitated through creative methods such as: 1) using of intelligent fridges, which inform and remind users by sending them messages about the state of the food inside by, for instance, the use of a fridgecam (Ganglbauer et al., 2013); 2) modifying the nature or size of packaging to better preserve what is inside it (Verghese et al., 2015); and 3) by using reduced packaging sizes to sell consumers a quantity of food that can be reasonably consumed before it becomes food waste (Evans, 2011). Despite these creative options, information and awareness interventions appear to be the default method used to reduce food waste (Hebrok & Boks, 2017). This typically involves media and/or

on-line campaigns, which are mainly used to present food literacy information (e.g., purchasing, cooking, storage advice) (Manzocco et al., 2016).

Building on printed food waste recycling information, they provided to all multi-residential households, Bernstad et al. (2013) tested the impact of door-to-door visits to present oral information on the environmental benefits of recycling food waste, but found no significant differences in the weight of food waste recycled compared to households that were not visited. Schmidt (2016) discovered that strengthening food literacy by providing volunteer households partially customized (from information gathered in an initial survey) food waste reduction information resulted in an improvement of perceived prevention ability and self-reported food waste preventing behaviors.

In a study on reducing university cafeteria plate waste, Jagau and Vyrastekova (2017) used posters that included relevant food wasting information and solutions as a nudge based behavioral intervention. Customers were willing to ask for less food for the same price and their intentions to not waste food appeared to be nudged by personal norms, manifest as feelings of guilt and shame. The authors further suggested presenting information on household food wasting behavior in parts of a city, including relative performance, and to evoke social pressures, especially guilt and shame, as an intervention to reduce household food wasting. This idea echoes the work of Comber and Thieme (2013) who suggest that raising food waste awareness results in self-reflection and re-evaluation, and may lead to feelings of shame that one's attitudes are not manifest as requisite behavior. However, they also suggest the importance of perceived behavioral control to unlock behavioral change and highlight the significance of "signal triggers" to remind individuals about performing desirable behaviors.

Other researchers, such as Russell et al. (2017), proposed that people who have negative emotions about food waste and who intend to throw out less actually reported throwing out more food, and they argued for a more positive approach to interventions. Further, they contended that non-cognitive (or irrational) drivers, such as emotion and habit, should be considered as part of intervention development.

5.2.4 Study objectives and hypotheses

We developed and pilot-tested a "Reduce Food Waste, Save Money" household food waste reduction intervention in London, Ontario, Canada, and measured its impact on total,

unavoidable and avoidable household food waste disposal in the garbage stream. The rationale in undertaking this study was that there has been little research on household food waste behavior in North America, and to our knowledge, no research that has directly measured the change in curbside food waste disposal in the garbage stream after an intervention.

The theoretical context underpinning this intervention is the TPB to facilitate rational behaviors, and behavioral economics to nudge irrational behaviors. Visschers et al. (2016) reported on the positive impact of perceived behavioral control on intention to not waste food and self-reported food wasting behaviors. Strengthening this determinant can potentially be accomplished by improving food literacy. Our approach was to provide households with information on how to better manage food planning, purchase, storage, preparation, and leftovers. While this rational approach arguably provides households with the tools to reduce food waste, the competing daily behavioral interests that consume household time (e.g., getting the children to school, working a full-time job) mean that achieving a desired behavior requires moving beyond rational behaviors to identify and nudge irrational behaviours. This is essentially what is espoused in behavioral economics and nudges. In Table 3, overall survey respondents overwhelmingly selected "reduce amount of money wasted" over reducing environmental and social impacts as the key motivator to reducing food waste, confirming the conclusion of Stancu et al. (2016) that reducing this behavior may be motivated by self-interest. We posit that, except perhaps for the very wealthy, the management of household monetary resources is an ongoing and largely irrational activity. That is, within the context of available resources people generally automatically seek out the most cost-effective goods and services. We therefore focussed the irrational aspects of our intervention on nudging the need to save money, using locally calculated average dollars and quantity of food waste thrown out annually, with reduced environmental and social impacts presented as collateral benefits. To summarize, our intervention was developed to nudge the largely irrational behavior of reducing the amount of money wasted by wanting to save money, while building up household confidence or perceived behavioral control by providing households with information to increase their food literacy and help them better manage their food.

The first objective of this study was to test this intervention in a randomized control trial (RCT) and measure its impact on the amount of household food waste placed in the garbage on a household's garbage collection day. Researchers such as Visschers et al. (2016) recommended the direct collection, manual sorting and weighing of food waste samples to measure food

wasting behavior. A secondary objective was to develop and test a methodology to directly collect and sort household food waste from garbage samples.

Our study has two hypotheses: H1. Treatment households will reduce food waste set out in the garbage stream by at least 20% after receipt of an intervention package; H2. The change in total, avoidable and unavoidable food waste set out will be significantly different between treatment and control households.

5.3 Method

5.3.1 Procedure

An intervention was pilot-tested on single-family households recruited as part of a household food waste survey, whose purpose was to better understand self-reported food waste disposal and possible behavioral determinants. Employing an RCT that included both treatment (n=54) and control (n=58) households, the impact of this intervention was measured by comparing the weight of total, avoidable, and unavoidable food waste in pre- and post-intervention curbside garbage samples.

Research was undertaken on single-family households in London, Ontario, Canada (City) (population 390,000). The City has a six-business day, six zone garbage and recyclables curbside waste collection system for single-family households. Waste collection, disposal, and diversion are undertaken by a combination of municipal and contracted private sector forces. There is currently no curbside program to separately remove source-separated food wastes, although approximately 60,000 backyard composters have been distributed throughout the City in the last 25 years (J. Stanford, personal communication, 15 May 2017).

5.3.1.1 Household food waste survey design and dissemination

In addition to household recruitment, the survey provided various data that supported this study. Using TPB as a conceptual framework, we developed a survey with 71-items, including questions from previously-validated and well-used household/consumer food waste surveys primarily from Visschers et al. (2016), but also from Stancu et al. (2016) and (WRAP, 2007a). The survey was administered online using Qualtrics survey software.

The survey introduction collected socio-demographic information (e.g., housing tenure, number of people and children in a household, household income); the frequency of backyard composter usage, which was used as a proxy for pro-environmental behavior; the most common reason (e.g., purchased too much) their household throws out food for each of six food types; and the ranking of three possible food waste reduction motivators: reduce amount of money wasted, reduce environmental impact of wasting food (e.g., climate change), and reduce social impact of wasting food (e.g., hunger).

The remainder of the survey used the TPB model (Ajzen, 1991, 2015) to ask questions about behavioral determinants (i.e., psychological constructs), such as food wasting intentions, intention antecedents including attitudes (personal attitudes, financial attitudes, environmental attitudes, perceived health risk), subjective norms and perceived behavioral control, as well as non-TPB food wasting behavioral determinants (personal norms, good provider identity and household planning habits) (Figure 1). Questions about food wasting intentions, its antecedents and other possible determinants were directly adapted from Visschers et al. (2016, p. 77). A 7-point Likert scale was used, with higher scores representing more agreement with a given question. A final question asked survey respondents if they would volunteer their household for further study. This included the collection of curbside garbage samples on their waste collection day, and manually sorting and weighing the various food waste fractions in these samples.

The survey was available for completion from May to July 2017. An accompanying letter of information and consent explaining the study was also provided.

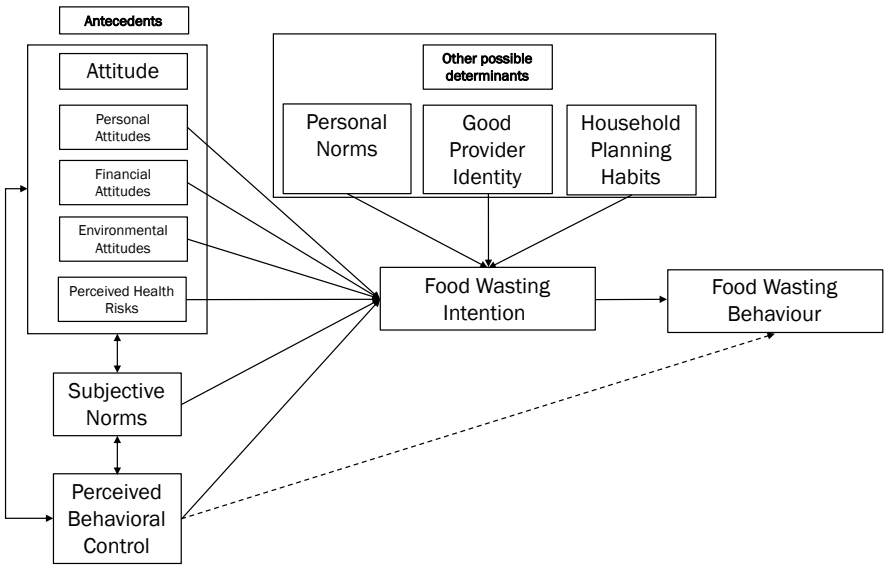

Figure 5.1 - Theory of planned behavior and other possible determinants Model (Ajzen, 1991; Visschers et al., 2016)

An opportunistic survey approach and concomitant comprehensive survey dissemination strategy (e.g., print ads, social media, contacting community groups) was deployed to inform the entire city about this survey and encourage city-wide responses.

5.3.1.2 Household recruitment and selection

A total of n=1,263 single-family households completed surveys, from which, 418 single-family households volunteered for further study. Due to resource limitations, it was not possible to include all volunteer households in this study. The key dependent variables of this study were total and especially avoidable food waste in household garbage set out on their collection day. Unavoidable food waste was also used as a dependent variable. Sample size calculations were used to determine the required number of single-family volunteer households into treatment and control groups.

5.3.1.2.1 Sample size calculation and initial food waste sampling methodology

To assist with sample size calculations, data were used from a food waste quantity and composition pilot study undertaken in London, Ontario in June 2016. A bespoke methodology was developed that used the methods described in (Stewardship Ontario, 2014; Waste Diversion Ontario, 2015) as a starting point, but, it was expanded to include total, avoidable and

unavoidable food waste categories, as well as six food sub-types (i.e., bread & baked goods, meat & fish, dairy, fruit & vegetables, dried food, and other food). These data were also used to calculate annual per household food waste disposal and the monetary value of that food waste, both of which were used in the intervention.

The methodology included the collection of curbside garbage samples from 100 representative households and manually sorting and weighing total and avoidable food waste. These households disposed a mean of 3.6 kg/week of total food waste (SD=1.1 kg/week) in the garbage stream. A post-intervention 20% reduction in treatment household total food waste disposal, in the garbage stream, was considered practically meaningful. The foregoing inputs were used to calculate the sample size required to detect this meaningful difference of 0.9 kg (i.e., 20%) of total food waste between the groups, assuming an alpha of 0.05. It was estimated that n=37 households were required for each group (i.e., treatment and control households). These households disposed a mean of 2.4 kg/week of avoidable food waste (SD=0.9 kg/week). The foregoing inputs were used to calculate the sample size required to detect this meaningful difference of 0.6 kg (i.e., 20%) of avoidable food waste between the groups, assuming an alpha of 0.05. It was estimated that n=53 households were required for each group (i.e., treatment and control households). This higher number of households was used to test the intervention. Thus, a minimum of 106 households was required to meet sample size calculation requirements.

Since we wanted to assess the impact of the intervention on food waste set out (i.e., in the garbage stream), only households from which both pre- and post-intervention garbage samples were collected could be used. There are two logistical challenges that can impede garbage sample collection and potentially hinder achieving the minimum sample size. From past study team experience, a minimum of 10% of households do not set out garbage on any given collection day. Secondly, even though the study team worked closely with the City of London to facilitate garbage sample collection, it was estimated that up to 10% of samples would inadvertently be collected by City waste collection vehicles prior to the arrival of the study team. Thus, to account for this estimated attrition, a 20% buffer of additional households was added to both pre- and post-intervention sampling rounds, resulting in a starting minimum of n=153 households. (i.e., 106 households*1.2=132 households*1.2=153 households), which was further rounded up to 160 households.

5.3.1.2.2 Selection of treatment and control households

The n=418 volunteer household locations were mapped and delineated by the City's six waste collection zones (i.e., collection in these zones occurs on consecutive weekdays). One hundred and sixty households were selected, consisting of 20 to 33 households per waste collection zone (as household volunteers per waste collection zone varied). Selecting sample households across all waste collection zones (i.e., urban and suburban) ensured the sample households represented the full range of socioeconomic status levels in the city. A focus was also on identifying clusters of households (i.e., households in reasonably close proximity to each other), in each waste collection zone, to facilitate rapid garbage/food waste sample collection. The selection of these clusters was completed "blind" of the results of the survey.

During the pre-intervention sampling round, 21 household samples were missed for the anticipated reasons described above, leaving 139 households. From these remaining households, 10-12 treatment households were randomly selected, per waste collection zone, resulting in 66 treatment households. The remaining 73 volunteer households were used as controls and were distributed 8-18 households per waste collection zone. Further, a twin-block facing analysis was undertaken to ensure that households in close proximity (i.e., on the same block) were either all treatment or control (to minimize the chance that a participant in the treatment group might share intervention info with a neighbour participating in the control group). On that basis, three adjustments were made where a household was converted from treatment to control or vice versa. During the post-intervention sampling round, 27 household samples were missed for the anticipated reasons noted above, leaving a final sample of n=54 treatment households and n=58 control households, which were considered in data analysis.

5.3.1.3 Intervention development

An intervention called "Reduce Food Waste, Save Money" was developed to nudge reducing the amount of money wasted on food waste and strengthening perceived behavioral control, by providing food literacy messaging. This was accomplished by providing households in London, Ontario locally-derived information on the quantity and average household value of food wasted, as well as information on environmental and social impacts of food wasting. The messaging focused on tips on how to: improve food planning; efficiently purchase, store and prepare food; and use leftovers, to ultimately reduce the amount of food that becomes waste. The intervention

package used a commercially available 4-litre container, designed to extend produce life, as an 'envelope'. The package included a "Reduce Food Waste, Save Money" postcard (Figure 2) affixed on the top of this container, along with a fridge magnet version of the postcard, and food waste reduction tools including an explanatory letter, freezer stickers, and a grocery list pad inside the container. All messaging included directions on how to access a purpose built www.foodwaste.ca website, which provided additional details on the various food waste reduction tips provided on the postcard and fridge magnet.

The intervention package was delivered to treatment households on 2 October 2017. Over the following two weeks, five email messages were sent to treatment households to reinforce that reducing the amount of food that became waste could save households money, to reiterate food waste reduction tips presented in the package, and to encourage visits to the website (Appendix).

Figure 5.2 - Postcard/fridge magnet included in intervention package

5.3.1.4 Collection and sorting of household food waste from garbage samples

A bespoke methodology to collect garbage and sort food waste is described in the 'Sample size calculation' section and this was logistically expanded to facilitate individual household and individual household food waste analysis collection (i.e., rather than groups collection and

analysis). Selected households were mapped using geographic information system software to create efficient routes for collection of daily samples. Pre-intervention garbage samples were collected once from each of the City's six waste collection zones between 18-25 September 2017. Post-intervention garbage samples were similarly collected between 18-25 October 2017. The samples were collected on a household's normal garbage collection day and what was set out was collected by three sampling crews. Households were not alerted to the specific day of the collection of these samples. Sample (i.e., bags of garbage) collection started at 7am in the morning and concluded by 8:30am each day. Samples were labelled, per household address, so that they could be identified after unloading. The number of recycling containers set out at the curb, by household, was also counted.

Household garbage samples were taken to an indoor sorting location. Each household garbage sample was individually weighed (using KPS-60SS scale; 60 kg capacity, sensitive to 0.02kg) and then manually sorted into six avoidable and unavoidable food waste categories: bread & baked goods, meat & fish, dairy, fruit & vegetables, dried food, and other food. Each category of food waste was weighed (using A&D SK-5001WP scale; 5,000 g capacity, sensitive to 1g). Weight data were normalized and expressed on a weekly basis for household garbage samples (kg/week) and food waste categories (g/week).

5.3.1.5 Statistical analysis

Data were analyzed for the final treatment (n=54) and control (n=58) households, only if both the pre- and post-intervention garbage samples were collected. Independent variables including survey-related questions on food waste reduction motivators, socio-demographic factors (i.e., housing tenure, number of people in a household, number of children in a household, household income), pro-environmental behavior (i.e., backyard composter usage, recycling container set out), quantity of garbage set out, and TPB psychological constructs (Figure 1) were utilized in data analysis of treatment and control households.

Data were analyzed using IBM SPSS Statistics version 25 (Armonk, New York). Categorical variables were summarized as percentages, and continuous variables were presented as mean ± standard deviation (SD) as well as medians and percentages where appropriate. Independent samples t-tests were used to assess the mean difference in total, avoidable and unavoidable pre- and post-intervention food waste (i.e., dependent variables) between the treatment and control

households. Paired samples t-tests were used to assess the mean difference between pre- and post-intervention for total, avoidable, and unavoidable food waste within treatment and control households. The Wilcoxon signed-rank test was used to assess non-parametric related samples, and specifically to determine if there were statistically significant differences between food waste reduction motivators.

As the focus of the intervention was on avoidable food waste, correlation and regression analysis were undertaken on this dependent variable. The Spearman rank correlation coefficient was used to assess the bivariate strength and direction of the association between the amount of avoidable food wasted (i.e., focus of intervention), socio-demographic factors, and waste management factors (i.e., garbage set out, recycling set out, backyard composter usage). Correlation coefficients were interpreted as follows: ≥0.75 very good to excellent; 0.50-0.75 moderate to good; 0.25-0.49 fair; and ≤0.25 little to no correlation (Colton, 1974). Multiple linear regression models were developed to assess the relative effects of various predictors on intention to avoid food waste, perceived behavioral control, and self-reported and curbside avoidable food wasting behavior wasted (i.e., focus of intervention). A 2-sided p value ≤0.05 was considered statistically significant.

5.3.2 Participants

The socio-demographic profile of the participant treatment and control households is presented in Table 5.1. Treatment households tended to be slightly larger with more children, have higher incomes and a have higher rate of home ownership, than control households; however, these differences were not statistically significant. The number of people and level of incomes in both treatment and control households were slightly higher compared to the city average (Statistics Canada, 2016), which was to be expected as our analysis focused on households in single-family dwellings to the exclusion of households in apartments and other multi-unit dwelling types.

Table 5.1 - Socio-demographic profile of treatment (n=54) and control (n=58) households

Number of people in a household	Treatment	Control	Household Income	Treatment	Control
	%			%	
1	7.5	10.3	<$40,000	17.0	20.7
2	30.2	32.8	$40-60,000	9.4	15.5
3	18.9	20.7	$60-80,000	18.9	15.5
4	20.8	24.1	$80-$100,000	24.5	13.8
5	20.8	6.9	>$100,000	30.2	34.5
6+	1.9	5.2			
Number of children in a household			Housing Tenure		
0	50.0	56.1	Live Rent Free	0.0	5.2
1	16.7	21.1	Pay Rent	13.2	12.1
2	16.7	14.0	Pay Mortgage	66.0	60.3
3	16.7	3.5	Own Home Outright	20.8	20.7
4	0.0	5.3	Other	0.0	1.7
5+	0.0	0.0			

5.4 Results

5.4.1 Food waste set out

The average amount of garbage set out, for the post-intervention sample compared to the pre-intervention sample, decreased by 1.2kg/household/week (-12%) for treatment households and increased by 0.2kg/household/week (+2%) for control households (Table 5.2). Similarly, total mean food waste (i.e., avoidable + unavoidable food waste) decreased by 1,044g/household or 31% for treatment households and increased by 21g/household or 1% for control households. Avoidable food waste decreased by a mean of 634g/household or 30% for treatment households. The amount of all food types decreased by at least 15%. For control households, avoidable food waste increased by a mean of 18 g/household/week or 1%. Only bread & baked goods and fruits & vegetables decreased with some food types, such as meat & fish and dairy, increasing by more than 20%. Fruit & vegetables followed by bread & baked goods were the top two ranked avoidable food waste types disposed for both intervention and control households. The change in total ($p=0.02$), avoidable ($p=0.05$) and unavoidable food waste ($p=0.05$) were significantly greater for treatment households as compared to control households. Further, total food waste

(p=0.01), avoidable food waste (p=0.02) and unavoidable food waste (p=0.01) decreased significantly after the delivery of the intervention for treatment households. The set out of total food waste (p=0.94), avoidable food waste (p=0.93) and unavoidable food waste (p=0.98) from control households did not change significantly after the delivery of the intervention to treatment households.

5.4.2 Overview of food wasting behaviors

It is important to understand not only *if* the intervention, which specifically targeted avoidable food waste, was successful, but also *how* it was successful. As noted, intervention development was informed by the most frequently selected food waste reduction motivator of "reduce amount of money wasted", as selected by overall household food waste survey respondents (Table 5.3). Treatment households also selected this motivator most frequently, although it was not significantly different from "reduce environmental impact". Control household motivator selection essentially mirrored the results of all survey respondents.

Correlations of socio-demographic factors, waste management factors, and psychological constructs with pre- and post-intervention avoidable food waste, by treatment and control households, were also measured to identify potential relationships (Table 5.4). The number of people in a household was significantly and positively correlated with total avoidable food waste for both post-intervention treatment and control households. The number of children in a household was significantly and positively correlated with total avoidable food waste for pre- and post-intervention control households only. Further, as would be expected, the amount of pre-intervention and post-intervention avoidable food waste was significantly and positively correlated with the amount of garbage set out for both treatment and control households. Backyard composter usage was significantly and negatively correlated with the amount of avoidable food waste set out for pre- and post-intervention treatment households and pre-intervention control households.

Psychological constructs, as related to food wasting behaviors, were measured as part of the household food waste survey.

Table 5.2 - Garbage (kg/household/week); and total, avoidable and unavoidable food waste (g/household/week)

	Treatment Households							Control Households						
	Pre Intervention			Post Intervention			% change	Pre Intervention			Post Intervention			% change
	M	SD	Mdn	M	SD	Mdn		M	SD	Mdn	M	SD	Mdn	
Garbage	9.9	7.2	8.3	8.7	5.8	8.2	-12	8.9	6.3	7.1	9.1	5.4	7.6	2
Total Food Waste	3,401	3,223	2,037	2,357	2,120	1,886	-31	2,480	2,056	2,212	2,501	2,248	1,984	1
Total Avoidable														
Bread & Baked Goods	430	608	196	311	371	176	-28	385	515	191	349	435	133	-9
Meat & Fish	151	246	54	124	222	33	-17	170	335	32	226	646	0	33
Dairy	55	142	0	34	99	0	-37	57	162	0	71	141	0	24
Dried Food	316	568	49	244	562	0	-23	166	265	22	196	441	3	18
Fruit & Vegetables	1,129	1,491	566	765	1,014	282	-32	727	841	449	681	1,072	237	-6
Other Food	58	116	0	26	76	0	-56	154	331	0	154	325	0	0
Total	2,138	2,281	1,296	1,504	1,519	985	-30	1,658	1,744	1,130	1,676	1,821	891	1
Unavoidable														
Bread & Baked Goods	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meat & Fish	249	358	120	109	247	33	-56	109	247	57	203	465	30	86
Dairy	0	3	0	0	0	0	-100	0	0	0	0	0	0	0
Dried Food	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fruit & Vegetables	916	1,221	406	605	884	245	-34	605	884	261	519	742	172	-14
Other Food	98	151	31	139	254	23	42	139	254	59	103	170	31	-26
Total	1,263	1,387	875	853	1,026	416	-32	853	1,026	569	825	935	502	-3

Table 5.3 - Ranking of food waste reduction motivators

Motivator	Overall		Treatment		Control	
	n	%	n	%	n	%
Reduce amount of money wasted	723	58.9[a]	27	50.0[a]	33	56.8[a]
Reduce environmental impact (climate change)	294	23.9[b]	19	35.2[ab]	14	24.1[b]
Reduce social impact (e.g., hunger)	211	17.2[c]	8	14.8[c]	10	17.2[c]
Total	1,228	100	54	100	58	100

Values in columns with different superscripts are significantly different ($p<0.001$)

Table 5.4 - Spearman rank correlations between total avoidable food waste and socio-demographic factors, waste management factors and psychological constructs

	Treatment		Control	
	Pre-Intervention	Post Intervention	Pre-Intervention	Post Intervention
Socio-demographic factors				
Housing tenure	-0.218	-0.12	-0.12	-0.228
Number of people in household	0.166	0.452**	0.258	0.291*
Number of children in household	0.105	0.268	0.304*	0.399**
Household income	-0.077	0.067	-0.059	-0.052
Waste management factors				
Garbage set out (weight)	0.767**	0.325*	0.577**	0.368**
Recycling set out (containers)	0.121	0.079	0.11	0.173
Backyard composter usage	-0.334*	-0.387*	-0.362*	-0.245
Psychological constructs				
Intention	-0.277*	-0.269*	-0.219	-0.185
Personal attitudes	-0.153	-0.357**	-0.208	-0.221
Financial attitudes	0.073	0.141	0.038	0.012
Food safety attitudes	0.284*	0.309*	0.126	0.224
Perceived behavior control	-0.237	-0.467**	-0.449**	-0.387**
Subjective norms	-0.251	-0.076	-0.067	-0.147
Personal norms	-0.108	-0.206	-0.317*	-0.275*
Good provider identity	0.367**	0.277*	0.478**	0.22
Household planning habits	0.128	-0.029	-0.136	0.006

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Intention and personal attitudes were negatively and significantly correlated, while food safety attitudes and the good provider identity were positively significantly correlated with post-intervention treatment household avoidable food waste. Perceived behavioral control was negatively and significantly correlated for post-intervention avoidable food waste from treatment households and for both pre- and post-intervention avoidable food waste set out for control households. Personal norms were negatively and significantly correlated with pre- and post-intervention avoidable food waste for control households only. The good provider identity was positively and significantly correlated with pre- and post-intervention treatment household avoidable food waste, and positively and significantly correlated with pre-intervention control household avoidable food waste. There were no significant correlations of household income and financial attitudes with avoidable food waste for both treatment and control households.

Multiple linear regression models were developed for treatment and control pre- and post-intervention avoidable food waste (Table 5.5). Each of the models had a high fit (R^2=0.52-0.59) and showed that garbage set out had a consistent positive and significant impact on the amount of avoidable food waste. For treatment households, personal norms, the good provider identity, and household planning habits had positive and significant impacts, while financial attitudes had a negative and significant impact on the amount of pre-intervention avoidable food waste. However, only the number of people in the household, garbage set out, and personal attitudes had a positive and significant impact on post-intervention avoidable food waste.

The pre- and post-intervention models were similar for control households, with housing tenure (i.e., in particular home ownership) having a significant negative impact and garbage set out a positive and significant impact on avoidable food waste. Perceived behavioral control had a negative and significant impact on avoidable food waste for the pre-intervention sample only.

Table 5.5 - Linear regression analysis on avoidable food waste

Treatment			
Pre-Intervention	B	SE	*β*
Constant	-3,572.30	2,853.64	
Recycling set out	-818.051	418.103	-0.221
Garbage set out	232.822	38.182	0.745***
Financial attitudes	-274.926	89.241	-0.413**
Personal norms	188.435	87.546	0.259*
Good provider identity	185.124	55.054	0.426**
Household planning habits	171.468	71.904	0.278*
Model statistics	R^2= 0.59, F(6,34)=10.573, p<0.001		
Post intervention			
Constant	3,580.27	1,443.01	
Number of people in household	340.297	164.875	0.222*
Garbage set out	121.092	27.175	0.489***
Personal attitudes	-250.772	70.197	-0.381**
Model statistics	R^2= 0.58, F(3,37)=19.036, p<0.001		
Control			
Pre-Intervention			
Constant	5,520.77	1,673.45	
Housing tenure	-679.461	321.721	-0.242*
Garbage set out	168.384	39.294	0.511***
Perceived behavioral control	-124.698	38.962	-0.384**
Model statistics	R^2= 0.52, F (3,34)=14.481, p<0.001		
Post intervention			
Constant	2,046.96	1,225.08	
Housing tenure	-881.196	330.356	-0.312*
Garbage set out	151.559	41.916	0.481**
Recycling set out	477.42	248.775	0.252
Model statistics	R^2= 0.52, F(3,37)=14.081, p<0.001		

As part of the household food waste survey, households were asked why they wasted different food types. For treatment households, buying too much was the most common reason for disposing bread & baked goods, dairy, fruit & vegetables, and other food, while for meat & and fish it was because it was past its best before date (Table 5.6). The mean was calculated across all food types and showed that the most common reasons for throwing out food were buying too much, food spoilage, and food that is past its best before date. The amount of food never thrown out ranged between 16.7% for fruit and vegetables to 62.3% for dried food. The reasons why food was disposed of were similar, but more pronounced, for control households. However, the percentage of these

households reporting that they ‘never throw out’ was less for all food types when compared to treatment households.

Table 5.6 - Reasons why various food types were thrown out

		Reason					
	Treatment n	Bought too much	Spoiled	Past Best Before	Leftover/Made too much	Other	Never throw out
		%					
Bread & Baked Goods	53	52.8	3.8	1.9	7.5	3.8	30.2
Meat & Fish	53	15.1	7.5	30.2	5.7	0.0	41.5
Dairy	52	21.2	21.2	3.8	7.7	0.0	46.2
Fruit & Vegetables	54	64.8	0.0	5.6	3.7	9.3	16.7
Dried Food	53	15.1	3.8	7.5	9.4	1.9	62.3
Other	52	21.2	9.6	15.4	11.5	1.9	40.4
M		31.7	7.7	10.7	7.6	2.8	39.6
SD		21.5	7.4	10.6	2.7	3.5	15.3
	Control n						
Bread & Baked Goods	58	58.6	13.8	0.0	8.6	3.4	15.5
Meat & Fish	57	31.6	7.0	35.1	8.8	1.8	15.8
Dairy	58	39.7	27.6	0.0	12.1	3.4	17.2
Fruit & Vegetables	58	75.9	1.7	0.0	3.4	8.6	10.3
Dried Food	58	12.1	10.3	10.3	12.1	1.7	53.4
Other	58	24.6	10.5	17.5	17.5	3.5	26.3
M		40.4	11.8	10.5	10.4	3.7	23.1
SD		23.3	8.7	14.0	4.7	2.5	15.7

5.5 Discussion

In one of the first studies of its kind, a household food waste reduction intervention, which was theoretically informed by both behavioral economics/nudging and TPB, was successfully tested using an RCT design (i.e., treatment and control). In short, this intervention attempted to nudge irrational money saving behaviors by providing households with locally calculated information on quantities and monetary impacts of their food waste, along with food literacy information, designed to strengthen perceived

behavioral control, by re-rationalizing the behaviors (e.g., shopping, food storage) that can lead to food waste generation. The foregoing allowed us to meet the primary objective of this study. Further, by using a bespoke methodology, household food wasting behavior was directly and successfully measured. This included the collection of pre- and post-intervention curbside garbage samples, and measuring total, avoidable, and unavoidable food waste. This allowed us to meet the secondary objective of this study.

Mean post-intervention total, avoidable, and unavoidable food waste set out in treatment household garbage samples were at least 30% lower than for pre-intervention food waste set out, meaning that our first hypothesis (H1) was confirmed. Further, pre- and post-intervention differences in total ($p=0.02$), avoidable ($p=0.05$), and unavoidable ($p=0.05$) food waste were significantly different between treatment and control households, meaning that our second hypothesis (H2) was also confirmed.

5.5.1 Possible reasons for decreased food waste set out by treatment households

There are several factors that could explain the differences in food waste disposed in the garbage stream between treatment and control household food waste reduction.

5.5.1.1 Quantity of pre-intervention treatment household food waste.

Although randomly selected, treatment households had considerably higher mean food waste set out (3,401 g/week, SD=3,233) in pre-intervention samples as compared to control households (2,480 g/week, SD=2,056). Post-intervention treatment household mean food waste set out (2,357 g/week, SD=2,120) was similar to control households (2,501 g/week, SD=2,248). Treatment households tended to have more people and children than control households. That is, treatment households generated more pre-intervention food waste at least in part due to their size, meaning that they have greater opportunity to respond to a food waste reduction intervention and intimating a possible food waste quantity response threshold. This response is in part borne out by the positive correlation ($r=0.45$, $p=0.01$) between post-intervention treatment household food waste

disposed and number of people in a household, and the emergence of number of people in a household as a positive and significant predictor in post-intervention regression analysis. Further, the response of treatment households to the intervention appeared to be comprehensive rather than coincidental, as all avoidable food waste types decreased by 17-56%, but generally increased or resulted in small decreases for control households. There were similar but less pronounced results for unavoidable food waste. The obverse of the preceding is that quantities of food waste set out by control households were relatively stable.

5.5.1.2 Impact of food waste reduction motivators

Both treatment and control households identified "reducing the amount of money wasted" as the key motivator that would spur them to reduce food waste. Further, both treatment and control households reported that the over-purchase of food was the most consistent reason why food was thrown out, suggesting a recognition that this is a money wasting behavior. In the intervention, this idea was molded to take advantage of people's aversion to monetary loss, (Kahneman & Tversky, 1979), but spun around after (Russell et al., 2017), as the positive message of saving money. However, save for the pre-intervention regression analysis of treatment households, where financial attitudes related to wasting food were significantly and negatively related to food waste set out, monetary matters were not reflected in any correlations and regression analyses between household income or financial attitudes and avoidable food waste set out. This suggests a possible discontinuity between this motivator, and financial attitudes and household income. Importantly, it did not appear to have any real bearing on post-intervention treatment household avoidable food waste set out, although any change in financial attitudes as a result of the intervention was not measured.

Mindful that our intervention was not based on preventing environmental impacts, for treatment households reducing monetary and environmental impacts motivators were not significantly different, this suggests that perhaps pro-environmental behaviors contribute to the amount of food waste set out. Sintov et al. (2017) suggested one pro-environmental behavior such as placing food waste in a composting bin could spill over into other pro-environmental behaviors such as food waste prevention behaviors. While they reported spillover effects to residential energy and water waste prevention because of compost bin

usage, none was noted for food waste prevention. We examined recycling and backyard composting pro-environmental behaviors; however, there were no correlations between recycling set out (i.e., that would have occurred on the same day as collection of food waste samples) and avoidable food waste set out. However, backyard composter usage, as measured during the household food waste survey, was fairly and negatively correlated with avoidable food waste set out. Further, the anti-environmental behavior of higher quantity garbage set out was consistently and fairly to excellently correlated with avoidable food waste in garbage. Indeed, garbage set out, as depicted in regression analyses, was a consistent and arguably the key predictor of avoidable food waste set out for both treatment and control households.

5.5.1.3 Psychological constructs

There was a change, from not significant to significant, in the treatment household TPB psychological constructs of perceived behavioral control and personal attitudes correlations, between the pre- and post-intervention avoidable food waste set out, suggesting possible intervention response triggers. This is tempered somewhat because for control households perceived behavioral control was significantly correlated with both pre- and post-intervention food waste set out, and this also carried through to linear regression analysis for pre-intervention food waste samples. This does speak to the relative importance of perceived behavioral control's relationship (i.e., as compared to intention) and possible role as a predictor of food waste. The change in perceived behavioral control as a result of the intervention was not measured.

There was a considerable change in regression models between pre- and post-intervention treatment households. Personal norms, the good provider identity, and household planning habits were significantly related to more avoidable food wasting, while financial attitudes were significantly related to less food wasting for pre-intervention treatment households.

As expected, the good provider identity was positively correlated to avoidable food wasting in both treatment and control households, suggesting that it may be a useful determinant and possible intervention point. Household planning habits were inconsistently correlated with avoidable food waste set out. Interestingly, personal norms

and household planning habits were positively related to pre-intervention but not post-intervention avoidable food waste in treatment households.

For post-intervention treatment households, personal attitudes emerged as the most consistent determinant of avoidable food waste. Beyond that, food waste set out is predicted by the amount of garbage set out, as in pre-intervention households, and the number of people in the household.

5.5.2 Comparison to other similar studies

Although there are a growing number of survey-based studies that investigated the determinants of food wasting behaviors and measures of self-reported household food wasting (Stancu et al., 2016; Stefan et al., 2013; Visschers et al., 2016), and a few studies that have directly measured actual household food waste (Bernstad et al., 2013; Bernstad et al., 2012; Lebersorger & Schneider, 2011; Parizeau et al., 2015; van der Werf et al., 2018; WRAP, 2013a), few researchers have directly measured food waste before and after a reduction intervention.

Parizeau et al. (2015) reported that the households they surveyed in Guelph, Ontario set out an average of 7.1kg/household/week of garbage and 12.5kg/household/week of organic waste (which consisted largely of food waste). This compares to 8.9-9.9 kg/household/week of pre-intervention garbage for London, Ontario households, of which 2.5-3.4 kg/household/week was total food waste. This food waste range compares favorably to the estimated 2.6 kg/household/week of total food waste generated by southern Ontario households without access to a program to remove source separated food wastes (van der Werf et al., 2018). As expected, this is higher than for households with such a program (i.e., diversion of mostly food waste to large-scale composting or anaerobic digestion facilities), which on average disposed 2.3 kg/household/week of food waste (van der Werf et al., 2018). This speaks well to the methodology developed and deployed to directly collect household food waste data.

WRAP launched the Love Food Hate Waste (LFHW) in 2007 and focusses on providing households with information about their food waste and how to reduce it. They used, among other methods, the direct measurement of household food waste, to extrapolate and develop broad jurisdictional food waste estimates (Quested et al., 2011; WRAP,

2009, 2013a, 2013b). They reported that food waste disposal declined by approximately 1.1 million tonnes, from 8.3 million tonnes to 7.2 million tonnes by 2010, with at least some of that 13% decrease attributable to the LFHW program and some to poor economic conditions (Quested et al., 2013; Quested et al., 2011). Our 31% decrease in food waste set out between pre-intervention and post-intervention treatment household food waste compares favorably but has unknown long-term sustainability.

5.5.3 Future research

While this intervention looks promising, further research is required to understand if the reduction of food waste set out is sustainable in the long-term, and if not, what would be required to sustain this behavior. This would require the collection of additional garbage samples.

Further research is also required to understand if and how treatment household psychological constructs were altered as part of this intervention. For instance, have household financial attitudes about wasting food and perceived behavioral control been strengthened. This could include a follow-up survey. It would also be interesting to repeat and compare this intervention in another community with a program to separately remove source separated food wastes as well as other ones without such program.

5.5.4 Limitations

The key limitation of this study is that it measured only food waste found in the garbage stream. As such, this represents the minimum amount of food waste generated at the household and does not account for food poured down the drain, fed to pets, and put into a backyard composter. There is currently no existing objective methodology (i.e., one that does not involve households self-reporting their behavior) to gather these data.

5.5.5 Conclusions

A household food waste reduction intervention was developed and tested in London, Ontario, Canada and resulted in a decrease of total (31%), avoidable (30%) and unavoidable (32%) food waste. Further, we were able to successfully develop and

implement a bespoke methodology to directly collect food waste samples, as recommended by researchers such as Visschers et al. (2016) to measure the aforementioned impact of this intervention. Key determinants of household food waste reduction efforts appeared to include personal attitudes, perceived behavioral control, the number of people in a household, and the amount of garbage set out. The sustainability and repeatability of this intervention should be investigated further.

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Appendix

Email tips sent to treatment households:

Tip#1 Did you know that on average London households each throw out $600 of food annually? Preparing your meals for the week (or for Thanksgiving) can help you buy the right amount and reduce food waste.

Tip#2 Did you know that based on locally gathered data an estimated $60-$100 million worth of food is thrown out by London households annually? Making a grocery list and sticking to it is an excellent way to manage your household food costs and reduce food waste.

Tip#3 Did you know that on average London households each throw out $600 of food annually? Proper storage of food helps food last longer and reduces the amount of food (and money) that is wasted.

Tip#4 Did you know that an estimated $60-$100 million worth of food is thrown out by London households annually? Learning how to cook just enough can help reduce the amount of leftovers (and waste if you don't like to eat leftovers).

Tip#5 Did you know that on average London households each throw out $600 of food annually? A lot of people like leftovers…some don't. Eating your leftovers makes best use of the food you bought.

Chapter 6

6 Discussion and Conclusions

The intent of this chapter is to summarize the research described in the four manuscripts (i.e., Chapters 2-5), highlight academic contributions, describe policy implications, identify limitations and possible avenues for future research. As laid out in the conceptual framework (Section 1.3), a positivistic approach was used for this research and quantitative methods were used to improve food measurement methods, measure food wasting behavior and then measure the impact of the "Reduce Food Waste, Save Money" food waste reduction intervention. Behavior measurement and intervention development were theoretically informed by the theory of planned behavior (Ajzen, 1991) (TPB) and behavioral economics (Sunstein, 2015; Thaler & Sunstein, 2009b).

6.1 Summary of manuscripts

The three key objectives of this thesis were: (1) to refine existing waste characterization methodologies to develop better estimates of household food waste disposal and composition, as well as its monetary, environmental and social impacts; (2) to conduct a household survey to gain a better understanding of household food wasting behaviors and reduction motivators; and (3) to develop and implement an intervention comprised of presenting households with local food waste quantity and impact data (e.g., monetary, environmental and social) coupled with information to improve their food literacy, and to evaluate its effectiveness for motivating households to reduce their food waste disposal. Overall the objectives set out in Section 1.1.5 were met.

To meet these objectives, the research was presented as a series of interlinked studies, each building upon the other in sequence. The first step was to better understand how to measure food waste. This included preparing a systematic review of the literature (Chapter 2) to discern prevailing approaches to food waste measurement and current food waste estimates along the food supply chain. The remaining research presented in this dissertation focused exclusively on household food waste. This part of the food supply

chain was selected because it represents food production's end point (Chapter 2, Figure 2.1), and, according to available literature examined in the systematic review, where most food waste is generated. It was clear from the review that many of the currently available food waste estimates were developed using indirect mass flow methods, that is, without directly measuring food waste generation (Buzby & Hyman, 2012; Gustavsson et al., 2011). Mass flow, in simplest terms, takes estimates of food produced, by food type, and applies a factor (i.e., percentage of a food type that becomes waste) to estimate waste. This is repeated for all food types and summed to develop an estimate of food waste.

These estimates are tenuous at best; they are not subject to academic rigour and therefore largely end up in self-published grey literature. This includes global (Gustavsson et al., 2011) and Canadian (Gooch & Felfel, 2014) food waste estimates. While these pan-jurisdictional estimates illustrate the possible extent of food wasting, they offer very little in terms of assessing food wasting over time, and in particular, after the implementation of an intervention.

To better understand and assess household food waste, direct measurement of food waste has been recommended (Abdulla et al., 2013; Visschers et al., 2016). The United Kingdom's Waste Reduction Action Programme (WRAP) made attempts to directly measure household food waste and the impact of the 'Love Food Hate Waste' food waste reduction intervention (WRAP, 2009, 2013a). More recently, there have been attempts to add more consistency and rigour to food waste measurement, across the food supply chain, embodied in the development of a food loss and waste measurement protocol (FLW Protocol, 2016).

This research attempts to improve the quality of household food waste quantity and composition estimation by incorporating additional rigour and detail in its direct measurement. Part of the struggle with direct food waste measurement, and why it is uncommon, is that it is challenging. For household estimates, this requires a systematic process to directly collect food waste samples. Waste characterization analysis, which estimates waste quantity and composition, is used in some jurisdictions to better understand the household waste stream. This involves the collection of waste samples, manual sorting into various categories, and weighing of the various waste types. This approach is logistically challenging, as well as time and resource intensive. In Ontario

and other parts of Canada, a standardized method of waste quantity and composition estimation is employed, using a methodology developed by Stewardship Ontario and Waste Diversion Ontario (Stewardship Ontario, 2014; Waste Diversion Ontario, 2015). This methodology, which is broadly used to assess all waste types (e.g., glass, plastic, metal, paper, organic waste etc.), was assessed as a possible starting point for developing the bespoke food waste measurement methodology, and is summarized in Chapter 3. This chapter concludes that it does appear that this methodology is valid and reliable, usable by different research teams, and able to be scoped (i.e., narrowed to focus on food waste only). It was therefore used as the basis of the bespoke food waste measurement methodology, which was successfully deployed to measure the impact of the "Reduce Food Waste, Save Money" food waste reduction intervention (Chapter 5).

To reduce the amount of food that becomes waste, it is imperative to understand the human behaviors that result in this outcome. There is a small but growing body of research that has employed Ajzen (1991's) TPB as its theoretical model (Stancu et al., 2016; Stefan et al., 2013; Visschers et al., 2016). To date, all of this research has taken place in Europe. The household food waste survey research undertaken by (Visschers et al., 2016) in Switzerland was successfully replicated in London, Ontario (reported in Chapter 4). While there were some differences between the two studies (e.g., self-reported food waste disposal being marginally higher in London, Ontario than in Switzerland), the findings were similar overall (i.e., with respect to psychological constructs), suggesting behavioral similarities between the two study areas. Overall, this approach appeared to work well and could serve as a template for further North American research.

Broadly speaking, previous research (Stancu et al., 2016; Visschers et al., 2016) has reported that intention was not equivocally related to self-reported food wasting behavior, and that perceived behavioral control and non-TPB constructs (e.g., good provider identity, household planning habits) were possibly better determinants of this behavior. The London, Ontario research results were similar in that regard. Linear regression analysis showed that perceived behavioral control and personal attitudes resulted in less self-reported food wasting, while more children in a household resulted in more food wasting.

The household food waste survey also asked respondents about whether reducing monetary, environmental or social impacts would motivate them to reduce their food waste. Households overwhelmingly and significantly ($p<0.001$) selected reducing the amount of money wasted as a key motivator, meaning that hypothesis H2 (Section 1.1.5) was satisfied. This may speak more to the immediacy and actionability of wallet issues, rather than some disdain for the broader and more nebulous ideas of reducing environmental and social impacts. Finally, households were asked why they threw out various food types (e.g., bread & baked goods, fruits & vegetables), and overall, the most common reason was 'bought too much'. This complements the most commonly selected food waste reduction motivator. The foregoing speaks to the usefulness of incorporating a monetary aspect in a food waste reduction intervention.

In terms of converting household food waste survey results to intervention development, these results suggested that little effort should go into improving people's intentions with regard to food wasting. It was argued in Chapter 4 that people do not intend to throw out the food they have purchased, and therefore answer strongly and affirmatively that this will not be the case. However, it is clearly the case that food is thrown out. Perceived behavioral control then becomes a proxy for household intention, as it is a survey respondent's response to the degree of control they have (over their household) to prevent food from becoming waste. This household behavioral efficacy can potentially be improved by enhancing their food literacy, that is providing a household information that helps them better purchase, store, cook and consume their food.

Thus, the "Reduce Food Waste, Save Money" food waste reduction intervention was designed to nudge innate money saving behaviors and strengthen perceived behavioral control through improved food literacy. This is fully described in Chapter 5. Treatment households were presented with a food waste reduction kit that included a container, designed to extend produce life, food literacy information (e.g., fridge magnet, post card), as well as some food management tools (e.g., grocery list planner, freezer stickers). The treatment package also included a purpose built website address (www.foodwaste.ca), which included access to more detailed food literacy information on food management and how to reduce food waste. This address was included on the post card and fridge magnet. The food waste reduction messages were kept relatively simple so that

households would take the time to review the information and hopefully go the www.foodwaste.ca website to gather more details. To reinforce key food literacy messages, treatment households were sent five emails, during the two weeks following receipt of the intervention package. These simple 2-3 line emails also directed households to the www.foodwaste.ca web site.

The intervention was tested in a randomized control trial (RCT) with treatment and control households. To measure the impact of this intervention, pre- and post-intervention curbside garbage samples were collected on a household's garbage collection day and sorted/weighed. A bespoke food waste measurement methodology was developed by adapting and scoping the broad household waste characterization methodology, developed by Stewardship Ontario (2014) and Waste Diversion Ontario (2015) (described in Chapter 3). It included dividing food waste into avoidable and unavoidable categories, as well as six food type sub-categories (e.g., bread and baked goods).

Treatment households decreased food waste disposal by 30% between pre- and post-intervention curbside garbage samples, and this difference was significantly greater ($p=0.02$) than for control households where food waste increased by one per cent. This was similar for both avoidable (31%, $p=0.05$) and unavoidable food waste (32%, $p=0.05$), meaning that hypothesis H1 (Section 1.1.5) was satisfied. Further, in treatment households, but not control households, food waste decreased for all six food types after intervention delivery. This suggests that the "Reduce Food Waste, Save Money" intervention had, at the very least, short-term impacts on the amount of food thrown out by treatment households.

6.2 Contributions to Knowledge

In summary, the key contributions of this research include a better understanding of the amount of food waste disposed in developed countries and the limitations of these estimates; the development of a bespoke methodology to directly measure food waste; a survey template, adapted from Visschers et al. (2016), that can be used to measure food wasting behavioral determinants; and an intervention tool that resulted in household food waste reduction.

A key personal motivator to undertake this research were the very poor-quality estimates of food waste being used to characterize these issues. These estimates, (described in Chapter 2), in some cases mischaracterize and, in many cases, likely overestimate food wasting behavior because an indirect measurement approach is being used. In Canada, the number that gets flaunted in the media is $31 billion (Mancini & Vellani, 2016) and $1,560/household/year (Vhyhnak, 2018). Both emanate from the self-published and the unverified calculations of Gooch and Felfel (2014). The background data used to calculate this estimate are dubious at best and inaccurate at worst. However, this number keeps getting published and presented as truth. While these estimates provide a public service, in as much as they highlight the food wasting issue, they do nothing to inform food wasting interventions and nothing to help verify the impact, good or bad, of food waste reduction interventions.

An important contribution of this dissertation research was highlighting, in summarized fashion, current food waste estimates in developed countries, and pointing out the fallibility of the indirect sample collection estimates that seem to inform media reporting. This was used as a springboard to identify and develop a method to directly collect household food waste samples. This method, which uses an existing and widely used waste characterization methodology as its basis, scoped it to include and focus on food waste detail. A key difference of this methodology is that it is set up to examine food waste on a household-by-household basis. The method is relatively straightforward and should be readily usable by other researchers.

The penultimate contribution of this research is the adaption of a European survey method to measure household food wasting behavior in a North American context. The contributions are two-fold. Firstly, research by Visschers et al. (2016) was adapted and effectively used as a template. This same approach, and survey questions, can be used in other North American jurisdictions, and it may be useful to do so to measure jurisdictional differences.

The more important contributions are a better understanding of food wasting behaviors and food waste reduction motivators, at least in London, Ontario Canada. It appears to be perceived behavioral control, not intention, that is the greatest determinant of food wasting behavior, within the context of the TPB model. It seems very clear from survey

responses, from both Visschers et al. (2016) and this research, that people do not intend to throw out food. However, it appears that people do struggle with how to convert their intention into household behavior and how to strengthen their perceived behavioral control. This can, in part, be rectified by developing interventions that work to strengthen the level of control that people/households have over this behavior, rather than changing people's intentions. From an intervention development perspective, this could include providing people with the informational or food literacy tools to effect the behavior they already want to perform.

On issues that transcend food waste, people appear to be motivated to saving or not wasting money. An important contribution of this research is confirming that this motivator is significantly greater than reducing environmental and social impacts of food wasting. This means developing interventions that nudge behavior to not waste money rather than appeal to people's environmental and social proclivities. This can be introduced as collateral benefits for effecting food waste reducing behaviors.

The final and most important contribution is that the "Reduce Food Waste, Save Money" food waste reduction intervention worked and helped treatment households reduce the amount of food that becomes waste. A combination of reminding people about the annual value of food waste thrown out and using this as a behavioral nudge, along with information to improve their food literacy, appeared to stimulate food waste reduction behaviors for avoidable and unavoidable food waste. Further, for avoidable food waste, which was the focus of the intervention, there was an at least 15% reduction (and as high as 56%) for the six food types. The methodology deployed to collect pre- and post-intervention garbage samples and then sorting/weighing out food waste worked well and can serve as a template for other similar research.

6.3 Implications for Policy

The study of why food becomes waste is growing in both societal and academic spheres. Much of this interest has been at the end of the food supply chain, and in particular, households (i.e., consumption of food) and food retailers (i.e., purchase of food by consumers). There is pressure on both of these sectors to develop policies to reduce the amount of food that becomes waste.

Furthermore, the measurement of food waste and food wasting behaviors, and development and testing of an intervention described in this dissertation, can be used to assist this policy development in real time, particularly for households, but also for food retailers. There is also an opportunity here for academia to contribute to civil society by helping to inform the development of effective food waste reduction policies. To date, food waste reduction initiatives and interventions do not include methodological rigour, and for food waste quantification in particular, rely almost exclusively on largely unsubstantiated information published in the grey literature. The research in this dissertation suggests that the veracity and applicability of these existing data are an issue.

At the household level, where most of this dissertation is situated, food wasting is a practical issue that is dealt with by municipalities. To date, most policy instruments have been focussed on its *post facto* management, first as part of the garbage stream, then via self-management in back yard composters (although this is only practical for single-family households) and more recently through the separate collection of food and other organic wastes (e.g., paper towels) (although this has proven only practical for single-family households). The latter two policy solutions are part of the third R (i.e., recycle) of the 3R's hierarchy (i.e., reduce, re-use and recycle). There has been very little policy consideration given to the first 2R's. This research can contribute directly to food waste reduction policy, and to a lesser extent, food re-use (i.e., with re-use defined here as an alternate usage than originally intended) in national, provincial, and municipal contexts.

There is not yet a formal legislated food waste reduction policy in Canada, although there are a number of organizations working to undertake research and develop documents that could become part of a future national policy. The research in this dissertation is being used (i.e., through the author's invited attendance at workshops) to help inform, particularly as it relates to food waste quantification, ongoing development of informal (i.e., no legislative standing) national policies, such as the National Zero Waste Council's food loss and waste strategy for Canada (National Zero Waste Council, 2018), and tri-partite (i.e., Canada, USA, Mexico) research into characterization and management of food loss and waste in North America (CEC, 2018).

Since 2016, the province of Ontario of has released policy documents that include consideration of food wastes. While the objectives of Bill 151, the Waste Free Ontario

Act, 2016 (Province of Ontario, 2016) revolve around traditional materials, such as the blue box, it is accompanied by the Strategy for a Waste Free Ontario: Building the Circular Economy (Strategy) (Province of Ontario, 2017), in which the management of food and organic waste is considered. The Strategy shows a clear objective to divert greater volumes of food waste and organics as a whole, in large part because of their role in greenhouse gas emissions in landfills. Further, the Proposed Food and Organic Waste Framework (Framework) (Ontario Ministry of the Environment and Climate Change, 2017), released in November 2017, strives to reduce food and organic waste, recover resources from food and organic waste (e.g., biogas), support resource recovery infrastructure, and promote beneficial use of recovered resources. The Framework is supported by the Food and Organic Waste Action Plan (Action Plan) and Food and Organic Waste Policy Statement (Policy Statement). The Action Plan contains a number of provincial objectives regarding waste reduction, including a future ban of food and organic waste from landfills. The author contributed to the latter two documents, on behalf of the province by, among other things using the results of various waste characterization studies to estimate province-wide quantities of food waste generation and the estimated costs of implementing a food to landfill ban. The most important finding of this policy work, related to this dissertation, is that at least 50% of food waste in the garbage stream is avoidable and the cost to manage food wastes would result in at least $1.5 billion in new capital costs (i.e., for collection and processing infrastructure), operating costs, not to mention the value of the wasted food. The question then becomes how we minimize the amount of avoidable food waste entering the disposal system to avoid a portion of the foregoing costs. It seems prudent, from a policy perspective, to include some focus, efforts and resources on keeping avoidable food out of the waste stream.

In southern Ontario, single-family households in most large cities (i.e., greater than 100,000 people) already have a green bin program. A notable exception is the City of London. They are in planning stages of a landfill expansion. As part of the provincial approval process, they have also re-rationalized their various waste diversion program. To that end, they have committed to increasing the City's waste diversion rate to 60% (it is currently 45%). Given the programs already in place, the only way to meet this goal is

to implement a green bin program. While no definitive program date has been announced, it seems likely that a program will be implemented within the next five years.

The research in this dissertation will help the City of London shape a future green bin program and, to some degree, scope it to minimize the amount of food that is disposed. The City of London (particularly the Director of Environmental Programs & Solid Waste, within the Division of Engineering & Environmental Services) was an integral part of this research, and we worked together, in real time, to develop data to support their ongoing policy development. For instance, as described in Chapter 5, the amount of avoidable food waste in pre-intervention garbage samples was >50%. Further, it was estimated that food waste in the City averaged $600/household/year and represented $75-$100 million/year in lost value. On this basis, it is completely undesirable to attract avoidable food waste in a green bin and, indeed, the foregoing can be used to create a compelling value proposition to residents to have them reduce the amount of food that becomes waste. This was a large part of the basis of the “Reduce Food Waste, Save Money” intervention. This intervention can be further tested, refined and applied on a larger basis.

Finally, the research in this dissertation has some policy applicability for food retailers. If not symbiotic, then they at least have an integral relationship with households, as they purchase food. The knowledge governing household food wasting behavior can be transferred to food retailers to help them better sell to their customers, so that they more fully eat what they buy. Household consumers identified ‘reduce the amount of money wasted’ as the key food waste reduction motivator, and ‘bought too much’ as the key reason why food is wasted. While perhaps counter-intuitive, food retailers have an opportunity to help households better match their food consumption with food purchase by making adjustment to how they sell food and reminding their clients about how to better match consumption with purchase.

Food retailers essentially have a similar problem as households: in this case, it is matching food on hand for sale with what is actually sold. Much of this is due to food retailer food sale policies that focus sale on maximum freshness and quality. This does result in a considerable amount of food that is no longer desirable to sell and that can become waste. The food waste measurement methods developed for the research in this

dissertation can be adapted for food retailers, so that they better measure the types and quantities of food that are being wasted.

6.4 Limitations

The key limitation of this research is that food waste measurement was confined to what was set out in the curbside garbage stream. This means that it captures, for the most part, only solid or semi-solid food wastes. Liquid food wastes are typically poured down a drain. They would be managed with sewage at a waste water treatment plant. Secondly, this measurement method does not capture any self-management of food waste, including feeding to pets or putting it into a backyard composter. The only practical way to measure these food wastes would be through self-reporting. The food waste found in curbside garbage samples then represents a minimum estimate for household food waste generation. Arguably, it captures the most important part of this waste stream because this is the food waste that currently ends up in landfill and, in the future, it may be directed to a green bin waste diversion programs.

A second limitation is that the long-term sustainability of the intervention was not tested. This could include the collection of additional curbside garbage samples over time to measure whether the noted decrease in food waste remained, or if food waste disposal increased back to previous levels. Further, we did not re-survey treatment and control households to assess what part of the intervention helped treatment households reduce the amount of food that becomes waste.

6.5 Future Research

There are three main threads of future research: (1) Measuring the sustainability of the "Reduce Food Waste, Save Money" intervention; (2) Testing this intervention over more households and in different seasons; and (3) Testing the household food waste survey tool and "Reduce Food Waste, Save Money" intervention in other geographical regions.

In this research, the impact of the "Reduce Food Waste, Save Money" intervention was tested once by collecting a curbside garbage sample. The collection of additional curbside garbage samples would help determine if the measured food waste reduction in treatment

households is sustainable, or if it returns to previous levels. It would also be useful to re-survey treatment and control households to measure any changes to attitudes, intentions etc., and to find out what component(s) of the intervention helped them reduce the amount of food that becomes waste. A scoped version (i.e., without questions on the intervention package) of the survey could also be delivered to all volunteer households (i.e., agreed to allow additional research), recruited as part of the household food waste survey. (Note: This was completed as part of an undergraduate thesis in January 2018 but is not part of this dissertation). To date, all research has been quantitative, and it would be useful to undertake some qualitative research. For instance, one-on-one interviews could be undertaken with treatment and control households to measure any changes in their food wasting attitudes, intentions etc. (i.e., after intervention delivery) as well as their perceived barriers to achieving food waste reducing behavior. The level of detail of these interviews could be increased by adopting the ethnographic approach used by Evans (2011) and Evans (2012) to measure food wasting behaviors and its pre-cursors.

The "Reduce Food Waste, Save Money" intervention was tested over a relatively small number of City of London treatment households (i.e., n=66 delivered and n=54 set out curbside garbage samples); however, it did meet sample size calculation requirements. This intervention could be refined, based on the results of follow-up research with treatment households, and tested over a much greater number of households in a municipality. For instance, it could be tested over a series of contiguous households (e.g., n=300) in three-to-six neighbourhoods in the City of London, stratified by socio-economic status (i.e., high-, middle-, and low-income). This would provide further evidence of this intervention's efficacy, and the impact of neighbourhood socio-demographic determinants on this efficacy. Additionally, the intervention could be undertaken during different seasons within the same municipality, to determine if the efficacy of the intervention is affected by seasonal variations in food availability, backyard gardening, composter usage, and other household practices (e.g., holidays).

Finally, the household food waste survey (adapted from Visschers et al. (2016) and the "Reduce Food Waste, Save Money" intervention were both designed as templates that could be replicated in other regions in North America, including those with different political structures (e.g., municipal jurisdictions with different laws and procedures

around waste). It may also be possible to extend the research further, beyond North America and Europe, to explore adapting the survey and intervention templates in studies of regions with different socio-cultural practices and realities related to food (e.g., cultural norms, scarcity). It would be useful to test it in other jurisdictions to determine if: (1) self-reported food wasting; (2) TPB and non-TPB behavioral determinants; and (3) food waste reduction motivators are similar and, if not, how they differ. The intervention could then be fully tested to determine the extent to which it is generalizable to different settings. If the key food waste reduction motivator is different (i.e., not reducing money wasted), then the intervention could be adjusted accordingly. In Ontario, key jurisdictions in which to conduct further research include other municipalities without a green bin program (e.g., City of Windsor) and those with a green bin program.

6.6 Conclusions

It is clear that societal and academic interest in the amount of food that becomes waste is galvanizing into action. For these actions (manifest as policies and interventions) to be successful, it is important to have a well-developed and defensible quantitative backbone of food waste quantity and human behavioral data. This can be used to facilitate the establishment of accurate baselines and to measure progress as a result of policy and intervention implementation. Without this backbone, progress is only measured on an anecdotal basis, and thus there is no real understanding of whether the amount of food waste has been reduced.

At its core, the research in this dissertation presents the trifecta of (1) better food waste measurement; (2) a template to better understand household food wasting behavior; and (3) an intervention that has been shown to reduce household food wasting behavior. It is clear that food waste measurement is relatively undeveloped. A method to measure household food waste measurement was developed and this can readily be adapted to other parts of the food supply chain. The household food waste survey, largely adapted from Visschers et al. (2016), was successfully used in London, Ontario, and it can be used as a template to measure food wasting behavioral determinants. Finally, the “Reduce Food Waste, Save Money” intervention was successfully tested in London, Ontario and can be used as a template in other jurisdictions. This research contributes to larger efforts aimed at preventing edible food from becoming waste. Ultimately, it is hoped that the

research presented in this dissertation will inspire additional rigorous academic studies, a rethinking of municipal policy and practices, and a broader recognition that *food is food*.

6.7 References

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Appendix 1- Ethics Approval

Western Research

Western University Non-Medical Research Ethics Board
NMREB Delegated Initial Approval Notice

Principal Investigator: Dr. Jason Gilliland
Department & Institution: Social Science\Geography,Western University

NMREB File Number: 108899
Study Title: Determining current household food wasting intentions and its impact on self-reported household food wasting behaviour.

NMREB Initial Approval Date: March 27, 2017
NMREB Expiry Date: March 27, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Western University Protocol	Received February 10, 2017.	
Letter of Information & Consent		2017/01/03
Instruments	Revised Survey	2017/02/10

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the above named study, as of the NMREB Initial Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

[redacted]
Ethics Officer, on behalf of Dr. Riley Hinson, NMREB Chair or delegated board member

EO: Erika Basile ___ Nicole Kaniki ___ Grace Kelly ___ Katelyn Harris___ Nicola Morphet ___ Karen Gopaul ___

Appendix 2- Household Food Waste Survey

Socio Demographics

Household Food Waste Survey

Western University researchers, in association with the City of London (Environmental and Engineering Services), are working to develop a better understanding of household food waste generation. In particular, we are interested in understanding how often and how much food you throw out, and your intentions related to throwing out food. The research results will ultimately be used to help develop programs and policies to help reduce and manage food waste. We are looking for adults, 18 years and older, to complete this survey.

THROUGHOUT THIS SURVEY when we talk about FOOD we mean the EDIBLE portion of food. This includes both uncooked and cooked foods. For example, this could include anything from part of a banana, a slice of bread, plate scrapings or yoghurt. It also includes any untouched foods such as a whole apple, a whole egg or a whole chicken (even though parts of it are inedible). PLEASE NOTE, this DOES NOT include the INEDIBLE parts of food such as peelings, bones, egg shells, coffee grounds, etc.).

All of the survey responses will be combined for analysis and no one will be personally identified or identifiable by name in any of the results or documents related to this survey. All of the information collected in this survey is kept strictly confidential. Your name will not appear on any materials or be linked to any data files.

The Survey should take you only 15-20 minutes to complete. While we would appreciate if you answered all questions as honestly and completely as possible, you are able to skip any questions you don't want to answer.

At the end of the survey you will have the opportunity to be entered for a draw for one of ten $25 gift certificates from the Western Fair Farmer's Market.

Should you have any questions please don't hesitate to contact us at foodwastestudy@uwo.ca

City of London Disclaimer: All information collected will be kept completely confidential and protected under the Municipal Freedom of Information and Protection of Privacy Act, and will only be used anonymously to develop programs and policies to help reduce and manage food waste. Names and addresses will be destroyed at the end of the study, and all other personal information will be anonymized. The personal information will not become part of the public

record. Questions about this collection of personal information should be addressed to Jay Stanford, Director, Environment, Fleet & Solid Waste, City of London, 300 Dufferin Avenue, London, Ontario, N6A 4L9 or by email at jstanfor@london or by telephone at 519-661-2500, ext. 5411.

Please tell us a little about yourself...

What is your gender?

Female ○ Male ○ ☐ ○

What is your age?

18-24 ○ 25-34 ○ 35-44 ○ 45-54 ○ 55-64 ○ 65+ ○

What is your postal code (e.g., A1A 1A1)?

☐

In what type of housing do you live?

Apartment ○ Detached/Semi Detached House ○ Townhouse ○ Other ○

What is your housing status

Live with family or friends rent free ○ Pay rent ○ Pay mortgage ○ Own home outright ○ Other- please specify ☐ ○

How many people live in your household?

1	2	3	4	5	6+
○	○	○	○	○	○

How many children under 18 live in your household?

0	1	2	3	4	5+
○	○	○	○	○	○

Please select one category that best describes your employment status?

Unemployed	Student	Stay at home parent	Work part time	Work full time	Retired
○	○	○	○	○	○

What is your before tax annual household income?

under $40,000	$40,001-$60,000	$60,001-$80,000	$80,001-100,000	$100,001 or greater
○	○	○	○	○

Filter Questions

Please tell us a little about your food purchase and preparation responsibilities as well as your waste management responsibilities:

To what extent are you responsible for the food shopping in your household?

Never	Seldom	About 50/50	Often	Always
○	○	○	○	○

To what extent are you responsible for the cooking and preparation of food in your household?

Never	Seldom	About 50/50	Often	Always
○	○	○	○	○

To what extent are you responsible for taking out the waste and recycling and placing it at the

curb in your household?

Never	Seldom	About 50/50	Often	Always
○	○	○	○	○

Is a portion of your household's food waste currently disposed of using a garburator?

Yes	No
○	○

In the last 7 days how many times has your household put food waste in your back yard composter?

0	1	2	3+	Not applicable. We do not have a backyard composter
○	○	○	○	○

TPB Behaviour FREQUENCY

The following questions ask HOW OFTEN your household throws out food.

NOTE: When we talk about FOOD we mean the EDIBLE portion of food. This includes both uncooked and cooked foods. For example, this could include anything from part of a banana, a slice of bread, plate scrapings or yoghurt. It also includes any untouched foods such as a whole apple, a whole egg or a whole chicken (even though parts of it are inedible). PLEASE NOTE, this DOES NOT include the INEDIBLE parts of food such as peelings, bones, egg shells, coffee grounds etc.

Please answer the following question, per food type. In the last SEVEN DAYS my household has thrown out the following foods approximately this many times:

Bread and Baked Goods

0 times	1	2	3	4	5	6	7+ times
○	○	○	○	○	○	○	○

Meat and Fish

0 times	1	2	3	4	5	6	7+ times
○	○	○	○	○	○	○	○

Dairy (e.g. milk, cheese and yoghurt)

0 times	1	2	3	4	5	6	7+ times
○	○	○	○	○	○	○	○

Fruit and Vegetables

0 times	1	2	3	4	5	6	7+ times
○	○	○	○	○	○	○	○

Dried Food (e.g. cereal)

0 times	1	2	3	4	5	6	7+ times
○	○	○	○	○	○	○	○

Other Food

0 times	1	2	3	4	5	6	7+ times
○	○	○	○	○	○	○	○

TPB Behaviour PORTIONS THROWN OUT

You just finished answering some questions about HOW OFTEN does your household throw out food now we would like to ask you about HOW MUCH you throw out.

NOTE: When we talk about FOOD we mean the EDIBLE portion of food. This includes both uncooked and cooked foods. For example, this could include anything from part of a banana, a slice of bread, plate scrapings or yoghurt. It also includes any untouched foods such as a whole apple, a whole egg or a whole chicken (even though parts of it are inedible). PLEASE NOTE, this DOES NOT include the INEDIBLE parts of food such as peelings, bones, egg shells, coffee grounds etc.

NOTE: Think of a PORTION of food as being approximately one handful.

Please answer the following question, per food type. In the last SEVEN DAYS my

household has thrown out approximately this many PORTIONS of the following foods:

Baked Goods (e.g. bread and baked goods).

0 portions	1	2	3	4	5	6	7+ portions
○	○	○	○	○	○	○	○

Meat and Fish

0 portions	1	2	3	4	5	6	7+ portions
○	○	○	○	○	○	○	○

Dairy (e.g. milk, cheese and yoghurt)

0 portions	1	2	3	4	5	6	7+ portions
○	○	○	○	○	○	○	○

Fruit and Vegetables

0 portions	1	2	3	4	5	6	7+ portions
○	○	○	○	○	○	○	○

Dried Food (e.g. cereal)

0 portions	1	2	3	4	5	6	7+ portions
○	○	○	○	○	○	○	○

Other Food

0 portions	1	2	3	4	5	6	7+ portions
○	○	○	○	○	○	○	○

TPB Behaviour WHY IS FOOD THROWN OUT

You just finished answering some questions about how often and how much food is thrown out,

now we would like to ask you about the REASONS your household throws out food.

NOTE: When we talk about FOOD we mean the EDIBLE portion of food. This includes both uncooked and cooked foods. For example, this could include anything from part of a banana, a slice of bread, plate scrapings or yoghurt. It also includes any untouched foods such as a whole apple, a whole egg or a whole chicken (even though parts of it are inedible). PLEASE NOTE, this DOES NOT include the INEDIBLE parts of food such as peelings, bones, egg shells, coffee grounds etc.

Please answer the following question, per food type. The most common reason my household throws out this food is for the following reason:

	Purchased too much	Spoiled (e.g. moldy, smells off)	Past "Before Date"	Leftovers/Made too much	Other (any other reason)	Never throw out
Bread and Baked Goods	○	○	○	○	○	○
Meat and Fish	○	○	○	○	○	○
Dairy (e.g. milk, cheese, yoghurt	○	○	○	○	○	○
Fruit and Vegetables	○	○	○	○	○	○
Dried Food (e.g. cereal)	○	○	○	○	○	○
Other food	○	○	○	○	○	○

Rank the following three reasons in terms of what would motivate your household to reduce the amount of food that is wasted, in order of preference from 1 (most motivating) and 3 (least motivating).

	1	2	3
Reduce amount of money wasted	○	○	○
Reduce social impact of wasting food (e.g hunger)	○	○	○
Reduce environmental impact of wasting food (e.g. climate change)	○	○	○

TPB Intentions

The remaining questions ask you about your intentions related to wasting food. There are no right or wrong answers.

Please answer the following questions thinking about the near future (e.g. next one/two weeks) and your household. (Unless otherwise noted: 1=strongly disagree to 7=strongly

agree).

I try to waste no food at all.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I always try to eat all purchased foods.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I try to produce only very little food waste.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I aim to use all leftovers.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

TPB Attitudes

Please answer the following questions thinking about the near future (e.g. next one/two weeks) and your household. (unless otherwise noted: 1 strongly disagree to 7 strongly agree).

It is unnecessary to waste food: it can always be used in some way.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

It is immoral to discard foods while other people in the world are starving.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

It upsets me when unused products end up in the waste bin or garburator.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I think that wasting food is a waste of money.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I cannot afford to pay for foods that are then discarded.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

Saving money does not motivate me to discard less food.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I rarely think about money when I throw away food.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

Throwing out food does not have an environmental impact.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I rarely think about the environment when I throw away food.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I believe that the risk of becoming ill as a result of eating food past its "best before" date is high.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I am not worried that eating leftovers results in health damage.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I think that consuming leftovers is harmless.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I think that one can very safely eat food products whose "best before" dates expired a few days

ago.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

TPB Perceived Behavioural Control

Please answer the following questions thinking about the near future (e.g. next one/two weeks) and your household. (Unless otherwise noted: 1=strongly disagree to 7=strongly agree).

I find it difficult to prepare a new meal from leftovers.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I find it difficult to make sure that only small amounts of food are discarded in my household.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I find it difficult to plan my food shopping in such a way that all the food I purchase is eaten.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I have the feeling that I cannot do anything about the food wasted in my household.

1 Strongly						7 Strongly

disagree	2	3	4	5	6	agree
○	○	○	○	○	○	○

Other household members make it impossible for me to reduce the amount of food wasted in my household.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

TPB Subjective Norms

Please answer the following questions thinking about the near future (e.g. next one/two weeks) and your household. (Unless otherwise noted: 1=strongly disagree to 7=strongly agree).

People who are important to me find my attempts to reduce the amount of food wasted unnecessary.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

People who are important to me disagree when I try to reduce my food waste.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

TPB Personal Norms

Please answer the following questions thinking about the near future (e.g. next one/two weeks) and your household.(Unless otherwise noted: 1=strongly disagree to 7=strongly agree).

I feel bad when I throw food away.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I feel obliged not to waste any food.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

It is contrary to my principles when I have to discard food.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I have been raised to believe that food should not be wasted and I still live according to this principle.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

Good Provider Identity

Please answer the following questions thinking about the near future (e.g. next one/two weeks) and your household. (Unless otherwise noted: 1=strongly disagree to 7=strongly agree).

It would be embarrassing to me if my guests ate all the food I had prepared for them. They would probably have liked to eat more.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I regularly buy many fresh products although I know that not all of them will be eaten.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I like to provide a large variety of foods at shared mealtimes so that everyone can have something he or she likes.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I always have fresh products available to be prepared for unexpected guests or events (e.g. illness).

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

When I am expecting guests, I like to buy more food than is necessary because I am a generous host.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

Household Planning Habits

Please answer the following questions thinking about the near future (e.g. next one/two weeks) and your household. (Unless otherwise noted: 1=strongly disagree to 7=strongly agree).

When I have made a shopping list, I always keep strictly to it.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I am a person who likes to plan things.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

Before I prepare food, I always consider precisely how much I need to prepare and what I will do with the left overs.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

I always plan the meals in my household ahead and I keep to this plan.

1 Strongly disagree	2	3	4	5	6	7 Strongly agree
○	○	○	○	○	○	○

Looking for volunteers and draw

The research team from Western University, in conjunction with the City of London (Environmental & Engineering Services) , is looking for volunteers who would be willing to let us examine their garbage bin at curbside to measure the amount of food waste that is thrown out. This would involve visiting you, in person, to administer a second short survey and collecting waste samples from the garbage bins you put out for City pickup on your waste collection day. All data collected would be made anonymous, grouped together and presented in a summarized fashion so that it would not be possible to identify information from individual households.

If you are willing to help out with this research project PLEASE INCLUDE YOUR NAME, STREET ADDRESS AND/OR EMAIL ADDRESS PHONE NUMBER and we will contact you.

Name	
Street Address	
Email Address	
Telephone Number	

To finish the survey and have the opportunity to be entered for a draw for one of ten $25 gift certificates from the Western Fair Farmer's Market please proceed to the next page.

Survey Powered By

Appendix 3- Curriculum vitae

Curriculum vitae

Name: Paul van der Werf

Post-secondary Education and Degrees:
University of Guelph, Guelph, Ontario Canada
1983-1988 B.Sc. (Agr), (with honours)
1990-1992 M.Sc.

Western University
London, Ontario, Canada
2015-2018, Ph.D.,

Honours and Awards:
Western Graduate Research Scholarship – 2015-2018
Pass with Distinction, PhD Comprehensive Examination – 2017

Related Work Experience:

Guest lecturer, Western University – 2017-2018

van der Werf, P., Seabrook, J. A., & Gilliland, J. A. (2018). The quantity of food waste in the garbage stream of southern Ontario, Canada households. *PloS one, 13*(6), e0198470.

van der Werf, P., & Gilliland, J. A. (2017). A systematic review of food losses and food waste generation in developed countries. *Proceedings of the Institution of Civil Engineers-Waste and Resource Management*(May), 1-12.