

# Household food waste: drivers and potential intervention points for design – an extensive review

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## Abstract

This review describes the consumer related material and socio-cultural drivers behind food waste found in academic and grey literature. The aim is to identify intervention points for design interventions to reduce household food waste. Within the reviewed literature, an array of different aspects of consumer food waste is studied such as consumer behaviour, attitudes, beliefs and values, quantifications and compositional analyses of food waste in Western countries, waste prevention and concrete design interventions. This illustrates that the problem of consumer food wasting practices is an issue that is complex and involves both socio-cultural and material factors. However, the literature is more focused on generating knowledge about the problem than on finding solutions. Thus, further research should attempt to find ways to test new ideas and interventions that could reduce food waste in households.

Keywords: food waste, design, sustainable behaviour, consumer, intervention, drivers, review

## 1. Introduction

Food waste is a contemporary environmental, social and ethical issue, which in a historical context is a result of moving from scarcity to abundance in Western society. The pressing issues of climate change, food security and economic development make food waste emerge on top of the agenda at the level of The European Union (European Commission 2011a) and The United Nations (FAO 2011, 2013, 2014), and thus on the agenda of governments across the world. Substantial amounts of food is wasted from farm to fork. In the EU households stand for about 53% of the food wasted within the value chain (Stenmarck et al. 2016). This calls for increased attention towards finding new ways of intervening into food waste practices within households. Scholars from a wide range of disciplines, applying quantitative and qualitative methods, have addressed food waste as a topic of research. Recent research has extensively mapped amounts, composition and demographic variables, as well as social and cultural antecedents of food waste - although the latter may still be somewhat underexplored (Porpino et al., 2015, Waitt and Phillips 2015). However, now is the time to focus on finding solutions.

Design thinking may be an approach to the problem of household food waste that could bring about new ideas. Within design research there has been some recent interest in this issue (Bucci et al., 2010; Farr-Wharton et al., 2012; and Ganglbauer et al., 2013), however the output is still modest. Thus there is still great potential in engaging the design community in this complex issue and spur practitioners to apply the problem solving tools that lie within design thinking. Several fields within design are suitable in different ways for researching the potential of interventions. For instance; Design for Sustainable Behaviour (DfSB), Practice Oriented Design (POD), User Centred Design (UCD), Service Design and Interaction Design. However, in order for the design community to contribute in a meaningful way it needs to have access to a solid foundation of knowledge, and what in design thinking is called “empathy”. Meaning both qualitative and quantitative research. Usually designers do not engage in an issue by compiling all relevant research from academia on a topic. They go straight into the field to build empathy. However, when dealing with an issue as complex as consumer food waste, this may not be sufficient to truly understand the drivers behind food waste and how to intervene. A mediator of knowledge can, as the authors attempt with this article, create a starting point for design thinking that would otherwise not be within reach.

This article reports a synthesis of consumer-relevant studies of food waste, with the aim of finding potential intervention points for design. Although, some literature on consumer food waste has been summarized within recent reviews and reports (E.g. Aschemann-Witzel et al. 2015; Canali 2014; Parfitt et al., 2010; Thyberg & Tonjes 2016; van Geffen et al. 2016), there is no extensive review of household food waste drivers found that is structured in a way that connects drivers with possible and existing interventions. In order to move from generating knowledge to finding solutions it is imperative that these two elements are seen in connection. The questions we ask are: What are the drivers of food waste, and where can designers intervene in order to influence consumers to waste less food?

The first section of the article describes the methods used in the relevant studies of food waste. The second section looks at the drivers behind food waste related to behaviour, practices, attitudes, beliefs and values, while the third section reviews literature related to material design interventions concerning storage, fridge/freezers and packaging. Finally, food waste drivers and their relationship to suggested interventions are discussed, and suggestions for further research and design interventions are made.

## 2. Method

The search was conducted using the database Oria and Google Scholar. Oria covers a large number of databases, including Scopus, Web of Science and ACM Digital Library. The results were limited to articles in peer-reviewed journals, written in English between 2000 and 2015. Older publications than from 2000 were not included in order to compile the research most up to date with social developments, thus most relevant to possible interventions today. Relevant articles that describe the relationship between food waste and consumer behaviour were identified, using the search term “Food waste” in combination with the words “household”, “packaging”, “consumer”, “behaviour” and “design”.

The reference lists from the identified relevant publications were reviewed for more relevant literature. A final inventory was made of in total 112 scientific sources, sorting them according to different criteria such as topic, academic field, country of origin and year of publication. Additionally, online available reports from three major food waste initiatives currently running in Europe were reviewed and the most relevant selected. These include:

- **ForMat** (2010-2014) was a project where the retail industry, food industry, organizations and governments collaborated to identify and reduce food waste in Norway (Hanssen & Schakenda, 2011).
- **WRAP** (Waste & Resources Action Programme) is an ongoing registered charity in the UK that works with different partners within academia, businesses and communities. WRAP is the organisation that has, since 2004, published most extensively on quantification and composition of food waste, as well as issues related to attitudes and socio-demographic aspects of food waste behaviour.
- **FUSIONS** (Food Use for Social Innovation by Optimising Waste Prevention Strategies) was a 4-year EU project (August 2012 to July 2016). Amongst many other food waste related issues it focused on developing a common method for gathering food waste statistics, in order to be able to compare across countries.

The literature on household/consumer food waste is diverse and covers many angles. It reports on food waste quantities and composition, consumer behaviour, attitudes, beliefs and values, waste prevention and design interventions. The selection of literature for this review has however been focused on connecting the food waste drivers that can be identified within this literature with possible and existing opportunities for intervention.

## 3. Researching food waste

Many academic fields show an interest in the problem of food waste, such as sociology, psychology, design, economics, Human Computer Interaction (HCI), waste management, engineering, geography, dietetics, and biology. As illustrated in the table below an array of different research methods are applied in order to define, quantify, describe and understand household food waste. Several of these methods are familiar to the design community and routinely applied in design processes based on design thinking.

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Methods	
Questionnaire	Prototyping and testing
Survey	Participatory design session

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Interview	Food waste diary
Stakeholder interviews	Focus group
Literature review	Case study
Market review	Inventory
Waste weights	Photo documentation
Participant observation	Life Cycle Analysis (LCA)
Shop-a-longs (Contextual Enquiry)	Waste flow analysis
In-home-tours (Contextual Enquiry)	Waste composition analysis
Go-a-longs (Contextual Enquiry)	Action research
Experiments with design intervention/technology	
Discrete Event Simulation (DES)	

Table 1. Methods used in studies of food waste

This review focuses on understanding household food waste from a consumer perspective. Some methods are thus more applicable than others. For instance do focus groups and interviews provide a deeper understanding of how practices are interconnected and how they affect food waste, often deeper than questionnaires and surveys are able to provide. Surveys are very useful for creating a broad view of waste related issues, but not for providing an in depth analysis of the different findings that emerge from the material. For instance, a survey may reveal that people do not plan their shopping or use shopping lists, but it does not necessarily reveal why. This can better be explored through qualitative studies.

By following consumers during shop-a-longs and in-home-tours, and in general by observing them in an everyday setting, it may be possible to gain deeper understanding of how consumers act and how they may be influenced by their surroundings. Because there is a gap between what people say they do and what they actually do, food waste diaries may be a more accurate way to assess people's food waste than self-reporting in surveys, because people generally tend to underreport the quantities of food waste by 40% (Quested et al., 2013a). Many of these methods are relevant to design research and have been identified as key methods to explore design interventions for sustainable behaviour (Daae and Boks, 2015).

However, it is not sufficient to understand why people waste food, what they waste and how much is also important to know in order to generate ideas on how to intervene. Great effort has been invested in mapping amounts of food wasted in affluent countries during the last decade. Several quantitative studies have been conducted in Europe recently on how much food is wasted in households in countries including Finland, UK, Sweden, Denmark and Switzerland (e.g. Beretta et al., 2013; Gjerris and Gaiani, 2013; Hanssen et al., 2013; Katajajuuri et al., 2013). Studies also provide knowledge about what food categories are most wasted - these are fresh fruits and vegetables, bread and other bakery goods, and leftovers (Foley and Hilton, 2011; FSA, 2016; Hanssen, 2010; Hanssen and Schakenda, 2011; Hanssen et al., 2013; Koivupuro et al., 2012; Quested et al., 2013a; Stenmarck et al., 2011; Stensgård and Hanssen, 2016; Ventour, 2008). Foods with short shelf lives e.g. dairy products, meat, and vegetables are also more likely to be wasted (Sonesson et al., 2005) and amount to about 2/3 of total household food waste in Norway (Hanssen & Schakenda, 2014).

Common methods to describe the composition and character of food wasted include waste composition analyses, surveys, and food waste diaries. Most studies of food waste do however rely on self-reported amounts stated by consumers in surveys. In order to get more accurate results studies are also increasingly utilising food diaries and food waste composition

analyses. A general problem in studies of food waste is that waste levels are underreported and efforts and environmental awareness exaggerated (Neff et al., 2015).

#### 4. Food waste drivers

Food waste occurs within many different but interconnected practices of everyday life such as shopping routines, storing, cooking, and eating. Consumers are not aware of all drivers behind the food they waste because they are deeply entangled in the routines of everyday life (e.g. Quested et al., 2011). Sociological studies of food waste describe how food practices are socially organised around everyday life activities in households (Evans, 2011ab, 2012, 2014), and explain how cultural, social, material and temporal aspects of food waste practices determine if food is perceived as edible or inedible, and how they should be studied in context (Fiddes, 1995; Mavrakis, 2014). Also material properties of food itself and the material infrastructure in terms of living situation, available space for storing food, geographical access to stores and means of transportation have great impact on food waste as they influence every day routines (Quested et al., 2011; Waitt and Phillips, 2015). Thus, decisions and actions made long before food is wasted may actually be the root of the cause, such as choosing what and how much to buy, how food has been treated before the consumer takes it home, how it is stored when it arrives in the household, and how meals are planned.

Seen in connection, the literature illustrates that food is wasted in households because of how it is valued and because some values people try to live by are not always compatible. Our values influence our awareness and attitudes, but so does our lifestyle and the required convenience we need in order manage everyday life. Lifestyle is mainly defined by household constellation and everyday practices that influence important food waste related practices such as planning of purchases, handling of leftovers and management of food risk. Additionally, there are an array of material and structural aspects that shape and restrain our interaction with food, for instance storage, packaging, the fridge etc. In order to reduce food waste levels cultural and social norms and values residing within people as well as material and structural conditions out there in the experienced world need to be addressed simultaneously. The figure below shows an illustration of interrelated major food waste drivers.

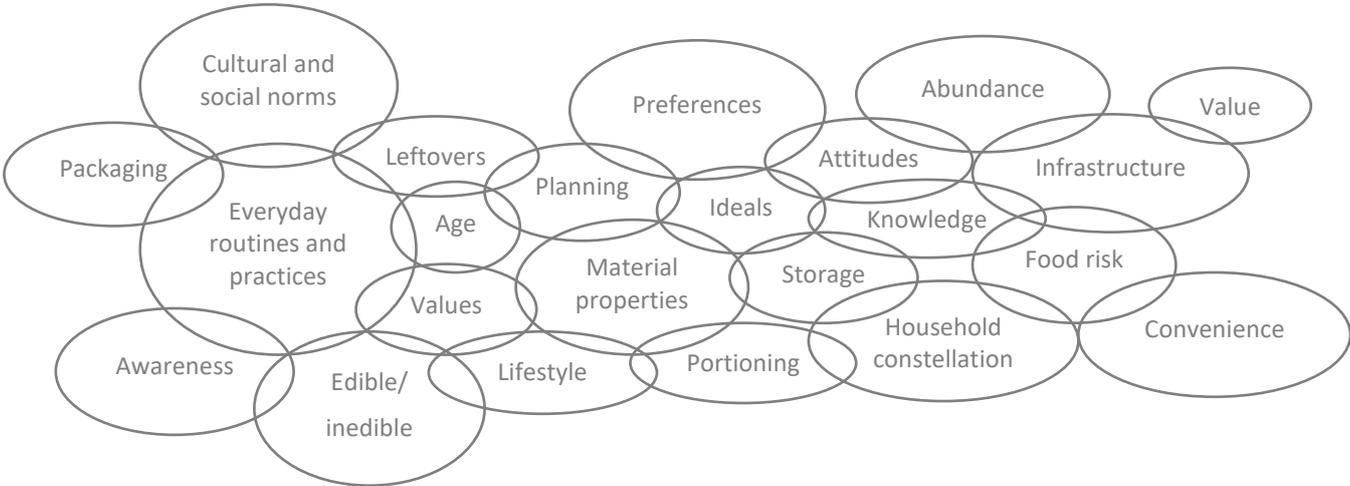


Figure 1. Major food waste drivers.

In the following sections non-material, material and structural drivers of food waste identified in literature are described, and subsequently linked with interventions suggested in literature and some already on the market. The analysis illustrates the status quo and points to where further attention is needed.

#### 4.1 Do we realise the true value of food?

Apparently not, since consumers in the EU waste 53% of the food they buy. However, educating people may not reduce food waste because knowing and valuing is not enough to change norms and practices only indirectly linked to food waste. The following section addresses food waste drivers connected to values, knowledge and attitudes described in literature.

##### 4.1.1 Values and the perceived value of food

The abundance of food available at low prices in affluent countries influences how food is valued and how much food is wasted. Scarcity and rising food prices would inevitably reduce food waste in households (Aschemann-Witzel et al., 2015). In the absence of this condition, it remains a challenge in the Western world, to create interventions that will make a difference.

Research gives conflicting answers to the question of how income influences food waste. According to Stuart (2009) and Parfitt et al. (2010) affluent households waste more food than low income households because they can afford to, and there is a clear correlation between the proportion of income spent on food and the amount of food wasted. However, there is evidence that low-income households waste a substantial amount of food as well (Porpino et al., 2015), and that there is no significant relationship between household income and attitudes towards food waste (Melbye et al., 2016). Low income households strive for abundance because they do not want to be identified as poor – food is seen as wealth (Porpino et al., 2015).

Age is a significant factor in how food is valued within different consumer groups. British people over 65 years of age waste less food than other age groups (Quested et al., 2013a). However, this is not motivated by environmental concerns, but rather by financial and moral considerations about wastefulness. Researchers hypothesize that people over 65 are influenced by their past, having experienced times of scarcity; they bring with them a different “education” when it comes to handling food than other age groups (Brook Lyndhurst, 2007; Melbye et al., 2016; Quested et al., 2013a). However, this “value nostalgia” of efficiency and thrift (Brook Lyndhurst, 2007) is also found to be valued by younger consumers. Hval (2012) finds that her informants often agree that food should not be thrown away, but cannot really explain why. It is “just the way it is”, something they might have learned growing up that has been internalized and incorporated into routines. Some argue that wasting food is the same as wasting money. Others point to the ethical implications of wasting food when others go hungry.

The connection between food waste and environmental issues is not necessarily established within peoples’ minds (Graham-Rowe et al., 2014; Stancu et al., 2016). A “global warming fatigue”, makes messages focused on environmental issues tiring, just like messages against smoking or obesity (Brook Lyndhurst, 2007). Thus, targeting food waste prevention campaigns at the environmental conscience of people may have a limited effect. Australian, US and UK studies show that consumers are more motivated by saving money than by protecting the environment when it comes to food waste (Baker et al., 2009; Graham-Rowe et al., 2014; Neff et al. 2015; Quested et al., 2013b). Moreover, money is found to trump environmental concerns even among environmental aware groups studied (Graham-Rowe et al., 2014).

Nevertheless, people (most often women) often feel guilty when wasting food because they feel they are not doing a good job managing the household and providing for the family (Brook Lyndhurst, 2007). Thrift, sacrifice and family relationships are in the centre of Cappellini and Parsons (2012) analysis of food waste related to the creation and handling of food leftovers, and the mother often sacrifices her preference in favour of the family. The “good provider identity” (Graham-Rowe et al., 2014) or the “good mother identity” (Porpino et al., 2015) are therefore seen as barriers to minimize food waste.

Both what value consumers attribute to food, and what values are triggered in the management of food, is important when analysing the drivers behind household food waste. Mavrakis (2014) argues that monetary value, novelty value, resource value and the value of social relations may all determine disposal decisions. Unsurprisingly, efforts are greater to preserve food that had a high perceived value, for instance by having a high price, by being something new and interesting, by having required work and effort to grow, or that had been made by a loved one. Furthermore, freedom of choice is highly valued and deeply embedded in the consumer identity (Brook Lyndhurst 2007). People feel that they should be able to consume any food they like at any time. This abundance of choice influences food waste quantities.

Both Mavrakis (2014) and Hval (2012) find that how the value of food is constructed influences the amount of food wasted. Small amounts of left overs are for instance often discarded because they have low value for a new dish. Food such as rice, potatoes and pasta is seldom saved for a later meal, it is cheap and difficult to portion (Hval, 2012). Hval finds that her informants do not adjust their attitudes to their actions - they rather manipulate food in a way that it becomes “OK” to throw it away because they have no other choice. For instance by letting it go bad in the fridge. They still hold the attitude that it is wrong to waste food, but in those particular cases where food has become inedible it is ok. Through this Hval shows that wasting food is not a mindless activity conducted by people with “bad” attitudes, but a process involving a complex network of social interaction, routines and practices, material infrastructure, emotions and knowledge. Furthermore, different ideals can collide such as the ideal of not wasting food with the ideal of offering guests an abundance of food.

#### 4.1.2 Awareness and attitudes

The majority of consumers are not conscious of the food they are wasting, and see food waste as inevitable and a mere fact of life, and in that way unavoidable and therefore acceptable (Brook Lyndhurst, 2007; TÆNK et al., 2012). The effect of raising consumer awareness about food waste is however debated amongst researchers. Some studies conclude that awareness needs to be raised in order to change food wasting behaviours (Quested et al., 2011), as it will cause a sense of responsibility and guilt, which can influence practices in a way that reduces food waste (Grandhi and Singh, 2016; Parizeau et al., 2015; Quested et al., 2013b). Other studies find that interventions aimed at increasing awareness do not sufficiently reduce food waste, because it is caused by complex processes that are in motion in order to feed the household, and that raising awareness does not change these processes in practice (Watson and Meah, 2013). Food practices are part of daily routines, and people use mental short cuts to get through the day most efficiently (European Commission, 2011b). Moreover, Cappellini and Parsons (2012) find that attitudes and lack of knowledge and skills are not the main problem for reducing food waste, and that blaming consumers is unproductive. Evans (2012) proposes therefore that efforts be targeted at the material context of food practices such as for instance packaging sizes in order to make food products better adapt to everyday challenges (Evans, 2012).

Moral awareness may define people's intentions not to waste food, but does not necessarily impact behaviour and food waste (Stefan et al., 2013). The Theory of Planned Behaviour (TPB) suggests that intention is connected to awareness, knowledge, and attitude, and hence determines behaviour (Graham-Rowe, Jessop and Sparks, 2015; Visschers et al., 2015). There is however the problem of the intention-behaviour-gap (Ajzen and Fishbein, 1980; Sheeran, 2002) - intentions to avoid food waste may not lead to behaviour because of lack of actual control, due to for instance the behaviour of other family members, or lack of appropriate tools (Graham-Rowe et al., 2015). Ganglbauer, Fitzpatrick and Comber (2013) derive from this that design interventions should support positive intentions to avoid wasting food.

A paradoxical consequence of persuading people (through raising awareness and education) to do something for the environment, such as composting food waste, has shown to make them feel that they are already 'doing good', and that there is no need to make an effort to reduce food waste (Brook Lyndhurst, 2007). This suggests that how people perceive their environmental efforts does not necessarily reflect the environmental impact of their practices. People make many excuses for not making an effort to reduce food waste such as 'Supermarkets and restaurants waste more', 'The problems don't immediately affect me', 'What's the point in me changing if others won't?', 'Half of my food waste is peelings', and 'There are other, bigger, issues to contend with' (Brook Lyndhurst, 2007). These reasons partly externalize the responsibility of food waste, partly deny that it is a problem, as well as express a sense of helplessness.

#### 4.2 The hurdles of everyday life – convenience is everything!

As the organization of the household has changed in recent history, with the increasing participation in work life by women, so has the management of food, with convenience gaining importance in order to free up time (Jackson and Viehoff, 2016). Danish consumers argue that what is not convenient to do in a busy everyday life will not be done in the long run (TÆNK et al., 2012). This is symptomatic for the ever-increasing demand for convenience in food provisioning (Bava et al., 2008). Consumers are constantly working to minimize inconvenience (Graham-Rowe et al., 2014) and perceived constraints. This causes trade-offs between ideals and convenience (Bava et al. (2008). Ideals such as keeping leftovers, managing food risk, eating healthy, being hospitable, planning, and food diversity (Southerton & Yates, 2015). Moreover, the creation of excess food has become normalized within the interrelated practices of everyday life (Evans, 2014). The next section will address how household composition, lifestyle and practices are driving food waste.

##### 4.2.1 Households and lifestyles

Research concurs that age and gender influences food waste amounts - older people waste less than younger people, and women more than men. (E.g. Brook Lyndhurst, 2007; Jørisen et al., 2015; Melbye, Onozaka and Hansen, 2016; Quedsted et al., 2013b; Secondi et al., 2015). According to a comprehensive study conducted by WRAP in the UK in 2008, single person households waste the most food per capita. This result concurs with results from studies in Australia (Baker et al., 2009), Finland (Koivupuro et al., 2012), and the EU (Canali, 2014). Food practices of young food consumers are characterized by pleasure, improvisation and social activity, but also by a view of it simply as necessity and contributor to health. Hanssen and Møller (2013) find that Norwegians over 40 become more aware about food waste as a problem and are more likely to reduce their waste.

Recent research shows that household sizes, life phases and constellations greatly influence food practices and food waste quantities. Planning for shopping and meals is more difficult in some life phases than in others. As formulated by Watson and Meah (2013:10) it is within a “mess of practices and routines through which food provisioning is accomplished within a household (...) This ongoing accomplishment demands coordination of complex flows and relations between foods, products, technologies, skills, meanings, values and purposes, all within the spatial and temporal conditions of people’s lived days”. Unsurprisingly, households without children have much more freedom in how they organize food practices (Comber et al., 2013). Families with children produce more total waste and types of food waste, but less per capita – they also more often plan for shopping and buy in bulk (Parizeau et al., 2015). An OECD Working Paper states that “the presence of children under 5 years of age has a positive significant impact on food waste” (Millock, 2014:20). It can be difficult to foresee how much food children eat at each meal, which often results in preparing too much. Also, lunch boxes that children take to kindergarten and school are often not finished, and food waste from this source seems inevitable and out of parental control (TÆNK et al., 2012).

The impact of unpredictable busy lifestyles on food waste is an issue that emerges in many studies on food waste and consumer behaviour and practices (e.g. Bava et al., 2008; Comber et al., 2013; Evans, 2011a;). The most important aspect of food practices as expressed by informants of many studies is that eating has to be fitted around main everyday activities, such as work and socializing (Comber et al., 2013; Halkier, 2009). According to Evans (2011b) disruptions in everyday food practices are a main cause of food waste. This causes a mismatch between the time slot in which fresh food can be consumed and other household activities. Family members not eating together, but at different times has also be found to cause food waste (Brook Lyndhurst, 2007). Time is often restricted, and many people are concerned that quick food is not healthy food, which is a worry they often encounter when trying to fit food into their busy timetables (Comber et al., 2013). In the end, food consumption is about caring for oneself and those that are close (Watson and Meah, 2013).

#### 4.2.2 Planning

A busy lifestyle and a family with children makes it difficult to plan food provisioning, meals and food stock. This is identified as a significant driver of consumer food waste. However, not only families with children do not bother planning, this is a general phenomenon across consumer groups. Few consumers make shopping lists, younger people more seldom than older. Comber et al (2013) find that a third of their informants use shopping lists but only for items they might forget. The shopping list serves as a reminder rather than a detailed plan for exactly what items to shop. Many consumers go for a weekly large shopping trip and then add one or two top-up-shops (Quested et al., 2013b). There are both planners and improvisers among consumers; those who plan tend to have a better overview of the stock at hand and thus avoid overbuying (Farr-Wharton et al., 2014). The improvising consumer seldom makes plans for shopping or meals; food products bought and the meals prepared are rather a result of improvisation. For them, it is important that preparation and eating of the meal is pleasurable and social (Halkier, 2009). Flexibility and choice is highly valued by consumers. Planning meals for a whole week can be difficult and tiresome and feel inflexible (TÆNK et al., 2012). Stocking food is thus a strategy often used for being set for all eventualities (Graham-Rowe 2014). To have food available just in case can save time, but it can also cause food waste, because it becomes unpredictable how and when stocked food will be consumed. Buying food in bulk that will not perish, such as canned food and freezer food, in order to have food available

without wasting it, is a strategy that could reduce food waste by over stocking (Comber et al., 2013).

#### 4.2.3 Leftovers

This lack of planning often results in overstocking and over preparing of food. Leftovers is the category of food waste that consumers are the least aware of (Brook Lyndhurst, 2007). According to Mavrakis (2014) laziness and safety issues are the main reasons for leftovers not being eaten. The feeling of disgust towards leftovers is another problem voiced by informants (Watson and Meah, 2013). Waitt and Phillips (2015) see the refrigerator as a means to avoid disgust, and to maintain boundaries between that which is fresh and that which is spoiled, edible-inedible, clean and dirty. Furthermore, they see the practice of piling up left-overs in the fridge as both a sign of care (for the family) and of wastefulness.

What happens with leftovers is determined by different material and socio-cultural aspects of food consumption. Socio-cultural aspects may pertain to preferences of the other family members and what they consider a proper meal (Cappellini, 2009), how everyday life is organized and planned, and if serving leftovers is compatible with “the good provider”/“good mother” identity (Evans, 2012; Graham-Rowe et al., 2014; Porpino et al., 2015). Material aspects may relate to the organization of the fridge, and how leftovers are stored.

People are generally not good at saving and eating leftovers. They prepare too much food because they do not know how to portion or do not care, and because they are afraid that there will not be sufficient food, especially for special occasions with guests (e.g. Brook Lyndhurst, 2007; Mavarkis, 2014; TÆNK et al., 2012). Many consumers routinely buy too much food every week, and then struggle to consume all of it. The reason is often that a food product is bought for a specific meal, and that the quantity bought is too big (Evans, 2011b). Portioning is something many consumers find difficult. However, some people cook more than they need on purpose to store leftovers in the fridge or freezer in order to save time on a later occasion (Mavrakis, 2014). Even if they do save food in containers in the fridge, they may forget about it and/or find it undesirable to eat after a while, and dispose of it after all.

Leftovers are often put in the fridge after the meal in order to postpone any uncomfortable feelings that may result from wasting it immediately (Evans, 2012; Waitt and Phillips, 2015). Porpino et al. call it a “maturation time” which will reduce perceived guilt. This use of time as a way of ridding oneself of responsibility is also found by Evans (2011b). Even though the intention is to eat it later, food may be forgotten in the fridge and thrown in the bin at a later time when it has gone bad and it is “easier” to do so (Hval, 2012). This shows that people may find it difficult and/or undesirable to use their leftovers in new dishes; because they desire to eat something new and fresh, or because they are uncertain if it is still good to eat. A survey in Australia shows that many people plan meals according to what they desire to eat rather than what is in the fridge (Baker et al., 2009). Several campaigns across Europe (e.g. Love Food Hate Waste (UK), Matvett (Norway), Kliekipedia (the Netherlands) and Stop Spild av Mad (Denmark) try to inspire use of leftovers through websites and apps providing tempting and easy recipes with leftover foods. However, utilizing this information requires time, effort and dedication that might not be present in every-day-life, and may only appeal to consumers that already have the intention to prevent waste.

Social media platforms that aim to connect people with excess food with people who want a home cooked meal are emerging, but there are some barriers to this kind of distribution of leftovers both related to social norms and food risk. Giving excess food away may be suitable for redistributing leftovers, but according to Evans (2012), people may experience this as being

too much within the perceived private sphere of food preferences and food skills, causing potential embarrassment and loss of privacy.

#### 4.2.4 Food risk

There is a conflicting relationship between reducing food risk and reducing food waste (Watson and Meah, 2013). According to Neff et al. (2015) literature shows that people have different ways of judging if food is still fit for consumption. Date labels and use of smell and visual judgements are the most practiced ones. A Canadian study shows that people who use the highest number of strategies to determine edibility tend to waste more food than those relying on only one or two strategies, for instance look and smell (Parizeau et al., 2015). This is probably due to having more occasions for defining something as waste. Most people are aware that different food poses different levels of risk; meat being high risk and vegetables low risk. Food management in families is often determined by emotions and sense of responsibility to 'provide and protect' (Brook Lyndhurst, 2007). Causing food waste is not something most consumers take lightly on, rather the opposite, many consumers are troubled by it. However, avoiding risk and ensuring food safety is a priority over avoiding food waste (Evans, 2011a; Farr-Wharton et al., 2014). People do not want to risk getting ill and rather dispose of food that could be edible than take that risk (Graham-Rowe, 2014). Thoughts of health are closely connected to food risk and nutrition. Some people report to buy lots of fruits and vegetables as they are healthy, but when it comes to it they do not eat them (e.g. WRAP, 2007). Sometimes good intentions come in conflict with each other, for example continuously putting fruit out in a bowl on the counter to encourage the family to eat healthy, but resulting in high amounts going bad every week (Mavrakis, 2014).

### 4.3 Managing food stock in households

Wrong and too long storage is a significant driver of food waste. The storage of food is most often connected to fridge/freezer practices and packaging as described above, but food is also stored outside the fridge/freezer. In the following section the literature addressing storage, packaging related drivers of household food waste is presented.

#### 4.3.1 Storage

Farr-Wharton et al. (2014) argue that storage is the most critical practice to address when aiming for food waste reduction, and that consumers should be enabled to organise food storage better to allow for easier location of food items. Campaigns such as the British Love Food Hate Waste, the Danish Stop Spild av Mad and the Norwegian Matvett provide detailed advice online as to how different food products should be stored, however the extent to which this information reaches consumers is uncertain. There are also conflicting advice given on this by different parties. For instance, WRAP advises to store tomatoes in the fridge for optimal freshness (WRAP, 2008), but in Norway the Norwegian Food Safety Authority advises to keep tomatoes outside the fridge (Matportalen.no, 2016). This may pertain to different goals, where keeping them in the fridge will make them last longer, whilst keeping them outside gives them more flavour. However, some food may be damaged by storing them at too low temperatures such as bananas, melons, papaya, and avocado. How to store different kinds of fruits and vegetables seems to cause the most confusion amongst consumers and the practices are diverse. Fruit and vegetables release ethylene gas that causes deterioration, thus WRAP recommends using

polyethylene bags to store the most wasted fruits and vegetables. Matprotalen recommends that some vegetables such as potato, carrot, asparagus and chicory should not be exposed to light because they will turn bitter and sprout. Furthermore, keeping the moisture balance and avoiding decay at the same time is a challenge, as well as keeping products that ripen away from fruits that release much ethylene gas. The ideal for fruits and vegetables not stored in the fridge is to be in a cool place, about 10-15 °C.

A recent report from the UK Food Standards Agency shows that consumers are confused about when food can be frozen, how long it can be frozen, and if it is safe to freeze cooked meat (FSA 2016).

Refrigerators and freezers play an important part in the modern household, enabling convenience, freshness and food safety (care) (Waite & Phillips, 2015). Changing practices related to incorrect storage and wasting food after an arbitrary time-period, as well as correct use of fridges/freezers and packaging will prolong the lifespan of food.

How food is placed and moved around in the fridge has considerable influence on food waste - visibility and timely consumption is essential, and the fridge is not a neutral part of this process. Two categories of solutions are suggested in literature pertaining to fridge and freezer use and reduction of food waste. The first solution category to reduce food waste focuses on improving information, labelling and advice, to encourage consumers to refrigerate and freeze food that could become waste. The second category suggests technology-oriented designs (such as apps) to help people get a better overview of stock and to plan better for their meals.

Freezing food is often used for unforeseen events, such as more people for dinner than usual, or to enable flexibility when days are difficult to plan due to for instance working hours (Comber et al., 2013). Many consumers also state that they sometimes cook in batches to freeze or refrigerate for a later meal in order to save time and avoid food waste (Graham-Rowe 2014). Freezing food to avoid waste is mainly done by those who find time and convenience more important than freshness (Mavrakis, 2014). No reference was found in literature to reasons for freezing food related to buying in bulk because certain products are temporarily on offer (like frozen pizzas or ice cream).

Many consumers in the UK are uncertain about what food is suitable for freezing; freezing advice on packaging is usually absent (Brown et al., 2014; George et al., 2010; Maxey, 2010). Encouraging people to freeze food to avoid food waste by providing more and simplified information, labels and advice is recommended. Lowering refrigerator temperatures and ensuring food stays cold from store to home can also reduce household food waste (Brown and Evans, 2012, Brown et al., 2014; George et al., 2009, 2010). Better storage advice on packaging to refrigerate food that is sometimes kept outside the refrigerator, but will stay fresh longer in the fridge, such as apples and carrots, is suggested by Johnson et al. (2008). Emissions caused by increased use of energy by freezing food and lowering refrigerator temperatures are far smaller than those caused by food going to waste, which justifies the recommendations (Brown and Evans, 2012; Brown et al., 2014).

#### 4.3.2 Packaging

The role of food packaging is to protect, preserve, inform and seduce. It plays an important role through the whole value chain of food from farm to fork. A Swedish study (Williams, 2011) estimates food loss due to issues with packaging to be 20-25% of household food waste. Excessive packaging sizes, difficulty completely emptying packaging and date labelling were reported to be main causes for food waste related to packaging. A report by WRAP (2011) estimates that approximately 20% of food waste in the UK is discarded due to being out of date,

and that it is the most important reason for 30% of disposal decisions. Nevertheless, mere understanding does not necessarily influence action; factors such as perceived health risks may be more important, as discussed earlier. At home date-labels are most often used to justify or confirm the disposal decision, not so much when deciding what to eat. As could be expected, simple clear formats are most easily understood. The study shows that younger consumers tend to rely more rigidly on the date to evaluate food safety and when to discard compared to older consumers. The most risk sensitive consumers depend strongly on, but often misinterpret date labels when using them to determine safety. WRAP (2011) argues that how people use date labels is often related to their confidence in their own knowledge and skills with food. Attitudes and practices related to food planning, risk, leftovers and food expiry are found to be significant in how date labels are interpreted. Unsurprisingly, the majority of consumers would purchase products with the longest use-by periods, and they pay more attention to date-labels on high safety risk products such as meat and dairy products. To optimise the use and understanding of date labels, WRAP (2011) recommends further clarification, removal of 'display until' dates, consistency within product categories, label redesign for better interpretation, improve storage and freezing guidance.

In the debate about the environmental impact of packaging, the material of the packaging itself is often the focus of attention. Consumers frequently have negative attitudes towards packaging when asked in context of the environment - however, Plumb and Downing (2013) find them to be equally concerned about food waste. This contradicts findings from Brook Lyndhurst (2007) that people are significantly more aware of throwing away packaging than food waste, and consider it a bigger problem, underestimating the amount of food waste they are actually wasting. Scholars generally agree that for packaging, the function of preserving and protecting food is significantly more important in an environmental perspective than reducing packaging material or making it more biodegradable (Silvenius et al., 2011; Wikström and Williams, 2010; Wikström et al. 2014; Williams, 2011; Williams et al., 2012). Less packaging may mean more food waste, and often trade-offs need to be made between the environmental impacts of packaging versus those from food waste (Verghese et al., 2013). The balance between packaging and food waste is influenced by what kind of food product is analysed. For example in the case of cheese, large increases of packaging impact can be justified in order to preserve it (Verghese et al., 2015; Williams and Wikström, 2011). This is not the case for ketchup, where the packaging has a high environmental impact relative to its content. There is however, great uncertainty about the impact packaging design may have on consumer behaviour and thus on real food waste reduction through changes in packaging, and urge for more research in this area.

Date labelling on packaging is a way to create trust and distribute responsibility in the relationship between producer/retail and consumer – which has become more important as consumers have less and less knowledge of the place of production (Watson and Meah, 2013). There are two sorts of date labelling, the "use-by-date" and the "best-before-date". The latter pertains to freshness and quality, and not to decay or health risk. Wansink and Wright (2006) suggest that there "may be more to lose than to gain from freshness dating". They find that perceived quality of the product decreases substantially from the first day after the "best-before-date has passed.

Consumers often use rules of thumb instead of checking storage guidance on every product. They are also sceptical towards information that does not resonate with their own experiences. For instance, they more often follow freezing guidance on packaging (e.g. freeze on day of purchase or freeze before use by date) if it corresponds with perceived speed of deterioration of the product (WRAP, 2011). Nevertheless, reported use of storage guidance is very high – it is however unsure if it pertains to product quality or safety.

#### 4.4 Top-down control of food waste practices

Is it possible to control consumer food waste practices through laws and regulations? As of today this option is not particularly well explored. However, there are a few examples of governments attempting just that.

Policies and regulations across nations aim to a great extent to increase recycling of food waste and diversion of food waste away from landfills through for instance landfill tax, incineration tax and “pay as you throw” (PAYT) (Chalak et al., 2016). The weight based billing system or PAYT, has proven to increase recycling in Sweden (Dahlén and Lagerkvist, 2010). However, the effect on reducing food waste is not investigated specifically. It is however expected to have an impact on amount of food waste as well. This is also concluded by a new report from the FUSIONS project that investigates the potential of market based instruments and economic incentives as mechanisms in international policy for reducing food waste (Aramyan et al., 2016). Thyberg and Tonjes (2016) propose to change the design of municipal waste collection systems, such as a transition towards volume based systems or reducing collection frequency. The economic incentive is seen as a tool to reach those that are not reached by awareness campaigns, but the risk of waste being discarded in illegal ways, such as dumping and burning, is considerable. In Seoul, South Korea a new high-tech system for weight based billing through the use of key-card-registration is being tested in selected urban areas (YALE Environment 360, 2016). The effect of this innovation is yet to be measured, and the possible diverting of food waste through other conduits to be discovered.

Several studies have indicated that there may be a connection between household food waste collection services and reduction in the amount of food wasted (E.g. Changeworks, 2010; Defra, 2009; Mills and Andrews, 2009; Parfitt and Bridgwater, 2010; Robb and Parfitt, 2009; Somerset Waste Partnership, 2010; Tucker and Farrelly, 2015; Waste Watch, 2007). Researchers have suggested that seeing the amount of food collected in the separate bag within the household may influence food waste related attitudes and behaviours (E.g. Miliute-Plepiene and Plepys, 2015). However, a literature review undertaken by WRAP (Holey and Hilton, 2011) concludes that there is little evidence to support this. Although a decline of food waste amounts has been observed it is unclear whether food waste that is not collected ends up as for instance municipal waste or home compost.

When speaking about big societal challenges, to which extent the individual or the governments are responsible for contributing to change is widely debated. Halkier (2009) suggests two kinds of routinization initiated by both entities. She argues that environmentally friendly food practices can be routinised in such a way that they are fully integrated in the consumption of food. Such as for instance buying organic food, or deciding what to buy based on perishability. She calls it ‘routinisation of environmental reflexivity’. Another kind of routinisation she describes is ‘routinisation as relief from reflexivity’. It is when larger regulatory systems enable people to act environmentally friendly without actively reflecting about it. Halkier concludes that environmentalised consumption should neither be understood as dependent on the political consumer nor the victims of social conditions. Furthermore, environmentally friendly food practices can be seen both as part of food practices, as well as practices by themselves. Thus, when searching for potential intervention points for design, and identifying those that will bring about actual change, the challenge is to address practices on different levels of routinisation and reflexivity.

Similarly, Spaargaren and Oosterveer (2010) propose two perspectives on changing consumer practices - the individualistic/agentive approach from economics and social psychology, or the structuralist/systemic approach from sociology. In order to reduce household

food waste changing consumer food practices is imperative. It is however unclear how this change should come about; whether it is the individual consumer who should be persuaded through awareness campaigns and good suggestions for how to manage leftovers and portioning, or whether it is a systemic challenge that can be addressed by policy, or perhaps both. Answering these questions is beyond the scope of this article, but they illustrate the multilevel challenge of food waste.

## 5. Interventions

Literature reports on several design interventions aimed at food waste reduction in households; some prototyped and tested, some merely suggestions for improvement, and others already on the market. The majority of literature is to be found on packaging, refrigerator and freezer related interventions. Other concrete objects of interest are bins, plate sizes, written communication, mobile technology, social innovation, fruits and vegetables, potatoes and milk. Of course, design interventions with potential to reduce household food waste are not only found in academic literature, some already exist in real life, and will be mentioned here. These interventions all seek to address different drivers of food waste. In this section we will describe the interventions found in literature and how they relate to the drivers of food waste. The first part of this section pertains to interventions aimed at the storing and portioning of food, and the second part discusses interventions aimed at increasing knowledge, awareness and attitudes.

### 5.1 Storing and portioning food

An important aspect of food handling is storing food in the home. Many products are essential in this, most of which are located in the kitchen. Food is stored in fridges and freezers, in cupboards, containers, packaging and drawers. How food is stored is important to its shelf life, and consequently to how much is eaten or wasted.

#### 5.1.2 Intelligent fridges and apps – keeping track of our food

In the past twenty years, literature has provided several suggestions for fridge concepts that tackle one or several of the challenges pointed out above, such as modular solutions or transparent doors. Recently, more advanced technology has enabled affordable intelligent solutions in fridge concepts to tackle food waste issues. Scholars within Human-Computer-Interaction have developed three different fridge concepts that aim at helping the consumer reduce food waste (Bucci et al., 2010; Farr-Wharton et al., 2012; and Ganglbauer et al., 2013): 1) ZmartFri, 2) Colour Coding the Fridge and 3) FridgeCam.

1) The ZmartFri technology developed by Bucci et al. (2010) is an intelligent fridge concept, based on insights from field methods and results from a participatory design process, which include an expiration date alert and an ability to print a grocery list and send it by sms or email. 2) The concept of the Colour Coding the Fridge aims to raise people's awareness of what they have in the fridge, in order to reduce expired food waste (Farr-Wharton et al., 2012). The qualitative methods used in the study are interview protocols and visual ethnography, and seven households participated. Based on the insight that expired food waste is caused by lack of visual overview of what the fridge contains, the design intervention is based on a colour coding scheme where each colour represents a food group and its placement in the fridge. It is reported to potentially reduce food waste by a quarter to a half through heightened awareness of the content of the fridge. 3) The FridgeCam concept (Ganglbauer et al., 2013) is also based on

ethnographic methods to identify everyday practices related to food and their influence on food waste. The FridgeCam is a camera that is attached within the fridge displaying its content and sends images to a website. In the experiment, some users actually used the camera to plan shopping for instance by accessing the website from work or from within the store. Some were confronted with the disparity between their perceived and aspired food practices and their actual food practices.

An intelligent fridge may provide consumers with updated knowledge of stock, and what is about to expire and should be used. It may answer to causes of food waste addressed in literature including food storage, planning, shopping, preparation and consumption, provided it can be successfully integrated into the household routines. As of 2016 some brands such as LG, Samsung, Bosch, and Siemens already offer smart-fridges on the market. LG's *Smart ThinQ* concept enables use of a screen to track inventory of groceries, expiration dates, and calendar events. It also has four "smart-functions" mainly aimed at saving energy. Siemens and Samsung have already implemented camera concepts in some of their refrigerators. *The Family Hub* concept by Samsung has a Food Management function enabled by three built-in cameras, that make it possible to see what is in the fridge when not at home, using a smart phone. The Family Connection function enables family members to share calendars, photos and notes from their mobile device, which could help them plan meals and food provisioning better. Bosch has integrated a new technology called Vita Fresh, which automatically maintains the right balance of temperature, humidity, and air circulation within drawers with the help of climate sensors. According to Bosch this does not only make fresh produce last longer, but also preserves vitamins and nutrients. Freshness boosters that can just be put in the drawer of a more conventional fridge can also be bought on the market, including the Green Hearts and Frigidair PureAir Freshness Booster. They work in similar ways, by removing ethylene gas from the drawers, thus prolonging shelf life.

Keeping inventory by the aid of the fridge is still hampered by time consuming scanning of items or receipts as well as manual registration. This creates scepticism towards the maturity of the smart fridge concept within tech press (The Guardian, 2016). In light of the importance of convenience illustrated by food waste research, smart fridges may not be ready yet for large scale implementation. Similar technologies have been developed outside the world of appliances. To cater to the need for convenience and planning various apps and online sharing platforms have emerged. Leftovers can be sold or donated through food sharing sites and apps. Apps are also developed to aid consumers in planning their grocery shopping and meals through shopping lists and recipes for instance. Also here it remains to be seen if these technologies will be used to an extent that will bring actual effect to food waste levels.

### 5.1.3 Packaging and containers

There is a widespread variation on the market of different food containers for storing food inside and outside the fridge. Tupperware being one of the most famous brands. Furthermore, Food huggers that help seal the ends of fruits and vegetables that have been cut are also in this product category of enabling optimal storage and shelf life within the fridge.

Amsterdam based designer Jihyun Ryou is rebelling against the narrow-minded mantra of keeping everything in the fridge, and has designed products that seek to translate traditional oral knowledge concerning food storage and preservation (Savefoodfromthefridge.com, 2016). She aims to re-introduce preservation techniques that make the refrigerator redundant. Her project has resulted in various objects that translate traditional knowledge into storage products to use in the kitchen. For instance the combined shelf and drawer that utilises the effect the ethylene gas from apples has on preventing potatoes to sprout, whilst keeping light away from

the potatoes, the marble watering base for leafy vegetables, and the box of sand that keeps root vegetables in a vertical position and ensures perfect humidity condition. These products not only provide an alternative to storage in the fridge, but also make fresh produce more visible and thus may prevent them from falling into oblivion in the bottom fridge drawer. Seeing what you have readily available may serve as a reminder and motivation for use.

Packaging is one of the most studied design interventions to reduce food waste found in literature. Main subthemes are preservation technologies, environmental impact of packaging versus food waste, date labelling, storage guidance, pack sizes, self-dispensing systems, and supply chain packaging.

Recently much progress is observed in packaging design, especially concerning date labelling, information on storage and use and pack sizes. There has been substantial development of technology that can prolong shelf life for many food products, such as multi-layer barrier packaging, modified atmosphere packaging, edible coatings, oxygen scavengers, moisture absorbers and aseptic packaging (Verghese et al., 2015). The effect of such technologies depends however on consumer trust and appropriate use. Many consumers are not aware, and consider the protective and hygienic properties of food packaging (Plumb and Downing, 2013) only in the context of transport, and not for storing purposes. Their practices may be counter-effective such as taking food out of the packaging and into another container, or piercing packaging to let it “breathe”.

Alternatives or supplements to date labelling are the new emerging technologies that communicate food expiration through visual and tactile means. The Bump Mark ([www.designbysol.co.uk/bumpmark](http://www.designbysol.co.uk/bumpmark)) is a bio-reactive food expiry label that is smooth when the food item is fresh and gets bumpy when it has expired. The Keep-it label ([www.keep-it.no](http://www.keep-it.no)) is continuously monitoring temperature and time and visualises time left to expiration through a line which is increasingly getting shorter as the expiration date is moving closer. These new technologies may represent a more comprehensible and intuitive way of understanding expiration of food items.

Pack sizes being too large is a problem with packaging reported by consumers, especially by smaller households (Evans, 2011b; WRAP, 2008). Furthermore, consumers were willing to pay a little bit more for a smaller pack. How much more varies between products. Portioned and divisible packaging is one way to address the problem which is to some extent already on the market for some food products such as frozen fish and chicken (EMMA project, 2010). According to WRAP (2011) adjusting the packaging of chicken in this way could reduce food waste by up to 10,000 tonnes per year. Also packaging design in general, such as using scripts or feedback, has documented influence on waste behaviour (Wever et al., 2008).

Self-dispensing systems in shops may contribute to reduce packaging and food waste (WRAP, 2007) although so far this is only based on assumptions that people will buy quantities more in line with their actual needs. Advantages with self-dispensing systems may include cost savings and increased profits, but hygiene issues, lack of information about the content of the food in the store and the home, and reduced options for branding may be disadvantages. Hygiene issues can be resolved by using gravity-feed bins, which are also preferred by consumers. These can display product information in-store, but this will not help the consumer at home. Written information available to bring home may solve this, such as brochures and leaflets. Hygiene considerations make the bin and scoop method less popular, and consumer fear liquid self-dispensing to be messy. WRAP (2007) considers the following food product categories as potentially suitable for self-dispensing: cereals, rice, pasta, grains, oats, coffee, tea, flour, spices, nuts, dried fruits, salads, pet food, cheese, oil, milk, sauces, dressings, water, wine and juices.

In addition to the design and development of better packaging, the supply chain behind food and its power structures have to be addressed in order to find ways to make knowledge generated by research influence actual packaging solutions on the market (Verghese et al., 2013; Williams, 2011). Verghese et al. (2013) argue that it is imperative to educate consumers and retailers about the role of packaging in keeping food fresh and the meaning of best-before and use-by stamps on the packaging. Furthermore, they urge to improve logistics and orderings systems to avoid over ordering and bad inventory practices resulting in food going off in shelves and storage in retail, as well as to increase collaboration and awareness within the food value chain as to the reasons for food waste. Silvenius et al. (2014) argue for a value chain approach as well, improving packaging at all stages, and increase the use of retail ready packaging to avoid unnecessary handling of food products which can reduce its quality - new technology such as aseptic packaging and edible coatings should be adopted more extensively in order to keep food fresh.

#### 5.1.4 Plate size

A Norwegian example of nudging is seen in Nordic Choice Hotels, where plate sizes for the buffet were reduced to make people serve themselves with less food, and rather go a second time if they desired more. This small intervention reduced food waste by 20% (Kallbekken and Sælen, 2013). This experiment illustrates findings from Wansink and van Ittersum (2006, 2013): plates, bowls, and spoons bias consumption volume, as people generally overestimate how much food they will eat and underestimate how much food fits a large plate. In an experiment (Wansink and van Ittersum, 2013) where diners could choose from different sized plates, those choosing the largest plate served themselves 52% more than the ones with the smaller plates. Although these people ate more, they also wasted 135% more food. The study suggests that aspects such as diameter of the verge ring (curvature), the diameter band on the lip of a bowl or plate, and patterns and colours, may be considered for redesign when aiming to reduce food waste. There are for instance plates on the market with patterns that show how to portion correctly in order to avoid over-eating. These are designed to help people to a better diet, but the same thinking would help reduce the wasting of leftovers from plates.

#### 5.2 The limited power of information

As mentioned earlier, governmental intervention most often comes in the shape of distributing knowledge and information in order to increase consumer awareness. This approach exhibits optimism as well as some level of powerlessness, as the effects are difficult to measure. Nevertheless, both WRAP and ForMat report a decrease in consumer food waste, in the UK and in Norway, during the period of efforts to increase knowledge and awareness, and attribute this result in part to their own work (Stensgård & Hanssen 2016, WRAP 2012).

The belief that awareness determines intention which in turn determines behaviour has resulted in various campaigns seeking to educate consumers and provide guidelines to food waste reduction, including Love Food Hate Waste (UK), Matvett (NO), Feeding the 5000 (UK), Stop Spild av Mad (DK) and Think Eat Save (UK). Moreover, social innovation concepts aimed at raising awareness and providing information and suggestions for how to avoid food waste have been emerging. FUSIONS is investigating how policy can encourage such innovation (Easteal 2013, FUSIONS 2014). Examples of social innovations are mostly based on creating accessible information, advice and suggestions for how to reduce food waste.

A successful design intervention will contribute to “nudge” people to reduce their food waste, perhaps without them having to change their attitude, be educated or raise their effort greatly. Research in the fields of behavioural science and economics has been exploring how people actually can be nudged into changing their behaviour. Thaler and Sunstein (2009) describe how sensible “choice architecture” can nudge people into making better decisions. They have shown that it is possible to nudge people into the “right” behaviour through social information. A Canadian study on food waste for instance finds that people are reluctant to see themselves as someone who wastes more food than others (Parizeau et al., 2015). Using information about how consumers “perform” in relation to their peers and neighbours may influence their behaviour. HCI scholars Comber and Thieme (2012) use this phenomenon in their development of the BinCam, a persuasive technology aimed at raising awareness and supporting intentions for behaviour change by sharing images of disposed of food waste on an online social network, evoking feelings of shame and lack of control, and thereby spurring reflection and more awareness.

The design of food waste bins has proven to be significantly influential in how much food people recycle. A Swedish study targeting increased food waste source separation rates in a residential area (Bernstad, 2014) showed that providing better equipment had a significant effect, whereas raising awareness and increasing knowledge by using written information had none. The author attributes this result to convenience, which facilitates increased source-separation; this could not be provided by written messages urging people to do better. Written messages were however successful in improving food waste behaviours in a University dining facility in the USA (Whitehair et al., 2012); these messages urged students to eat what they took and not waste food, and provided some information about how much food is wasted at the university and how many meals that food could have provided. This reduced food waste by 15%.

## 6. Discussion: food waste drivers and design interventions

This section will discuss the identified food waste drivers and their relation with the suggested interventions. Research within various disciplines provide us with extensive knowledge on food waste drivers. These drivers connect to values and perceived value of food, awareness and attitudes, household, lifestyles and convenience, planning, leftovers, storage, packaging, food risk, and policy and regulation. Interventions have been suggested in literature, products have been developed that are on the market, and campaigns have been launched to address some of these drivers. The table below shows drivers of food waste and the interventions aimed at influencing them.

Information & Awareness	Technology & Planning	Leftovers & portioning	Storage	Packaging	Food Risk	Policy & Regulation
<ul style="list-style-type: none"> <li>• Written messages</li> <li>• Social information</li> <li>• Awareness &amp; info. campaigns</li> <li>• Online advice</li> </ul>	<ul style="list-style-type: none"> <li>• Smart Fridge:</li> <li>• grocery list</li> <li>• calendar event</li> <li>• expiration dates</li> <li>• Fridge Cam</li> <li>• smart phone connection</li> <li>• recipe suggestion</li> <li>• inventory</li> <li>• Colour coding</li> <li>• Apps</li> <li>• Social sharing platforms</li> <li>• Online advice</li> </ul>	<ul style="list-style-type: none"> <li>• Plate size</li> <li>• Written messages</li> <li>• Food containers</li> <li>• Food huggers</li> <li>• Social platforms</li> <li>• Measuring tools</li> <li>• Awareness &amp; info. campaigns</li> <li>• Online advice</li> </ul>	<ul style="list-style-type: none"> <li>• Save food from the fridge</li> <li>• Containers</li> <li>• Food Huggers</li> <li>• Colour coding</li> <li>• Freshness booster</li> <li>• Packaging</li> <li>• Storage guidance</li> </ul>	<ul style="list-style-type: none"> <li>• Resealable</li> <li>• Divided</li> <li>• Smaller sizes</li> <li>• Storage guidance</li> <li>• Date labelling</li> <li>• Self-dispensing</li> <li>• Edible coatings</li> <li>• Modified atmosphere</li> <li>• Multi-layer barrier</li> <li>• Oxygen scavengers</li> <li>• Moisture absorbers</li> <li>• Aseptic</li> <li>• TheBumpMark</li> <li>• Keep-it</li> </ul>	<ul style="list-style-type: none"> <li>• Expiration dates</li> <li>• TheBumpMark</li> <li>• Keep-it</li> <li>• Awareness &amp; info. campaigns</li> <li>• Online advice</li> </ul>	<ul style="list-style-type: none"> <li>• PAYT</li> <li>• Landfill tax</li> </ul>

Table 2. Food waste drivers and interventions

From this table three dominating categories of interventions can be derived: 1) Technology that helps people plan, share, and keep an overview of stock, 2) Packaging and storing solutions that extend shelf life, and 3) Information and awareness campaigns.

This shows that there is a surprising lack of diversity in food waste interventions suggested in literature, and there is also a lack of studies on effects. Especially within the two product categories most extensively explored, smart fridge functions and packaging, itFoley remains to study the effect of the innovations in order to assess their impact on food waste quantities. Perhaps there are adjustments that should be made in order to enable intended use and subsequent effect? Food storage is a category that is surprisingly underexplored. There are no radical suggestions to how food could be stored in a way that reduces food forgotten in the fridge for instance. All suggestions but one (Save Food from the Fridge) are set within the construct of how a fridge looks today. Further research should look into alternative ways to store food.

Key insights from the reviewed literature show that the practices that cause food waste are deeply entangled in the routines of everyday life, and not easily influenced by providing consumers with best-practice information and education. In light of this, further research and design endeavours should focus on ways to address food waste drivers pertaining to values and perceived value of food, awareness and attitudes, food risk, and household, lifestyles and convenience in a way that does not necessarily presuppose that there is an automated relationship between knowledge, attitudes and action. Could there be potential interventions not yet discovered, in the shape of for instance new products, systems and infrastructures that could nudge consumers to reduce their food waste?

Furthermore, there is a need to address the potential of new policies and regulations aimed at households. However, addressing this issue lies outside the scope of design.

## 7. Conclusion

This extensive literature review has identified an array of different aspects and drivers behind household food waste. It clearly shows that the phenomenon of food waste can be seen as a process where food turns to waste within a web of interrelated practices, tools, concerns, skills,

knowledge and anxieties. Attempts to change this process will require finding places within this web where one can intervene.

Seen in connection, the literature illustrates that food is wasted in households because of how it is valued and because some values people try to live by are not always compatible. Our values influence our awareness and attitudes, but so does our lifestyle and the required convenience we need in order to manage everyday life. Lifestyle is mainly defined by household constellation and everyday practices that influence important food waste related practices such as planning of purchases, handling of leftovers and management of food risk. Additionally, there are an array of material and structural aspects that shape and restrain our interaction with food, for instance storage, packaging, the fridge etc. In order to reduce food waste levels cultural and social norms and values residing within people as well as material and structural conditions out there in the experienced world need to be addressed simultaneously.

There are design interventions suggested in literature as well as on the market that seek to address various material and non-material drivers of food waste, but there is little knowledge of their actual or potential effects on food waste levels. Thus there is great potential for more innovative thinking that can challenge existing practices in a more profound way.

Although designers can access published research on the subject of food waste, they most likely will not due to time constraints, lack of awareness or just unfamiliarity and set routine. By compiling and sorting this literature, this paper provides a more coherent starting point for designers wishing to focus on food waste and behaviour change, making existing research more available. However, this is not a task to be embarked upon only by designers.

Moreover, this research points to the importance of a synergy of different approaches to reduce household food waste through design, and that there is a need for collaboration between relevant stakeholders in order to address both material and non-material drivers of food waste simultaneously. Design disciplines can most certainly be important contributors to this endeavour and should be involved from the very beginning.

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