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Review: Consumption-stage food waste reduction interventions – what works and how to design better interventions.

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Review: Consumption-stage food waste reduction interventions – what works and how to do better.

Abstract

Food waste prevention has become an issue of international concern, with Sustainable Development Goal 12.3 aiming to halve per capita global food waste at the retail and consumer levels by 2030. However there is no review that has considered the effectiveness of interventions aimed at preventing food waste in the consumption stages of the food system. This significant gap, if filled, could help support those working to reduce food waste in the developed world, providing knowledge of what interventions are specifically effective at preventing food waste.

This paper fills this gap, identifying and summarizing food-waste prevention interventions at the consumption/consumer stage of the supply chain via a rapid review of global academic literature from 2006-2017.

We identify 17 applied interventions that claim to have achieved food waste reductions. Of these, 13 quantified food waste reductions. Interventions that changed the size or type of plates were shown to be effective (up to 57% food waste reduction) in hospitality environments. Changing nutritional guidelines in schools were reported to reduce vegetable waste by up to 28%, indicating that healthy diets can be part of food waste reduction strategies. Information

campaigns were also shown to be effective with up to 28% food waste reduction in a small sample size intervention.

Cooking classes, fridge cameras, food sharing apps, advertising and information sharing were all reported as being effective but with little or no robust evidence provided. This is worrying as all these methods are now being proposed as approaches to reduce food waste and, except for a few studies, there is no reproducible quantified evidence to assure credibility or success. To strengthen current results, a greater number of longitudinal and larger sample size intervention studies are required. To inform future intervention studies, this paper proposes a standardised guideline, which consists of: (1) intervention design; (2) monitoring and measurement; (3) moderation and mediation; (4) reporting; (5) systemic effects.

Given the importance of food-waste reduction, the findings of this review highlight a significant evidence gap, meaning that it is difficult to make evidence-based decisions to prevent or reduce consumption-stage food waste in a cost-effective manner.

Keywords
Food waste
Reduction
Household
Downstream
Consumption
Consumer

1 Introduction

Within the last decade, food waste has become an issue of international concern to policy makers, practitioners, and researchers across a range of academic disciplines. Recent estimates suggest that globally one third of food never reaches a human stomach (FAO, 2011), and global food waste is associated with large amounts of greenhouse gas emissions (FAO, 2013). Growing political and public consensus around the urgency of these challenges has provided the impetus for governments, regions, cities, businesses, organisations, and citizens to act. Measures have been taken to reduce the amount of food waste generated in agriculture, aquaculture, fisheries, food processing and manufacturing (upstream), and in supermarkets, restaurants, schools, hospitals, and homes (consumption).

Many food waste reduction targets have been set, including Sustainable Development Goal 12.3 which aims by 2030, to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses (Lipinski et al., 2017).[1] One of the key challenges facing many actors working in this area is deciding *where* and *how* to focus their efforts most effectively to reduce food waste. For each area of the food system (Horton, 2017), there are a number of potential strategies

[1] The Sustainable Development Goals are a collection of 17 global goals set by the United Nations General Assembly in 2015. The SDGs cover social and economic development issues including poverty, hunger, health, education, global warming, gender equality, water, sanitation, energy, urbanization, environment and social justice.

(which are not mutually exclusive), with diverse examples including: improved communication of forecasting between retailers and agricultural producers; public information campaigns, programmes to increase skills in the home or workplace; and changes in how food is packaged and sold. Within each of these strategies, there are numerous decisions to be made by policy makers and practitioners that could influence the effectiveness of interventions in preventing food from being wasted.

The aforementioned *where* can also be geographic in focus: a local area, region, country or globally. Recent quantification of global food waste highlights a split between developed and developing countries. In developing countries, the vast majority of food waste occurs in primary production and within the supply chain – for example in sub-Saharan Africa where more than 90% of food waste occurs prior to the consumption phase (FAO 2011). In contrast, in so called developed countries, the largest single contribution is reported to come from the consumption stage – with much of that at the household level, e.g. in Europe, around 50% of wasted food is estimated to come from households (Stenmarck et al., 2016). There is clearly a need for researchers, policy makers, and practitioners to understand how to prevent food from being wasted across the supply chain. For those working on the issue in developed countries, however, understanding how to influence food waste within the consumption phase – and, in particular, in households, where the majority of food is consumed and

wasted – is important to make a meaningful impact (Porpino et al., 2016). Due to this, there is current policy focused on the household food waste reduction, yet – as shown below – the evidence base for is lacking.

In order to enhance the understanding of how to influence food waste within the consumption phase, this paper set out to identify and categorise food-waste prevention interventions at the consumption/consumer stage. Growing attention to food waste is reflected in an increase in the volume of academic and grey[2] literature on the topic. As a result, several bibliometric studies and meta-analyses of prior literature and studies can be found. Our review of these studies (Table 1) reports how and what each study revealed (Aschemann-Witzel et al., 2016; Carlsson Kanyama et al., 2017; Chen et al., 2015; Hebrok and Boks, 2017; Porpino, 2016; Quested et al., 2013; Schanes et al., 2018; Thyberg et al., 2015; Xue et al., 2017). It can be noted that none of these studies reviewed the effectiveness of interventions aimed at preventing food waste in the consumption stages of the supply chain[3], although Schanes, Doberning, and Gözet (2018) do call for this to be carried out as an avenue of future research.

Table 1 – a summary of the nine bibliometric studies and meta-analyses that review food waste literature.

See attached file

[2] Grey literature refers to non-peer reviewed literature such as reports, conference proceedings, doctoral theses/dissertations, newsletters, technical notes, working papers, and white papers.

[3] I.e. where food is consumed such as in the household, and in hospitality and food service sectors.

In the grey literature, there are many documents summarising a wide range of food-waste-related issues. However, to the best of our knowledge, there is no review of the effectiveness of downstream food-waste interventions.[4] Four intervention studies were reviewed by WRAP (see appendix F of Parry et al., 2014). These were all from the grey literature and UK-based. Since then a number of further studies have emerged, the most important of which are mentioned in the discussion section below.

In summary, there is no peer-reviewed study that has considered the effectiveness of interventions aimed at preventing food waste in the consumption stages of the food system. This represents a significant gap, which, if filled, could help support those working to reduce food waste in the developed world, providing knowledge of what interventions are specifically effective at preventing food waste. This paper fills this gap, reporting a rapid review of the food-waste literature from 2006 to 2017 focussing on downstream food-waste reduction interventions[5]. Based on the findings, the paper then categorises the

[4] While this manuscript was in final stages of peer review, a review of downstream food waste interventions between 2012-2018 was published by Stöckli et al. (2018b). It identified the same papers as identified by this manuscript (with addition of 2017-2018 peer reviewed papers:(Qi and Roe, 2017; Romani et al., 2018; Stöckli et al., 2018a)), and came to similar conclusions regarding the need for systematic evaluation of interventions between. The additional novelty of our paper is 1) situating a broader range of peer reviewed intervention papers (2006-2016) within the broader food waste literature (see figures 1-5), and 2) our in-depth discussion and proposal of standardised guidelines for intervention development.

[5] "Downstream" being a wide definition, but meaning the consumer side of the food system. Downstream interventions could include interventions in supermarkets, hospitality and food service sectors (including food served in education and healthcare, government etc.), and household consumption.

152 successful interventions and discusses the components of a successful food
153 waste reduction intervention.

154 ## 2 Methods

155 The methodology for rapid reviews has emerged as a streamlined approach to
156 synthesizing evidence in a timely manner – rather than using a more in-depth
157 and time-consuming systematic review (Khangura et al., 2012; Tricco et al.,
158 2015). As discussed by Tricco et al., there is no set method for a rapid review;
159 however, there are several common approaches. For this study, a rapid review
160 was undertaken to provide fast and up-to-date information, responding to
161 demand from the policy and academic community (c.f. Lazell and Soma, 2014;
162 Porpino, 2016).

163 We used Google Scholar to identify relevant papers using combinations of the
164 following terms: 'Food waste', 'household', 'quantification', 'behaviour change',
165 'consumer', and 'downstream'. The time period was restricted to January 2006
166 until January 2017. This was a result of discussion with expert advisors and
167 evidence from other bibliometric studies that food waste studies only began to
168 be published from 2006/7 onwards (Chen et al. (2015), Hebrok and Boks (2017),
169 Carlsson Kanyama, Katzeff, and Svenfelt (2017), and Schanes, Doberning, and
170 Gözet (2018). This search enabled the inclusion of online first/only preprints of
171 2017 journal articles. The search was restricted to English-language publications.

Each paper was then mined using the Google Scholar “citation” function to explore the network of papers that have cited each paper. Each of these papers was then captured and explored via the process described above. Figure 1 outlines our rapid review method, with 454 items narrowed down to 17 peer reviewed journal articles focussing on downstream food-waste reduction interventions.

Though it is common in rapid reviews to use scoring criteria to sort and exclude papers on the basis of method or data quality, no such scoring method was used in this paper. This is due to the small number of studies found, and wishing to provide the food waste community with as comprehensive as possible assessment of recent intervention studies.

It should also be noted that the waste reduction percentages reported here have been calculated from all studies that reported weights and changes to waste generation. The waste reduction percentages are not directly comparable with each other as they have differing functional units, i.e. per plate, per person (participating or general population), per organisation (kitchen and front of house), per total weight of waste, etc.), or differing time scales (for data collection or experiment duration).

191 Figure 1 Outline of our rapid review methodology

Rapid review step	Result
Step 1 – Google Scholar search 'Food waste' with the addition of combinations of the following terms: 'household', 'quantification', 'behaviour change', 'consumer', and 'downstream'. The reference lists and papers that cite each paper found were then searched. Time periods January 2006 to January 2017.	454 items found – 340 items were journal articles, with 56 theses, 36 conference papers, 17 policy papers, reports, and magazine articles, 4 book chapters, and 1 poster.
↓	
Step 2 – Review of Abstracts for Scope The abstracts of the 340 journal articles reviewed for scope (downstream and household food waste) and retained if they included an applied intervention.	292 (of the 340) journal articles were found to be in scope, with 39 articles preliminarily identified as having an applied intervention from the abstract
↓	
Step 3.1 – Expert review. The list of 39 journal articles was distributed to an expert panel for review and to mitigate possible missed journal articles. The expert panel was recruited from members of the International Food Loss and Food Waste Studies Group, and from authors of journal articles from the sample.	The panel suggested eight additional journal articles to include that were not identified by Step 1. (Cohen et al., 2014; Freedman and Brochado, 2010; Jagau and Vyrastekova, 2017; Lazell, 2016; Lim et al., 2017; Martins et al., 2016; Wansink and van Ittersum, 2013; Whitehair et al., 2013) Two of these journal articles were published later in 2017 and so were outside the time period in the original search, but have been included due to the presence of an intervention. 47 journal articles progressed to Step 3.2.
↓	
Step 3.2 - Close reading and analysis A close reading and analysis was performed on the 47 journal articles by 2 individuals (Reynolds and Goucher). This was to determine 1) if the interventions aim was to reduce or divert food waste, 2) the intervention mechanism, objective, theoretical background, geographic region, and downstream area of the intervention. 3) if there was food waste quantification by waste audit or self-reported information; and 4) if there were any policy recommendations from the intervention. Unsuccessful interventions were included in the sample.	17 journal articles contained applied interventions designed to reduce the amount of food being wasted (***reduction*** interventions), the focus of this review. (This includes 2 journal articles which were interventions that reportedly achieved food waste reduction even though this was not the articles stated aim). Further information on these articles can be found in Table 1. 10 articles were interventions with an aim to divert food waste to recycling or higher up the waste hierarchy (***diversion*** interventions). As these were not the focus of the paper these were not included in the further analysis. 20 articles were found to have no intervention.

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3 Results

3.1 Broad rapid review

The rapid review identified 292 downstream food waste articles that were published in 39 journals between 2006 and 2017.

From 2006, the number of downstream food waste articles published yearly increased rapidly as greater attention was given to the challenge of food waste, with the largest spike in articles that quantify food waste (Figure 2) occurring in 2013 after the publication of reports highlighting the global issue (Institution of Mechanical Engineers, 2013; Lipinski et al., 2013). Out of the articles surveyed, only 17 (5%) feature applied downstream food waste reduction interventions. The most popular methodologies (Figure 3) used in the rest of the downstream food waste studies include surveys (n=80, 27%), reviews (n=77, 26%) and Life Cycle Assessment (LCA) modelling (n=50, 14%). Journal articles featuring qualitative, observational and ethnographic methods (following Evans (2014)) are consistently published throughout the time period (n=18, 5%).

48 countries or geographic areas were identified within in the broader downstream food waste literature (Figure 4) with 8 articles not identifying their geographic location, and 53 global studies. The next most studied areas were the USA (n=42), the UK (n=34), Sweden (n=21) and Italy (n=20). China (n=13) is the only developing country in the top 10 countries / regions studied. Our results show that global studies emerge after 2010 – as data quality and accessibility increases. Countries that had an early identification of food waste as a social problem (including USA, UK and, Sweden) continue to publish prolifically.

3.2 Intervention studies

The seventeen journal articles focussing on downstream food-waste reduction interventions were first categorised by the main intervention types that were

applied: information based, technological solutions, and policy/system/practice change. Journal articles can be in more than one category if multiple interventions were used (either applied separately or together). Table 2 provides a detailed summary of each intervention and paper.

Table 2 – a summary of the 17 journal articles found with interventions that achieved a food waste reduction

See attached file

The seventeen articles with applied interventions were found in sixteen journals covering nutrition and health (5 journals), psychology and consumer behaviour (5), environmental (3), human computer interactions (2), food (1) and economics (1). The majority of these articles were published in relatively 'low' impact factor journals (under impact factor 3)[6].

Within the applied downstream food waste reduction interventions ten countries feature, with the USA being the site for 6 articles, 3 in the UK (one of which is a cross country comparison with Austria), and 2 in the Netherlands. The geographic spread of these 17 articles is focused on the global north, with Thailand the notable exception.

The areas of study for the seventeen applied downstream food waste reduction interventions are focused on households and the community (n=6), hospitality and hotels (n=5), and educational establishments (n=6). This is a much narrower field of study than what is found across the rest of the downstream food waste literature with 8 categories of intervention area identified in Figure 4.

[6] This is also a representation of the cross-disciplinary and evolving nature of food waste research. In the social sciences an Impact Factor of 3 would be quite high. However, in other fields, an Impact Factor of 3 could be considered "low".

Information-based interventions ((Cohen et al., 2014; Devaney and Davies, 2017; Dyen and Sirieix, 2016; Jagau and Vyrastekova, 2017; Kallbekken and Sælen, 2013; Lim et al., 2017; Manomaivibool et al., 2016; Schmidt, 2016; Whitehair et al., 2013; Young et al., 2017)) are where information was provided to change the behaviour of the target group – i.e. households (Devaney and Davies, 2017), hotel managers and diners, (Kallbekken and Sælen, 2013) and social media users (Young et al., 2017). Various 'delivery' methods were used including information campaigns (Manomaivibool et al., 2016; Schmidt, 2016) and cooking classes (Dyen and Sirieix, 2016).

The success of these interventions varied. A student-focused education campaign (Martins et al., 2016) resulted in a 33% waste reduction in main dishes, while the Home Labs intervention (a collaborative experiment with householders) led to an overall reduction in food waste generation of 28% (Devaney and Davies, 2017). New hotel signage reduced food waste by 20% (Kallbekken and Sælen, 2013). E-newsletter use resulted in 19% reduction in self-reported food waste in the home (Young et al., 2017). Schmidt's information campaign resulted in a 12% perceived (self-reported) improvement in food waste reduction in the home (Schmidt, 2016). Whitehair et al.'s information prompt resulted in a measured 15% food waste reduction in a university cafeteria, while portion advertising information also resulted in greater uptake of smaller portions (up to 6% from 3.5%) (Jagau and Vyrastekova, 2017).

Technological solutions ((Devaney and Davies, 2017; Ganglbauer et al., 2013; Lazell, 2016; Lim et al., 2017; Wansink and van Ittersum, 2013; Williamson et al., 2016a; Young et al., 2017) involve the introduction or modification of technologies and/or objects that seek to alter the behaviours around food (waste). These included changes to plate or portion sizes (Williamson et al., 2016b) or the introduction of fridge cameras or food sharing apps (Ganglbauer et al., 2013). Only plate and portion size studies have quantified waste reduction.

The largest reported waste reduction (57%) was due to shifting to smaller plate sizes, although in this study there was also a 31% decrease in the amount of food consumed via the plate size shift (Wansink and van Ittersum, 2013).[7] Other studies have reported a 19% reduction in food waste due to reduction in plate size (Kallbekken and Sælen, 2013), and a 51% reduction in food waste was achieved by using permanent rather than disposable plates (Williamson et al., 2016a). A 31% reduction in french fries waste was enabled by moving to smaller portion sizes (Freedman and Brochado, 2010).

Policy/system/practice change (Cohen et al., 2014; Dyen and Sirieix, 2016; Freedman and Brochado, 2010; Kallbekken and Sælen, 2013; Martins et al., 2016; Schwartz et al., 2015) is where polices or systems are altered and the population changes food waste behaviours (or practices). Two articles involved changing school dietary guidelines, which resulted in a 28% (Schwartz et al., 2015) and 14.5% (Cohen et al., 2014) vegetable waste reduction, while changing how schools and students were taught about food waste resulted in a 33% waste reduction from main dishes (Martins et al., 2016). These results indicate that diet reformulation and healthy eating can be part of food-waste reduction strategies.

In the seventeen journal articles with interventions, five relied on self-reported (usually survey-based) measurements of food waste (a method that is relatively low-cost but suffers from substantial biases (World Resources Institute, 2016)). One paper did not disclose any waste weights, while another two estimated food waste via visual analysis or pictures. The remaining nine used weight-based waste measurement. It is a challenge to accurately quantify food waste prevented, largely due to the costs of waste measurement (especially in the home). The cost of waste measurement could explain why only 123 of the 292 journal articles (42%) identified by the broader rapid review include some

[7] Note had observational measurement and weight base measurement of waste in different experiments.

297 quantification of food waste generation/ diversion/ reduction. Due to this
298 reliance on self-reporting, only the accuracy of the three plate-change/size-
299 reduction interventions can be assessed with any certainty (Kallbekken and
300 Sælen, 2013; Wansink and van Ittersum, 2013; Williamson et al., 2016a). The
301 comparative measurement of these studies is also not directly comparable as
302 the methods of weight measurement and the unit of measurement vary (i.e. per
303 plate or aggregated total waste), and time intervals (study duration, number of
304 observations etc.) differ between each study as reported in Table 2.

305 Around a third of these studies (5 articles) do not integrate any theoretical
306 framework or disciplinary orientation into their experimental design. Those that
307 do are typically single theory in nature, and do not interact with the broader
308 food waste literature. Theoretical frameworks and disciplinary orientations in
309 the downstream intervention articles include Social Practice Theory; Behavioural
310 Economics (nudge-approaches such as visual prompts), Transformative
311 Consumer Research, pro-environmental behaviour change, behaviour change
312 determinants, and the integrative influence model of pro-environmental
313 behaviour.

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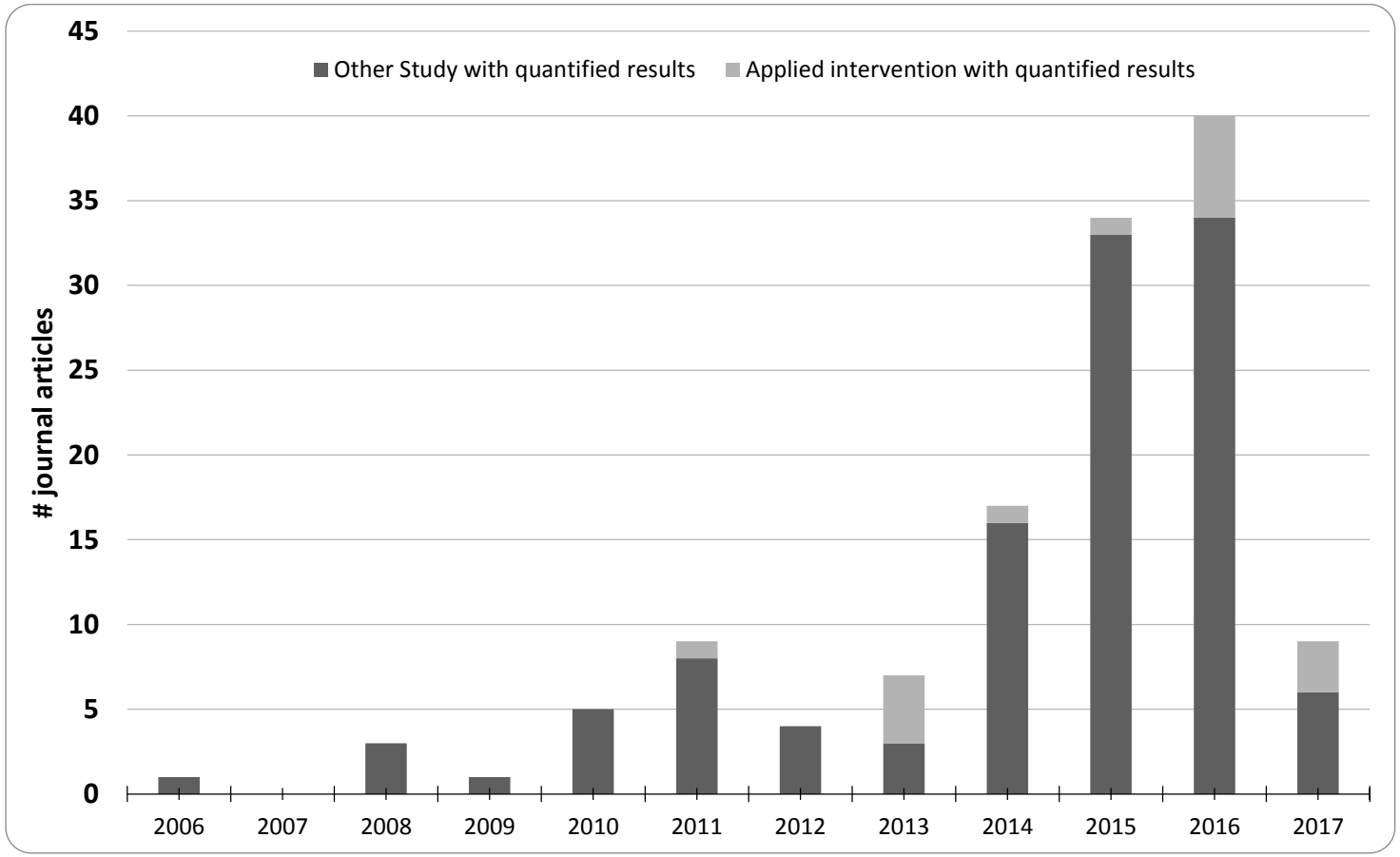

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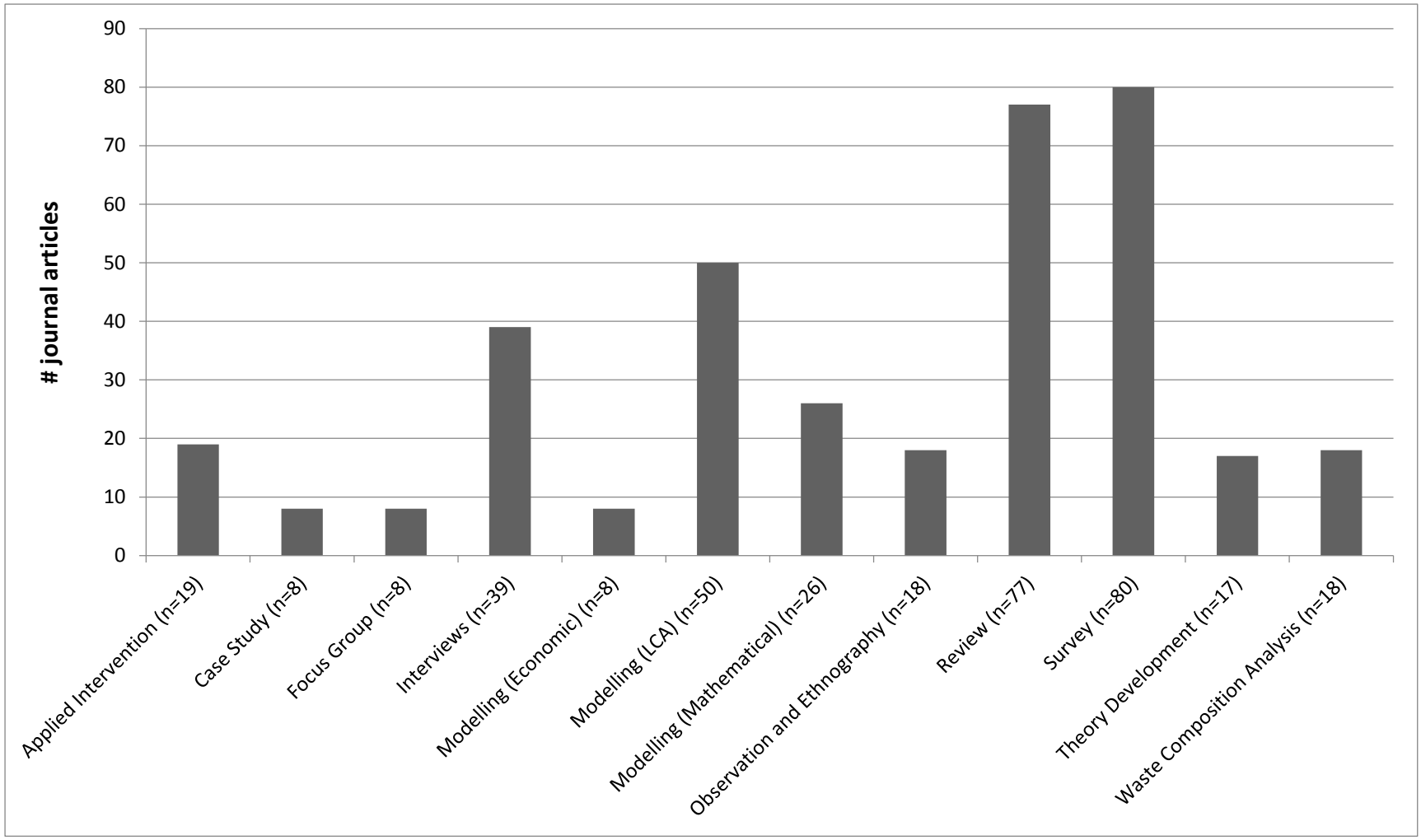
316 Figure 2 Downstream food waste studies with quantified results per year, 2006-2017, n=130.



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318 Figure 3 Methods used and numbers of downstream food waste studies published per year 2006-2017, n= 368.

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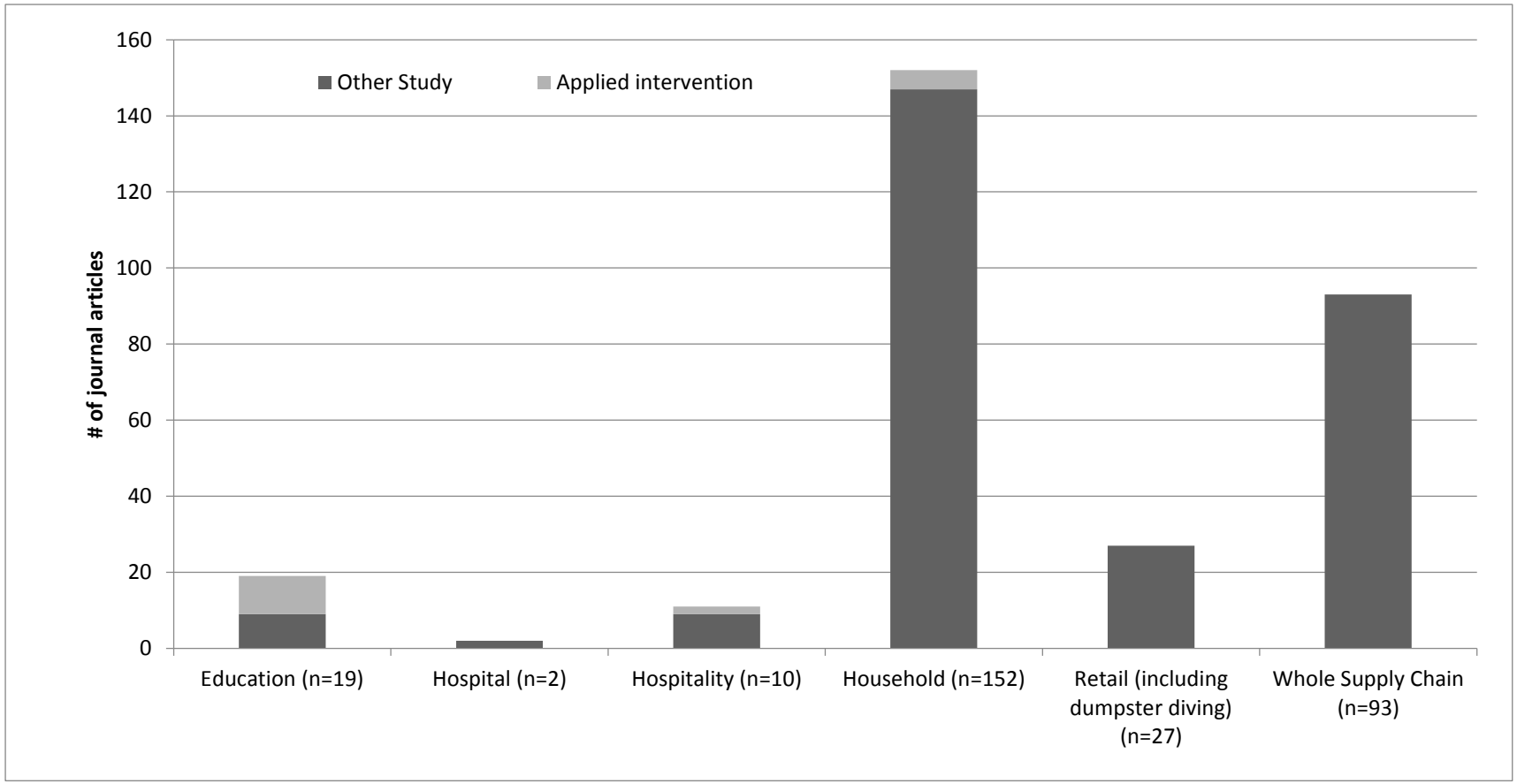

Figure 4 Areas of study and numbers of downstream food waste studies published per year 2006-2017, n=304, (generalist review studies excluded).

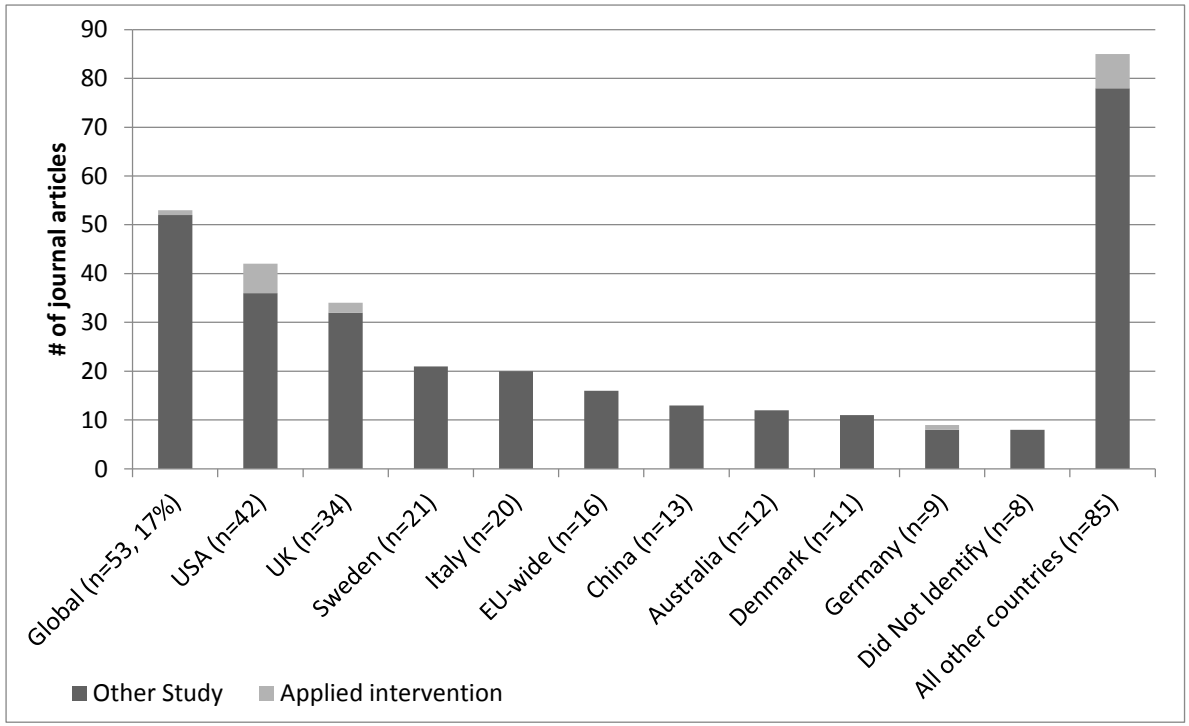

Figure 5 Geographic distribution of downstream food waste studies, the ten most prolific geographic areas, and all other countries. Note muli-country studies classified as "global" for this graphic 2006-2017, n=324

4. Discussion of themes and policy implications

In light of the above results, in this section we provide an overview of the methodologies, theoretical lenses and types of interventions employed in both the academic and grey literatures, and then recommended a series of recommendations – or principles – for organisations undertaking intervention studies relating to food waste prevention related to the consumption stages of the supply chain.

4.1 Methodologies

Although there has been a rapid increase in articles that quantify or investigate downstream food waste since 2006, there have been only 17 peer-reviewed journal articles that feature downstream interventions that resulted in a food waste reduction. Of these, nearly 30% (5 articles) used self-reported methods to measure food-waste reductions, while another two estimated food waste via visual analysis or pictures. Due to the methods used, the results from these studies should be interpreted with caution (as indeed many of their authors note); in these cases, a claimed reduction in food waste should not be read as an actual reduction. Furthermore, 16 of the 17 interventions occurred in developed countries and most interventions have focused on small groups with time-limited evaluations.

Part of this limited methodological development may be due to previous food waste research having had limited cross-pollination between disciplines, both in

terms of substantive questions as well as in theoretical development. Many researchers tend to rely on the theories they are comfortable with, resulting in a "silo"-ing not only of theories that could be useful in explaining food waste, but regrettably also a "silo"-ing of substantive findings related to actually reducing such waste. Further research is required to map the literature (and food waste's theoretical developments further) to understand if this is the case.

4.2 Theoretical lenses

The absence of explicit reference to theory means that readers are left to infer connections between cause and effect in food waste behaviours or that connections are imputed without explicit justification. Nearly 30% (5 articles) of the downstream intervention studies did not mention a theoretical framework. Of those that did, this was often not a key part of the paper or research design. This is an interesting finding: on the one hand, it could imply that those working on food-waste interventions are not aware of theoretical frameworks developed for interventions in other domains; on the other hand, it could imply – as discussed by Quested et al. 2013 – that food-waste prevention in consumption settings is very different from other areas of behaviour change (see also Evans et al. (2017)) and that many of the theories developed elsewhere are of limited value without further development. The lack of theoretical integration into food waste intervention design may also imply that theoretically rich accounts of household food waste (for example Waitt and Phillips (2016)) have yet to fully consider the implications of their analysis for interventions. We suggest that

there is a need for greater integration of theory and previous research findings into the design of interventions. We also suggest that there is need to discuss how different theoretical frameworks, disciplinary perspectives and methodological techniques could combine to contribute to the reduction of food waste. Would it, for instance, be possible to combine a qualitative account of the social practices that generate food waste with quantitative tools that model the effects of different interventions?

4.3 Intervention types

Reduction methods such as improved information (Manomaivibool et al., 2016) or changes to plate type and size (Lazell, 2016; Wansink and van Ittersum, 2013; Williamson et al., 2016a), portion size (Freedman and Brochado, 2010), or menu composition (Cohen et al., 2014; Martins et al., 2016; Schwartz et al., 2015), all accept that their effectiveness may be due to greater consumption of the food, or shifts in the types of foods consumed and wasted. That is, as has been observed in other interventions studies, there may be unintended consequences (Peattie et al., 2016) that need further investigation. If this unintended shift is towards the overconsumption of unhealthy foods or at the expense of healthy foods, this could lead to negative health outcomes. For this reason, attention must be given to communicating and encouraging people to monitor portion size rather than reducing food waste at the expense of public health. However some of the reviewed studies, indicate that some interventions result in a reduction in consumption alongside waste prevention (Kallbekken and Sælen,

2013; Wansink and van Ittersum, 2013[8]; Williamson et al., 2016a). Further research is needed to understand which (healthy or unhealthy foods) are involved in this consumption shift and waste reduction. Moreover, it could be the case that many of the unintended consequences could be due to a lack of understanding around causal mechanisms and supporting theoretical frameworks. If this is the case, further engagement with theory-based evaluations would be an obvious solution.

Cooking classes (Dyen and Sirieix, 2016), additional technologies such as fridge cameras (Ganglbauer et al., 2013) or apps (Lazell, 2016; Lim et al., 2017), and advertising and information campaigns (Young et al., 2017) were all reported as being effective but with no accurate quantification provided. This is worrying as all these methods are now being proposed by peer reviewed studies as options to reduce food waste with no reproducible quantified evidence to assure credibility or long-term effectiveness. Future research and resources are needed to test these interventions with accurate measurement methods. [9]

[8] The impact of Wansink and van Ittersum's research may have been affected by recent allegations of poor academic practices, with two other publications by Wansink and van Ittersum having had corrections published since the allegations were made (Etchells and Chambers, 2018; van der Zee, 2017).

[9] It is worth noting that preventing food becoming wasted (e.g. via preventing food waste at source, feeding to other people, etc.) may be more effective than diverting food that has already been categorised as waste away from landfill and incineration to other waste destinations higher up the food waste hierarchy (e.g. composting, anaerobic digestion). This is because, for a

For many organisations working on food-waste prevention, they would like to affect change across relatively large populations (e.g. a country, city or state / province / county). Therefore, to assess the appropriateness of interventions, these organisations require information on their cost effectiveness, how easy they are to scale up and whether they can be tailored to different 'audiences' within the population. However, this additional information is currently non-existent in the literature.

In addition, many of interventions that feature advertising or an information campaign did not provide enough detail to analyse and correlate the content type, and tone (positive, negative, shocking etc.), with the effectiveness of the campaign. This is an avenue for future research.

4.4 Links to other literature

As noted above, academic literature is not the only source of research and evidence relating to downstream food waste. Although not a primary focus of this review, the authors are aware of a small number of intervention studies in the practitioner/policy-focused 'grey' literature. For example, during 2016, the UK supermarket chain Sainsbury's undertook a year-long trial using a range of methods to prevent or reduce food waste in the home (Waste less, 2016). These interventions were a mix of information (via Food Saver Champions), technology

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given weight of food waste, preventing it being wasted usually has a much larger positive impact – socially, environmentally and economically – than diverting it from (Blatt, 2017; Garrone et al., 2014; Moult et al., 2018; Quested et al., 2011).

(fridge thermometers, smart fridges and cameras, apps etc.) and policy/system/practice change (introducing tenant welcome packs, new food waste events and school programmes). Some of these interventions included actual measurement of food waste (via audits or Winnow/Leanpath systems[10]) – resulted in between 18%-24% food waste reductions. Other interventions relying on self-reported measures, resulted in between 43% and 98% food waste reductions for the homes that took part.

In the USA, a partnership called *Food: Too Good To Waste* reported the findings of seventeen community-based social marketing (CBSM) campaigns aimed at reducing wasted food from households (U.S. EPA Region 10, 2016). These interventions were mainly information interventions, which introduced new information and tools into households. Measurement of food waste was conducted before and after the campaigns using a mixture of self-reported audits (participants weighing their own waste) and photo diaries. The results showed measured decreases between 10% and 66% in average household food waste (7% to 48% per capita) for fifteen of the seventeen campaigns. The successful interventions were between 4 and 6 weeks long, with samples of between 12 to 53 households.

[10] Winnow and Leanpath offer in-kitchen 'smart' food waste weighing services for the hospitality sector. Winnow was trailed in home as part of the Sainsbury's intervention

444 The EU project FUSIONS reported several waste prevention strategies focused
445 on social innovation (Bromley et al., 2016). Though most interventions involved
446 food redistribution, the *Cr-EAT-ive* intervention worked with school children
447 (n=480) and their parents (n=207) to reduce food waste in the home and
448 promote key food waste prevention behaviours. The results from 18 households
449 (of 29 households) that completed the kitchen diary activity managed to reduce
450 their food waste by nearly half – if scaled (with the intervention effects kept
451 constant) to a yearly quantity, this would equal a reduction of 80 kg per
452 household per year. However, it is not known how long the intervention effects
453 would last for, the longer term engagement/attrition rates of children and
454 households, and if some of this reduction was caused by the effect of
455 measurement itself (rather than the intervention).

456 During 2012/13, WRAP ran a food-waste prevention campaign aimed at London
457 households (WRAP, 2013a). These interventions were mainly information
458 interventions. This was evaluated via waste compositional analysis and reported
459 a 15% reduction in household food waste. However, as noted by the authors,
460 some of this reduction could have been the result of the research itself (i.e.
461 households being influenced by participating in a detailed survey).

462 Between 2007 and 2012, household food waste in the UK reduced by 15%
463 (WRAP, 2013b). However, it is not possible to isolate the effect of different
464 interventions that were running over this period. In addition, economic factors –

465 increasing food prices and falling incomes in real terms – are likely to have
466 contributed to this reduction (WRAP, 2014b).

467 These examples from the grey literature do not alter the main conclusions of
468 this review: that there is a lack of research surrounding interventions designed
469 to reduce the amount of food waste generated, and a lack of evidence of the
470 ease with which it is possible to scale up previous smaller interventions.

471 It is important for researchers, policy makers and practitioners working to
472 prevent food waste that this evidence gap is filled with research of suitable
473 quality. Below, we offer guidance and general principles that, if followed, will
474 improve the quality of this emerging field of study, and allow the effectiveness of
475 interventions to be compared and fully understood. Building on the
476 shortcomings of previous studies and improvement suggestions as outlined by
477 Porpino, (2016), we categorise these recommendations into 5 strands:
478 intervention design; monitoring and measurement; moderation and mediation;
479 reporting; and consideration of systemic effects. These recommendations are
480 based on our review of the literature and the authors' prior knowledge and
481 experience regarding food waste intervention design and application.

482 ### 4.5 Recommended principles for effective interventions

483 This section presents a series of recommendations – principles – for
484 organisations undertaking intervention studies relating to food waste prevention

485 related to the consumption stages of the supply chain. We then discuss
486 interventions with potential with reference to our results.

487 *1 Design of intervention*

488 We recommend that an initial decision should be made about whether the study
489 is focusing on an 'applied' intervention and/or one used to develop
490 understanding of the intervention process. This should be explicitly stated in the
491 methods and (experimental or intervention) design.

492 An applied intervention aims to reduce food waste across a given population or
493 sub-population (i.e. it is scalable, with a clear target audience). For the
494 interventions reviewed this was not always the case. For a communications-
495 based intervention, this would need to be similar to the type and tone of
496 material that could be used by a campaign group or similar organisation. If it
497 were a change to food packaging, for example, it would need to be a change that
498 could be adopted by a wide range of food retailers (e.g. it would have to ensure
499 food safety and other packaging attributes whilst still being cost-competitive). To
500 ensure that the 'quality' of such interventions is sufficient for the study,
501 researchers should consider partnering with appropriate organisations with
502 expertise in, for the above examples, developing communications materials or
503 packaging technology. Partnerships also ensure that work is not being carried
504 out in this area by organisations at cross purposes. In addition, applying
505 techniques such as logic mapping (based on theory of change – see The

Travistock Institute, 2010) can aid the design process to ensure that the intervention has the best possible chance of meeting its stated aims (i.e. preventing food waste in the home or other downstream settings). In addition, logic mapping and theory of change can enable the research to investigate *how* change occurs, as well as quantifying the degree of change. Much of this research and methods development has already been carried out on general behaviour intervention strategies within the field of environmental psychology, see Steg and Vlek (2009), or Abrahamse et al. (2005).

In contrast to 'applied' interventions, some research of interventions is designed to understand and evaluate how different elements of an applied intervention work. For these interventions the criteria discussed above are not strictly applicable. These types of studies may aim to understand which element of a larger intervention is responsible for the change – e.g. it may compare a range of campaign messages drawn from different disciplines and theories under controlled conditions. In such cases, it is not necessary that this module is scalable, although it would help future application of the research if the intervention studies needed only small modification to be deployed on a larger scale.

We also note that many studies use convenience sampling, which is likely to result in a group of study participants who are not representative of the wider population (or target populations within it). It will often include a sample with

higher than average levels of education and income (Schmidt, 2016). Therefore, where possible, the design of the study should be considered to ensure that the sample is as representative of the population of interest as possible, ideally through random selection or, failing that, some form of quota sampling.

Previous discussion has indicated a lack of theory involved in the development of interventions; we feel that this stage is a key part of the intervention design process where theoretical understanding could be used to help develop more effective interventions.

2 Monitoring and measurement methods

Measurement of outcomes and impact of the interventions is challenging. Objective measures of food waste – such as through waste compositional analysis of household waste – are relatively expensive and are more easily deployed in geographically clustered samples (World Resources Institute, 2016). In addition, these methods only cover some of the routes by which wasted food can leave the study area, and so food and drink exiting the study area via the drain, or food that members of a household/school etc. waste in locations outside of the study area are not covered by such measurement methods (Reynolds et al., 2014). However, where there is an opportunity to deploy methods involving direct measurement, it is beneficial as these are generally more accurate and also minimise the amount of interaction with the household, reducing the impact of the measurement itself on behaviour.

548 Most of the other methods rely on some form of self-reporting – e.g. diaries,
549 surveys, self-measurement of food-waste caddies, taking photographs. All of
550 these methods generally give lower estimates of food waste in the home
551 compared to methods involving direct measurement (e.g. waste compositional
552 analysis) when comparison is made for a given waste stream. For diaries – one
553 of the more accurate methods – around 40% less food waste is reported
554 compared to waste compositional analysis (Høj, 2012). More recent analysis has
555 shown that measuring food waste via caddies or photos gives similar results to
556 diaries (Van Herpen et al., 2016). This lower estimate is likely due to a range of
557 factors: people changing their behaviour as a result of keeping the diary (or
558 other method), some items not being reported, and people with – on average –
559 lower levels of waste completing the diary exercise (or similar measurement
560 method).

561 Few studies discussed the problems presented by self-reported data. However,
562 issues relating to self-report are discussed more extensively in the
563 environmental (in particular recycling) and social marketing literature where self-
564 reported measures of perceptions and behaviours are often considered
565 unreliable (Prothero et al., 2011) and a gap is expected between self-reported
566 and actual behaviour (Barker et al., 1994; Chao and Lam, 2011; Huffman et al.,
567 2014). This should be discussed with reference to each intervention to
568 understand the scale of uncertainty present in the results.

569 This means that those monitoring interventions have some difficult decisions to
570 make: methods that are accurate may be unaffordable while methods that are
571 affordable may be subject to biases that can compromise the reliability of the
572 results. For instance, a communication-based intervention monitored using
573 diaries may increase the level of underreporting of waste in the diaries, which
574 could be erroneously interpreted as decreasing levels of food waste. This could
575 have substantial – and costly – implications for those deploying the (potentially
576 ineffective) food waste intervention in the future.

577 To address these issues, studies should try to obtain the requisite funding to be
578 able to measure food waste directly (e.g. by waste compositional analysis). This
579 may mean fewer studies, or studies comprising a panel of households, in which
580 food waste is regularly monitored (with the householders' consent), creating the
581 possibility of longitudinal studies. To make such an approach cost effective, this
582 would likely require a consortium of partners, who could explore the emerging
583 data to answer multiple research questions.

584 For studies using self-reported methods, these should carefully consider the
585 design of the monitoring to ensure that reporting is as accurate as possible. The
586 smaller the gap between actual and measured behaviour arising, the less
587 measurement artefacts can influence the results and the ensuing conclusions.
588 Recent work calibrating these self-reported methods has been undertaken (Van
589 Herpen et al., 2016) and this type of information should be used in the

590 measurement design. Further advances in calibration, especially in the context
591 of intervention studies (i.e. is the level of underreporting stable during typical
592 interventions?) would also help to improve monitoring and measurement.

593 In some circumstances, effects relating to self-reported measurement methods
594 can be mitigated by the careful use of control groups. Where possible these
595 should be used, as levels of food waste may change over time, influenced by
596 food prices, income levels and other initiatives aimed at preventing food waste.
597 However, adding a control to the research will increase costs and there can be
598 practical difficulties in creating equivalent (e.g. matched) control groups,
599 especially where samples are geographically clustered.

600 This discussion raises wider questions about the most appropriate evaluation
601 approach and method, where different research designs may be fit for different
602 intervention purposes. For example, where the priority is to measure an impact
603 or effect, an experimental or quasi-experimental method should be considered,
604 while assessing multiple outcomes and causal mechanisms may require a non-
605 experimental research design (e.g. including qualitative methods). If the purpose
606 is to decrease food waste by X percent, then the level of food waste should be
607 measured over the course of the intervention (and beyond, to understand the
608 longevity of the effect). In some contexts however, the purpose is to achieve a
609 precursor to food-waste prevention (e.g. increased reflection on food waste, or
610 to improve cooking skills), which may eventually lead to decreased food waste.

In the latter cases, evaluation may want to focus on measuring the level of reflection, cooking skills, etc. to assess the effectiveness of the intervention.

We acknowledge that research on food waste is an interdisciplinary field. This can be a virtue, with many perspectives tackling this 'wicked problem'. However, it also means that different disciplines have different conventions and priorities, e.g. over the experimental scale or duration, and measurement of uncertainty *vis-à-vis* determining how much food is actually wasted. These differences should be acknowledged in order that more accurate and consistent measurement takes place.

3 Moderation and mediation

In addition to changes in the level of food waste, intervention studies may benefit from measuring changes in other quantities. This may help understand whether the intervention is effective, especially in situations where measurement of food waste is imperfect. Additional dietary (purchase and consumption) data can be collected and would provide greater certainty regarding food waste generation statistics. Additional waste generation data (beyond just food waste) could also be useful to help understand wider waste generation issues and drivers.

Examples of other measurements may include 'intermediate outcomes': depending on the intervention and how it operates, there may be intermediate steps that would need to occur for the intervention to operate as envisioned (as

articulated in the intervention's logic map – see stage 1). This is an approach often used in social marketing where changes in behaviour that are difficult to measure might instead track changes in knowledge, beliefs and/or perceptions (Lee and Kotler, 2015). For instance, an educational campaign aimed at increasing the level of meal planning prior to people going shopping could monitor the change in people's awareness of educational material and their (self-reported) level of meal planning. These types of learning processes are slower, and are more difficult to assess in the short term, but they might still be successful and might achieve more long-term effects. Triangulation data is not sufficient in itself to state whether an intervention was successful, but can provide supporting evidence. Such analysis of moderating or mediating effects is useful and often uncovers interesting insights that would not be highlighted if this analysis were not conducted.

Observational analysis and measurement can provide insight into why the intervention works. By observing the intervention in action, this allows insight into the intervention itself, in addition to the effects of the intervention. This expands upon the intervention proposals of Porpino et al. (2016) by not only measuring the main objective, but also the intervention process, reflecting recent studies that highlight the importance of both process and outcome evaluation in interventions (Gregory-Smith et al., 2017).

4 Reporting

In order to make any study replicable and repeatable, there should be sufficient information provided about the intervention and the measurement methods to be able to replicate both elements.

The reporting of food waste has become standardised with the publication of the Food Loss and Waste Accounting and Reporting Standard (World Resources Institute, 2016). This standard was designed for countries, businesses and other organisations to quantify and report their food waste; it was not developed with intervention studies in mind. However, many of the principles it describes are useful in this context: studies should clearly describe the types of food waste measured (e.g. just the wasted food (i.e. edible parts) or including the inedible parts associated with food such as banana skins; the destinations included (e.g. only material bound for landfill, or also food waste collected for composting); the stages included (e.g. in a restaurant, only plate waste, or also kitchen waste).

A description of the details of how the quantification method (e.g. for waste compositional analysis) was undertaken is crucial, alongside what the study classified as food waste and which waste destinations were included. Details of the sample sizes and how they were drawn should also be covered. Data reporting should include the average weight, alongside appropriate measures of the spread of the data (e.g. standard deviation, standard error, interquartile ranges). Detailed waste composition data, where available, should also be

provided. Changes of food waste between time periods should be reported as both weights and percentages, with significance and *p* values clearly stated. This minimum level of comparable data was lacking in many of the papers reviewed, with only 12 (70%) of the papers providing some statistics or statistical analysis, 2 (11%) providing waste composition analysis, and 5 (29%) providing results or analysis of food waste reduction from multiple time periods post intervention.

To allow for the actual measurement of food waste rather than participants' perceptions, several methods of disruptive thinking and scaling innovations could be considered. One such innovation is smart bins (Lim et al., 2017). This allows automatic recognition of food waste type and their weighting which can help remove uncertainty in self-reporting of food waste. Such data from smart bins (and also smart fridges and online shopping devices) could be shared with local authorities, policy organisations, community groups and industry, enabling planning and optimisation of food waste management locally. Smart bins are already being used in the hospitality industry to track food waste (e.g. products such as Winnow or Leanpath).

5 Considering systemic effects

None of the intervention studies in the review considered systemic effects. Systemic effects, like the rebound effect (i.e. improved technology to reduced environmental impacts may, due to behavior and other system effects, result in

694 no change, or increased environmental impacts. See Khazzoom (1987) or Sorrell
695 and Dimitropoulos (2008) for further discussion), are relevant and vital to
696 consider for measures that are saving money or time for the consumer. Several
697 of the measures presented above are not only measures that can lead to
698 reduced food waste, and thus reduced environmental impact, but also measures
699 that could lead to reduced costs, both for consumers and for other actors in the
700 food chain. Since less food needs to be wasted, less food needs to be bought.
701 Reduced costs can be an advantage from a private economic point of view, but it
702 can also in the worst case, lead to further negative environmental effects. The
703 money saved can be used for other types of consumption and perhaps
704 increased environmental impact. These type of system effects, are sometimes
705 called second order effects or rebound effects (Arvesen et al., 2011; Börjesson
706 Rivera et al., 2014). How consumers choose to spend the money saved
707 determines what the overall environmental impact will be. If the money or time
708 is used for something more environmentally friendly, then the effect will be
709 positive, and the environmental potential will be realised. But if instead the
710 money is used for activities with more environmental impact, such as a food
711 with higher environmental impact or, taking a trip with a fossil fuel driven car or
712 even a flight, then the environmental impact is negative. Sometimes the second
713 order effect exceeds the environmental benefits of the intervention, and the
714 situation becomes worse than it was from the outset (known as the Jevons

paradox (Alcott, 2005)). This means that measures for reduced food waste do not always only produce the desired results with regard to environmental impact, but also more unintended side effects.

This does not mean that measures to reduce food waste are ineffective, but that second order effects need to be taken into account. Otherwise, there is a risk that interventions might not be efficient in a systems perspective. Due to the complexities involved in considering full systemic effects, the practicality of detailed analysis must be weighed up for each intervention. The use of theory-based interventions, with extended logic mapping (e.g. with systems mapping as discussed above) will be useful in enabling this detailed analysis, as the theoretical background and logic mapping may be able to acknowledge cross-boundary input and outcomes (but not necessarily assist with measuring them).

Ideally, Intervention studies, where possible, should collect data to monitor these second-order effects, in addition to monitoring the direct impact on food waste. However, as this may involve recording household spending (on food as well as other expenditure) and food consumption, it will greatly inflate the cost of studies and may not be possible. Another option is to, at least, identify risks for second order effects, look for ways to minimize negative second-order effects and maximize any potential positive effects of this nature.

4.6 Policy implications

According to our review, in spite of the shortage of downstream intervention studies, there are still several evaluated interventions that have good potential for use in a wider context. These include so-called “low hanging fruits” which might not have a huge impact but also do not imply high cost, high maintenance or side effects, or interventions that have been assessed and have produced good results. One example of the former kind is to encourage guests at restaurants and in large-scale households to adjust the portions to how hungry they are (Jagau and Vyrastekova, 2017), or to take smaller portions at a buffet and come back if you want more (Kallbekken and Sælen, 2013). This kind of measure is relatively simple and inexpensive and could be combined with other measures, such as for example a lower price for a smaller portion. Examples of the latter kind, assessed with good results but with an economic cost, are the interventions with smaller plates (Kallbekken and Sælen, 2013; Wansink and van Ittersum, 2013).

A number of interventions use social media (e.g. Lim et al., 2017) and the evaluated studies indicate that there is potential for this in particular as a way of spreading knowledge and creating discussion and reflection. However, caution must be taken as using social media to message the correct audience with content that resonates has its own challenges due to audience segmentation. Another intervention that is quite simple and can be done without major investment in apps, is colour coding of shelving or sections in the refrigerator

(Farr-Wharton et al 2012). Similar initiatives have been tested in "Food: Too good to waste" where the solution was even easier - with just a note in the fridge on food to be eaten soon (U.S. EPA Region 10, 2016). More extensive campaigns (e.g. U.S. EPA Region 10, 2016 and WRAP, 2013b) have also had good effects, although it is difficult to estimate the impact of individual components of the overall campaign. With a mix of complementary interventions and actors at local level, this type of measure should have good potential given that the necessary resources and commitment, which seems to have been the case in both the UK and the United States.

5 Conclusion

This paper has summarised 17 applied food-waste prevention interventions at the consumption/consumer stage of the supply chain via a rapid review of academic literature from 2006-2017. This led to the identification of interventions that could be deployed effectively at scale in the home (e.g. fridge colour coding, product labelling, and information provision), and out of the home (e.g. plate and portion size adjustment, changes to menus and nutritional guidelines, and redesign of class room syllabus).

Our discussion has identified the weaknesses of the current literature; proposed guidelines for the development of further food waste interventions, and set out an agenda for further research:

- Well-designed interventions covering a range of types (including longer interventions and those exploring a raft of measurers),
- Tested using carefully selected methods to understand the outcome of the intervention and how it works (or not),
- Adoption of higher sample sizes and representative sampling for quantitative elements,
- Replication studies in different countries
- Consideration of systemic effects
- Improved, more consistent reporting.

This is a novel and important addition to the researchers', policymakers' and practitioners' tool kit. Our review found that the majority of current interventions achieve only a 5% to 20% reduction in food waste. To achieve Sustainable Development Goal 12.3 by 2030, (halve per capita global food waste at the retail and consumer levels) these interventions (and others) need to be combined, refined, tested further at different scales and geographies, and adopted on a global scale.

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Online Appendix 1. Time series detail of Figures 3, 4, and 5.

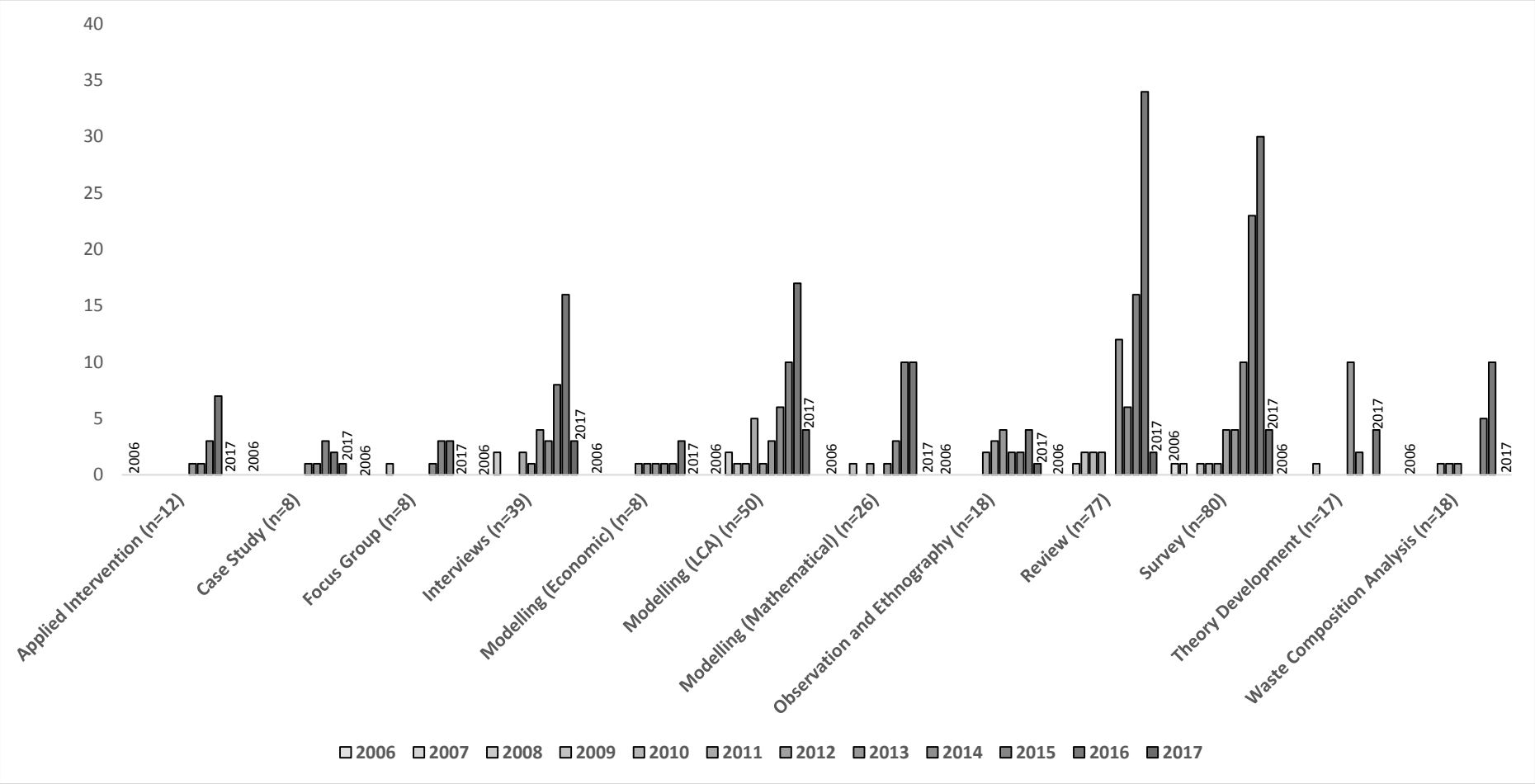

Figure 3 Methods used and numbers of downstream food waste studies published per year 2006-2017, with time series detail. n= 361.

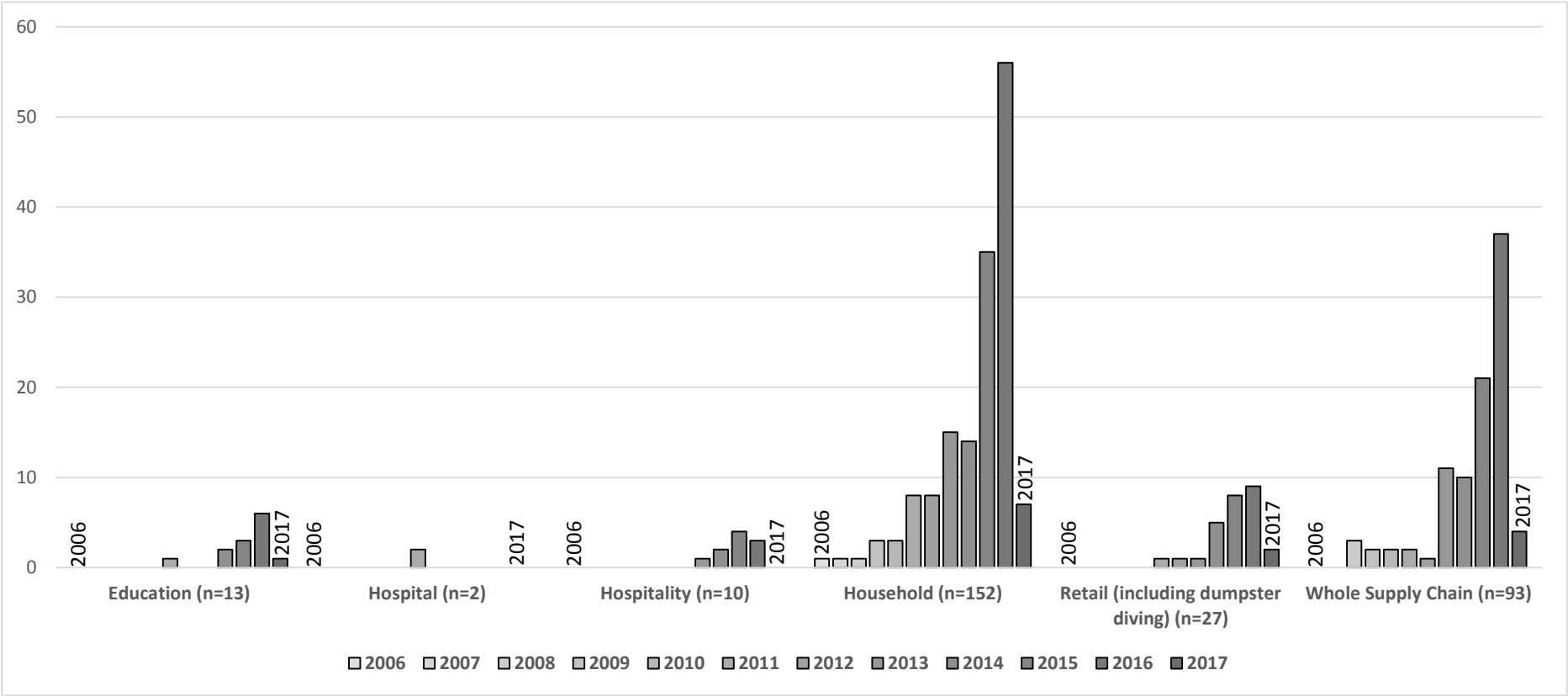

Figure 4, Areas of study and numbers of downstream food waste studies published per year 2006-2017, with time series detail. n=297, (generalist review studies excluded).

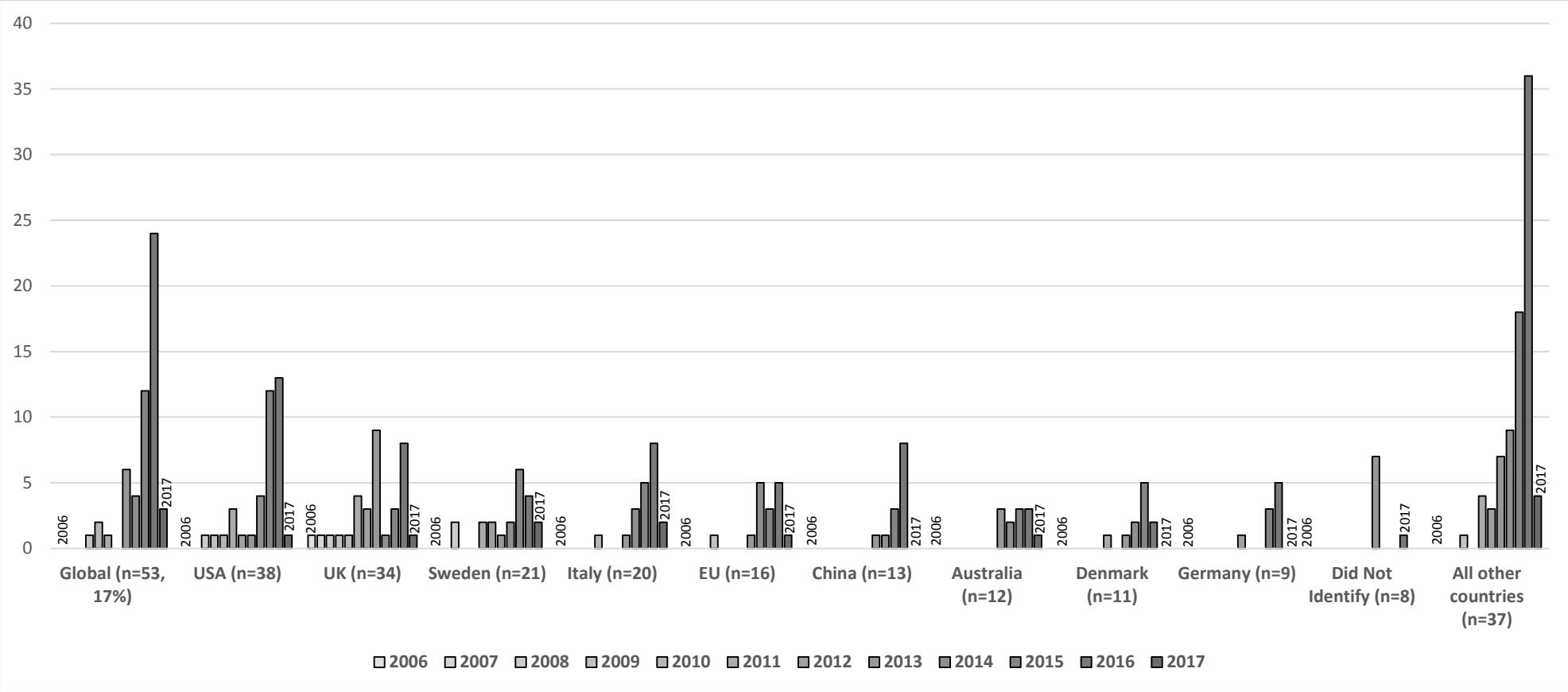

Figure 5, Geographic distribution of downstream food waste studies, the ten most prolific geographic areas, and all other countries, 2006-2017, with time series detail. n=317.

Table 1

Paper	Sample	Analysis methods	Aim	Measurement Time intervals	Setting, scope, search words	Geography	Year	Results
Quested et al., (2013) Resources, Conservation and Recycling	39 documents cited, 12 WRAP studies	research synthesis, and case study	Review of insights about food waste in the home, which has largely emanated from work funded by the Waste & Resources Action Programme (WRAP)	2006 to 2012	Household food waste behaviours	UK	2013	Reviews conceptualisations of food waste, and the multiple behaviours and practices of food waste. Discussion of how to integrate insights into behavioural models and the development of a successful public-engagement campaign. Highlighted discussion point that many behavioural models, are not designed for multiple, complex behaviours such as food waste.
Thyberg et al., (2015) Environmental Science & Technology	62 waste characterization studies	Meta-analysis and research synthesis, use of Google search engine.	Quantification of the US MSW food waste Determine if specific factors drive increased disposal.	1989 to 2013	MSW, Food waste, NOT Food loss	USA	2015	The proportion of MSW food waste increased with time. The aggregate proportion of food waste in U.S. municipal solid waste from 1995 to 2013 was found to be 0.147 (95% CI 0.137−0.157) of total disposed waste, which is lower than that estimated by U.S. Environmental Protection Agency for the same period (0.176).

Table 1

Chen et al. (2015) Journal of Cleaner Production	2340 research articles	Review and bibliometric analysis, use of Web of Science database	Quantitative analysis of peer-reviewed articles to summarize food waste publication, identify the research focuses and hotspots, identify the trajectories of research (including development of theoretical and practical contributions and future challenges)	1997 to 2014	“Food waste*” or “kitchen waste*” or “food residue*” or “kitchen residue*”	Global, Engish language	2015	The food waste literature around biotechnology and waste management was larger than that around waste reduction, with the themes of clean energy, treatment and valorization, and management innovation attracting extensive attention during the past decade. FW research output is distributed unevenly over all countries. The majority of research is published by industrialized countries. Discussion dominated by methods for treating or valorising food waste, mainly in the upstream stages of the supply chain (reflecting the relative amounts of research in this area in the literature). The literature on food-waste prevention obscured.

Table 1

Aschemann-Witzel et al (2016) Journal of Cleaner Production	26 existing initiatives	Case study approach	Review into case stuides to understand how to successfully design future interventons to reduce consumer-related food waste.	1998 to 2015	Case studies, food waste	23 from Europe, one from the US, and two from Brasil.	2016	Multiple success factors were identified. There are three main types of consumer food waste initiatives: information and capacity building, redistribution , and supply chain initiatives. Collaboration and knowledge sharing (building upon prior initiatives) are important to the success of future campaigns. Supply chain change should ensure growth in business opportunities, Redistribution initiatives need to stress multiple aims to get maximum stakeholder engagement. Information and capacity building initiatives should focus on the positive aspect of valuing and using the food (in a tasty and fun/humorous way). Focus tends to be on either motivating conscious choice and supporting consumer abilities or altering the choice context towards providing opportunities, both may be possible together. Only 4 case studies targeted at reducing downstream consumer food waste. The success of the interventions was judged by those involved in delivering the intervention and most had no estimate of their actual impact on levels of food waste. Furthermore, these case

Table 1

Porpino (2016) Journal of the Association for Consumer Research	24 papers	Review.	Provide a framework and solutions for conducting future research in the Food Waste research area	1975-2015	“wasted food” consumer food waste	Global	2016	Insights given for future impactful research (i.e. shopping habits, over consumption, income, . Provides future research recommendations based on previous studies. (Lack of emotional study, income, cultural factors, marketing, survey analysis and experiments, quantification.) Need for more ethnographic observations, measurements and experiments.

Table 1

Xue et al. (2017) Environmental Science & Technology	202 publications	Review and bibliometric analysis, use of Web of Science and Google Scholar	A critical overview of all the existing FLW data in the current literature. Sorting by Food Supply Chain, Food Commodity Groups, Geographical and Temporal Boundary.	1933 to 2014	Food Loss and Waste	84 countries (Global scope)	2017	Most existing publications are conducted for a few industrialized countries (e.g.,UK, USA). Over half of publications are based only on secondary data (signalling high uncertainties in the existing global FLW database). With these uncertainties, existing data indicate that per-capita food waste in the household increases with an increase of per-capita GDP. Focused on quantification and measurement of levels and types of food waste – mainly at the national level, focussing on the sectors with the most food waste. Paper did not discuss food-waste reduction interventions, nor what has been shown to be successful in the literature.

Table 1

Hebrok and Boks (2017) Journal of Cleaner Production	112 scientific sources	Review, use of Oria and Google Scholar, with additional scoping of reports from ForMat, WRAP, and FUSIONS	Review what the drivers of food waste are, and where can designers intervene in order to influence consumers to waste less food.	2000 to 2015	“Food waste” in combination with the words “household”, “packaging”, “consumer”, “behaviour” and “design”.	Results must be written in English, the resultant were from Western Countries	2017	Reviews aspects of consumer food waste (consumer behaviour, attitudes, beliefs and values, quantifications and compositional analyses, waste prevention, and design interventions). Literature is more focused on generating knowledge about the problem than on finding solutions. Little knowledge of the actual or potential effects on food waste levels of design interventions.
Carlsson Kanyama, Katzeff, and Svenfelt (2017), TRITA-SEED-Rapport 2017:05	350 studies	Review/report, english language, use of Google Scholar and Scopus. Included peer reviewed publications, conference papers and reports	Review of interventions to decrease avoidable food waste with the focus on private consumers	1987 to 2017	"food waste" AND "behavior change", "food waste" AND "intervention", "food waste" AND "sustainable consumption", "food waste" AND "nudging".	Global, Engish language	2017	Studies reviewed use various interventions E.g. education and information; apps, smaller plates. Mostly, the evaluations of the behaviour interventions have only been carried out using smaller groups of people. Longitudinal studies of their effects are mostly missing. Nevertheless, the studies of interventions where evaluations exist, indicate a significant effect regarding the decrease of food waste as well as raising households’ awareness and encouraging their reflection.

Table 1

Schanes, Doberning, and Gözet (2018) Journal of Cleaner Production	60 articles	Systematic literature review, using Web of Science, Scopus, and GoogleScholar	Review and analyse evidence on the factors impeding or promoting consumer food waste. Discuss the contributions of psychology-oriented approaches as well as social practice theory.	1980 to 2017	“food waste” AND “consumer”, and “food waste” AND “household”	Global, Engish language	2018	Food waste is a complex and multi-faceted issue that cannot be attributed to single variables. Authors call for a stronger integration of different disciplinary perspectives. Current food waste prevention strategies can be designed around determinants of waste generation and household practices. Discussion of policy, business, and retailer options for food waste reduction, with limited review of effectiveness. Call for review of effectivness to be carried out as an avenue of future research.

Table 2

Table 2

Paper	Sample	Setting	Waste measurement methods	Theory's used	Aim	Results	% of food waste reduction/ summary of qualitative findings	Intervention category type (Information, Technology, Policy/system/practice change)	Measurement Time intervals	Year	Geography
1. Kallbekken & Sælen (2013, Economic Letters) (Kallbekken and Sælen, 2013)	52 hotels (38 control and 2 test groups of 7).	Hospitality	Hotels reported food waste weights (assumed to be gathered by waste audit)	No theories discussed.	Using two separate non-intrusive 'nudges' – reducing plate size and providing social cues based on perceived social norms – in Hotels.	Both reducing plate size and providing social cues was effective at reducing food waste in Hotels.	Plate size reduction: 19.5% ($p < 0.001$), Signage: 20.5% ($p < 0.001$)	Information Technology, Policy/system/practice change	"Study duration: 2.5 months. The 52 hotel restaurants recorded and reported the amount of food waste daily over the whole period."	2013	Norway

Table 2

2. Young et al (2017, Resources, Conservation and Recycling)(Young et al., 2017)	4398 responded to the second follow-up survey	Household	Self-reported via online survey of participants.	Drivers of food waste, social influence theory.	Using traditional and online (social media) methods to distribute information to customers of a large UK retailer to reduce household food waste and disposal frequency.	Online and social media information methods can be as effective as traditional methods of information dissemination. Note that only the e-newsletter outperformed exposure to magazine.	No exposure: 10% (p = < 0.05), Exposure to electronic newsletter: 19% (p = < 0.05), Exposure to Facebook intervention: 9% (p = < 0.05), Exposure to magazine (found online and in-store) 10% (p = < 0.05).	Information	Online self report, One month before intervention, two weeks after intervention, and five months after intervention.	2017	UK

Table 2

3. Schwartz et al (2015, Childhood Obesity) (Schwartz et al., 2015)	12 schools, 3 years (Annual measurement days) 400-500 students per day	Education	Measurement by mass flow of food from kitchen to plates to bin. Waste weighed.	No theories discussed.	Examining the selection and consumption of 4 food items (Fruit, Vegetable, Entrée, and Milk) before (2012) and after (2013 and 2014) USDA regulation updates were implemented to school lunches.	Menu updates led to increased selection of items (Fruit and Entrée) and reduced plate waste (Vegetables and Entrée's having significant reduction in waste).	Fruit: 3% (Not significant), Vegetable: 28% ($p = < 0.05$), Entrée 15% ($p = < 0.05$), Milk 5% (Not significant).	Policy/system/practice change	Over 3 years, one measurement per year per school, collected each year in April, May, or June. To calculate average weight of serving, three servings of all food available weighed prior to lunch period, Pictures of food on trays taken before and after consumption. Trays collected and remaining food left on trays weighed and recorded.	2015	USA

Table 2

4. Williamson et al (2016, Journal of the Association for Consumer Research)(Williamson et al., 2016a)	Multiple studies. S1 n=68, S2 n=100, S3A n=40, S3B n=40, S3C n=240	Education	Waste weighed (plate and bin waste) post experiments.	Food choice (physiological and psychological explanations) including Sensory Transference Effects, Psycholinguistic Transference Effects and Automatic Categorization Effects	Using multiple studies to investigated the hypothesis that plate disposability affects amount of food wasted in lab environment and at buffet lunches.	People waste more food when eating on disposable plates compared to permanent plates, if snack (S1) or a buffet meal (S3A, S3B and S3C). In S3A the plates were different on each consecutive day, S3B the plates were replaced half way through the meal (first 20 participants had permanent plates) and S3C, the sessions with and without disposable plates were 4 weeks apart.	S1: Permanent plates had a 51% reduction in FW compared to Disposable plates ($p < .05$). S3A: Disposable plate waste: 15.5%, Permanent plate waste 8.4% ($p < .001$). S3B: Permanent plates had a 33% reduction in FW compared to Disposable ($p < .01$). S3C: Disposable plate waste: 19.5%, Permanent plate waste 10.8%. ($p < .001$)	Technology	S1: one of measurement event, food weighed prior, waste collected after and weighted. "S3A and B: Total weight of the buffet food was measured in the kitchen prior to being served" "S3C: All food weighed before service, any uneaten food was scraped into a waste bin, and weighed. 2 days of observations. Measure: average weights of waste per plate."	2016	USA

Table 2

5. Schmidt (2016, Resources, Conservation and Recycling)(Schmidt, 2016)	N=217. (experimental N=108, control N=109).	Household	Self-reported level of perceived ability to prevent household food waste via survey of participants.	Environmental psychological theory	Use environmental psychological theory (pro-environmental behaviour) to tailor information to specific audiences (households).	Measured perceived ability to prevent household food, pre and 4 weeks after intervention.	12% increase in perceived ability to prevent household food in Experimental group 4 weeks post intervention ($p < 0.01$).	Information	Baseline and post intervention measurements of self reported food waste behaviours	2016	Germany

Table 2

6. Manomaivibool et al (2016, Applied Environmental Research) (Manomaivibool et al., 2016)	319 pictures	Education	Picture measurement of plate waste (fraction left on plate).	Theory of planned behaviour psycho-social factors that cause the generation of food waste.	Measuring the impact of an awareness campaign to reduce food waste on campus.	Collect baseline data via visual analysis and photos. The awareness campaign included photo diaries, table information and a social media component. Pictures of plates and waste rather than weights collected at baseline and during intervention. This provided analysis of probability of types of waste occurring. Plate waste decreased due to intervention.	Probability of types of food waste occurring, 2 categories significant. Rice and Noodles: before campaign probability=0.521, after campaign probability=0.331 ($p<0.000$). Meat: before campaign probability=0.186, after campaign probability=0.088 ($p<0.007$).	Information	Visual pictures food waste collected, 314 valid pictures taken at baseline, 148 post intervention.	2016	Thailand

Table 2

7. Dyen, Sirieix (2016,International Journal of Consumer Studies)(Dyen and Sirieix, 2016)	4 interviews, 3 observations	Education	Self-reported via interview of participants.	Food as an educational tool. Food to create social ties.	Observe social cooking workshops to understand the impact they have on the adoption of sustainable food practices, and on the social inclusion of participants.	Interviews and observations of cooking classes were conducted. Food Waste was discussed during the interviews and it was claimed that the cooking classes helped people to manage their food and reduce waste.	No statistics presented.	Information , Policy/system/practice change	Self reported waste reduction	2016	France

Table 2

8. Devaney, Davies (2016, Journal of Consumer Culture)(Devaney and Davies, 2016)	5 Households	Household	Food waste Audits	Social practice lens of food waste generation. Transition management theory, living laboratory methodologies.	Using home based laboratory interventions ("HomeLabs") to promote resource efficient food consumption and eating practices. This included food waste reduction.	Selecting 5 households that represent common household types in Ireland. 5 weeks of phased intervention. Each week covered a different FW topic. Week 1 included FW audit. Semi-structured interviews conducted during intervention. Food waste decreased in all households, (including reductions of up to 5.25 kg in Household M).	Overall food waste generation reduction of 28%	Information, Technology	Week 1 and Week 5 food waste audit. Food waste was collected by householders for 3 days in advance of their next researcher visit, with participants asked to make a record of the type of food wasted and the reason for wasting it. The gathered food waste was then weighed by the researcher.	2016	Ireland

Table 2

9. Ganglbauer, E., Fitzpatrick, G. and Comber, R. (2013, ACM Transactions on Computer-Human Interaction) (Ganglbauer et al., 2013)	14 households, 5 had FridgeCams for one month	Household	Self-reported via interview of participants.	"theory of practice" lens	Using the FridgeCam technology probe to monitor and intervene in the food waste practices (shopping) and generation of 14 households in Austria and UK.	Interviews and tours of all households to understand FW behaviours. FridgeCams deployed to 5 households for 1 months, with follow-up interviews indicating the usefulness of FridgeCams in reducing and preventing food waste.	No statistics presented.	Technology	Self reported waste reduction	2013	Multiple country (UK and Austria)
10. Whitehair, Shanklin and Brannon (2013, Journal of the Academy of Nutrition and Dietetics) (Whitehair et al., 2013)	540 university students, 19046 trays of food.	Education	Weighing of plate waste.	Elaboration Likelihood Model of Persuasion	Use Prompt ("Eat	Over 6 weeks (2 weeks baseline, deploy Prompt message, 2 weeks deploy Feedback message, 2 Weeks. study). Data from student surveys and tray waste collected. Prompt message resulted in 15% FW decrease. Feedback messaging did not result in further FW reduction.	15% FW reduction from baseline to Prompt Intervention. ($P<0.05$)	Information	6-week data collection period. Plate waste individually weighed.	2013	USA

Table 2

11. Lim,Funk, Marcenaro, Regazzoni, Rauterberg, (2017 International Journal of Human Computer Studies) (Lim et al., 2017)	S1 (n=27), S2 (n=6), S3 (n=15)	Household	Weight collected by smart bin. Self reported via interview, survey, and focus group of participants.	The Wizard of Oz approach, Contento's (2010), factors that influence food choices: biological predisposition, sensory-affective factors, person-related determinants, and social and environmental determinants.	Can the use of emerging technology (social recipe apps, food logging, and smart bins) reduce household FW.	Using interviews (S1), Focus groups (S2), and Home deployment (S3) to test the usefulness of social recipe apps, food logging, smart bins and food sharing as ways for reducing food waste. No FW baseline, so no measured FW reduction. App alone not enough to reduce FW. However App with smart bins "eco feedback" and other measures, FW reduction possible.	No statistics presented.	Technology, Information	Self reported waste reduction	2017	Netherlands
12. Jagau and Vyrastekova, (2017 British Food Journal) (Jagau and Vyrastekova, 2017)	2500 meals	Education	Visual coding of plate waste (fraction left on plate).	Behavioural insights and nudges, theory of psychic numbing	How effective is an in-restaurant information campaign advertising the availability of smaller portions sizes.	14 days of study (5 pre), 9, intervention). Measure % of plate waste (not weight), and number of portion types. No difference in food waste pre and post intervention. This could be due to 1) smaller sizes available and 2) imprecise measurement of food waste.	Post intervention the proportion of meals where consumers asked for smaller portions was higher (6%) than pre intervention 3.5% (p=0.0129).	Information	One week baseline, two weeks intervention. Measured % of food waste left on plate (not waste)	2017	Netherlands

Table 2

13. Lazell (2016 Journal of Consumer Behaviour) (Lazell, 2016)	None stated	Education	None stated	Human computer interaction	The intervention in this study consisted of a social media tool (Twitter). This tool allowed participants to inform others of food that would have otherwise been wasted within the university. Tool advertised via poster and social media.	Insufficient usage of tool to justify an in-depth reporting of measurement/ findings	No statistics presented.	Technology	Possible self reported waste reduction	2016	UK

Table 2

14. Martins, Rodrigues, Cunha, and Rocha (2016, Public Health Nutrition) (Martins et al., 2016)	151 fourth-grade children from 3 Porto primary schools who ate lunch. 1742 lunches during 14 days over eight different menus	Education	Weighing of individual meals and leftovers for all meals	No theories discussed.	How effective either intervention A, (designed for children and focusing on nutrition education and food waste) or intervention B, (designed for teachers and focused on the causes and consequences of food waste;) are at reducing plate waste when compared to a control group.	Physical weighing of individual meals and leftovers was performed on three non-consecutive weeks (baseline(T0), 1 week (T1) and 3 months (T2). The study results demonstrated that Intervention A (designed for children) was more effective at reducing plate waste than the intervention B (focusing on teachers). However, food waste reduction decreased between the short and the medium term only. Intervention A, a decrease in soup waste was observed. The effect was greater at T1. than at T2. The plate waste of identical main dishes decreased strongly at T1; this effect was not found at T2. Intervention B did not have a	Intervention A % waste Soups T1 −11.9 (SE 2.8) % T2 −5.8 (SE 4.4) %. Main dishes T1 −33.9 (SE 4.8) %; T2 −13.7 (SE 3.2) %; Intervention B % waste Soups T1 −6.8 (SE 1.6) % T2 −5.5 (SE 1.9) % Main dishes T1 3.7 (SE 2·6) %; T2 −5.4 (SE 2.4) %	Policy/system/practice change	Five day baseline, with plates, food and plate waste weight collected for each child. Percentage of plate waste was calculated as the ratio of edible food discarded per edible food served to children. Weighed again in first week and then again after 3 months.	2016	Portugal

Table 2

15. Cohen, Richardson, Parker, Catalano, and Rimm (American Journal of Preventive Medicine) (Cohen et al., 2014)	1030 Children, 5936 Meals.	Education	Weighing of average meals (10 weights) and individual weighing of all leftovers. 2 days of meal measurement pre (2011) and post (2012)	No theories discussed.	If the new school meal standards had an effect on the consumption, and waste of school meals.	The new school meal standards resulted in no changes in entrée or vegetable selection. Fruit selection increased significantly. Milk selection Decreased due to policy change. Changed. The percentage of foods consumed increased for entrees and vegetables. There were no significant differences in the percentage or quantity of fruit consumed.	Meals consumed per student (%) Entrée Pre 72.3,Post 87.9 p-value <0.0001; Milk Pre 64.0 Post 53.9 p-value <0.0001; Vegetable Pre 24.9 Post 41.1 p-value <0.0001; Fruit Pre 51.8 Post 55.2 p-value 0.10. Meals consumed per total # of meals (%) Entrée Pre 63.4,Post 73.6 p-value <0.0001; Milk Pre 62.4 Post 50.1 p-value <0.0001; Vegetable Pre 25.8 Post 40.3 p-value <0.0001; Fruit Pre 59.1 Post 56.9 p-value 0.05.	Information , Policy/system/practice change	2 days of plate waste measurement per year, post meal trays collected and each meal components waste measured separately.	2014	USA

Table 2

16. Freedman and Brochado Obesity 2010 (Freedman and Brochado, 2010)	1,475 students	Education	Weighing of plate waste.	No theories discussed.	If the reduction in portion size of French Fries would reduce plate waste. Portion sizes tested 88g, 73g, 58g, 44g	On average, all consumed 81.6% of the FF, regardless of portion size. As portion size decreased, a greater number of portions was taken, however even with more portions, few diners took/consumed/wasted more than at baseline.	Total produced (g) 88g (44,727 ± 6,328), 73g (42,299 ± 3,299), 58g (37,033 ± 3,767), 44g (35,150 ± 3,350); Total consumed (g) 88g (23,282 ± 4,227), 73g (24,158 ± 2,698), 58g (18,295 ± 4,794), 44g (17,846 ± 1,318); Consumption per diner (g) 88g (74.3 ± 2.2), 73g (71.4 ± 2.4), 58g (53.0 ± 2.5), 44g (52.2 ± 6.0); Total wasted (g) 88g (6,168 ± 265), 73g (5,098 ± 250), 58g (4,983 ± 283), 44g (4,242 ± 90);	Policy/system/practice change	5 week study (1 week baseline), weight of food and waste measured for each bag.	2010	USA

Table 2

17. Wansink, and van Ittersum, Journal of Experimental Psychology: Applied, 2013. (Wansink and van Ittersum, 2013)	Study 1 n=219 Study 2 n=43, Study 3 n=237, Study 4 n=135.	Hospitality	Weighing of plate waste. (S2)	Pool and Store Theory. The Delboeuf illusion.	A multi study paper examining how visual norms (plate size) effect the amount of self-service food taken. Only study 2 had waste measurement. Study 1: Assessed norms of portion size and bowl size. Study 2: Plate size (small vs large) and waste at an All-You-Can-Eat Chinese Buffet. Study 3: Plate size (small vs large) after lecture on plate size and waste. Study 4: solving the Delboeuf illusion (serving bias towards different bowls)	Study 1: For normal-sized dinnerware, portions are anchored to 70% fill level. The larger the bowl, the more people overfill. Study 2: Diners who selected the larger plate served themselves 52.0% more total food than those who selected the smaller plate. In addition to larger plates serving 52.0% more food, they also consumed 45.1% more, and wasted 135.2% more than those with smaller plates. Diners with larger plates wasted 14.4% of all the food they served themselves, compared with 7.9% (smaller plates). Study 3: overall larger plates served more food than with smaller plates. Smaller plates took more tacos.	Study 2: Large plate: cm2 of food served 1216.9, consumed 1072.5, wasted 144.4. Small plate: cm2 of food served 800.5, consumed 739.1, wasted 61.4 ($p < .01$). Study 3: lettuce salad (7.25 vs. 2.25 trays), vegetable salad (6.25 vs. 1.75 trays), beef (6.0 vs. 3.75 trays), enchiladas (6.5 vs. 3.5 trays), and fried fish (5.25 trays vs. 3.0 trays) soup (.75 vs. .75 trays), tacos (1.25 vs. 2.25 trays).	Technology	Study 1 - self reported size of portion Study 2- 4 restaurants, visual observation of 43 diners, with visual estimation of plate waste. Study 3 - 2 lines at one lunch event (209 individuals). Food weighed pre service and post service. No waste measurement.	2013	USA

Table 2