



# Final report

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## **Practices of meat consumption and cold storage in Australian households: Consumer fridge behaviour and waste reduction of red meat**

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## Abstract

Meat & Livestock Australia (MLA) invests in research activities that include exploring optimising shelf life of red meat plus considering future market access barriers and/or issues that impact the positioning of red meat as part of a healthy diet. In this context, MLA supported research within the Fight Food Waste Cooperative Research Centre (CRC) that explored Meat as part of the wider types of food items wasted in Australia. Recent studies have found that 140,300 tons of meat are 'wasted' each year. One third of food waste is attributed to households, presenting an opportunity to understand how to reduce it.

Household meat waste has been attributed to refrigerator performance or household practices. Few studies have looked at how refrigerator performance and household practices interact to contribute to meat waste. This pilot, mixed-method project aimed to provide updated data on the temperature profiles of Australian fridges and develop an interdisciplinary methodology to understand householder practices related to red meat purchasing, cold storage, consumption, and wastage to determine how meat waste occurs and could be reduced. The results will inform future strategies for industry, government, and other stakeholders

Australian household and refrigerator practices were studied using interviews and ethnographic methods and refrigerator temperatures were monitored using data loggers over two seasons. The results highlight multiple sites of intervention where householder practices related to meat can be modified and supported to reduce meat waste. The results also indicate opportunities for householders to operate and maintain refrigerators efficiently; for stakeholders to communicate optimal refrigerator temperatures; and for manufacturers to develop product-optimised refrigerators, better temperature control, and new alert functions.

## Executive summary

### Background

Food waste is an endemic issue in Australia. The Australian National Food Waste Strategy Baseline has identified that nearly 300kgs of food is wasted in Australia per person per year (FIAL 2021). This equates to a total of 7.3 million tonnes of food, of which households generate 34%. Approximately 92% of household food waste goes directly to landfill, which has significant environmental consequences (FIAL 2021). Reducing this waste could save the average family between \$2200 and \$3800 per year (FIAL 2021).

Red meat is the focus of this report because red meat waste is one of the main food waste items identified in Australian households with 140,300 tonnes of meat wasted per year in total (FIAL 2021). This notion is considered by MLA as a future barrier to market access trade and/or impact the positioning of red meat as part of a healthy diet. The greenhouse gas emissions of meat waste going into landfill adds to the embodied energy and resources of meat production and transport. A Greenleaf report commissioned by Meat and Livestock Australia concluded that increasing the shelf life of meat (including within consumer fridges) could save wastage and losses (MLA 2019). To reduce meat waste there is a need to better understand quantitative refrigerator performance considering modern fridge technologies and energy efficiency standards, and householder practices concerning meat consumption and cold storage, and how these domains interact.

Very few mixed methods studies on fridge performance and detailed household practices concerning meat have been conducted in Australia since the 1990s. However, several quantitative studies focusing on fridge energy efficiency have been undertaken.

This pilot, mixed-method project aimed to provide updated data on the temperature profiles of Australian fridges and develop an interdisciplinary methodology to understand householder practices related to red meat purchasing, storage, consumption, and wastage.

### Objectives

The objectives of the project were to:

- Produce updated baseline temperature data of household refrigerators for use by industry
- Provide an evidence base on consumer practices involving meat consumption, storage and waste in connection with refrigerator use in homes.

This research used the following aims to fulfill the objectives:

1. Update knowledge on Australian consumers' fridge use, storage, and disposal of red meat and how wastage could potentially be reduced.
2. Understand how and why consumers are using their fridges and freezers to store meat and how this impacts how much meat they waste.
3. Monitor household refrigerators to measure the internal temperature of refrigerators in Australian households according to different seasons and understand how that temperature is affected by cooking and storing practices.

### Methodology

The research involved real-time temperature (and other parameter) monitoring of refrigerators in Australian households, combined with semi-structured interviews and fridge rummages with householders to understand how they buy, store, consume, and dispose of meat. This approach enabled the temperature data to be contextualised and interpreted in a household context. The chosen methods were selected to be as efficient and non-intrusive as possible with the minimum sample sizes targeted to create meaningful and robust data.

The interviews took place over two seasonal periods—autumn/winter 2022 and spring/summer 2022/23—to understand any differences in red meat consumption, use and wastage across different times of the year. This approach captured various practices and activities related to meat in Australian households.

Adult members of households with children were recruited for the qualitative part of the research. This household type is the most common household structure in Australia according to ABS 2016 census data, and previous research has shown that households with children may contribute more to food waste.

The refrigerator monitoring also took place during two seasons—winter 2022 and summer 2022-2023. The performance monitoring involved placing data loggers in discrete places in household fridges for at least one week. A variety of households, from single person households to families with children, were recruited.

The main target audiences for this report are the Fight Food Waste CRC (FFWCRC), Meat and Livestock Australia (MLA,) refrigerator manufacturers, large supermarket retailers, packaging companies, online meal and grocery companies and policy makers. The use of mixed quantitative and qualitative methods ensures that stakeholders can benefit from contextualised technical and social science results. In addition, the results provide an updated evidence base of consumer practices around food consumption and refrigerator performance to support changes in industry and householder practices through the creation of greater certainty about shelf life.

The mixed qualitative and quantitative methods included:

- semi-structured interviews with 20 households in winter and 16 households in summer to capture how meat and other food items were stored, consumed, and became waste. The interviews were accompanied by a rapid ethnography, or fridge rummage, which provided an opportunity for exploring how householders' fridges were organized. In this pilot project we were not seeking saturation as it was designed to be exploratory than exhaustive.
- real-time monitoring of 36 refrigerators over winter and 17 refrigerators over summer using data loggers. This method also required participants to complete a written form about their main fridge. The data were analysed to identify correlations between parameters and behaviours that can affect food waste.
- photographs of the fridges, either through online screenshots during interview, or taken and sent by participants.

### **Results/key findings**

A qualitative evidence base was produced that provides detailed and varied ways in which meat is consumed and wasted in households, as well as connections to refrigerators and freezers and the role of these devices in meat waste. These are the primary findings:

- 1) Householders find saving food and meat from waste challenging but experiment with novel and established ways to save food, especially regarding saving meat from going into landfill. This includes feeding it to their pets and composting.
- 2) Freezers are used to save meat from expiring at the date provided on the packaging. This practice is sometimes used deliberately to buy meat close to the expiry date, thus saving money on specials.
- 3) Quality of meat is regarded by some householders as reduced by freezing, and may lead to binning. Alternatively, freezing meat is avoided completely for this reason.
- 4) Managing leftovers from cooked meals and deli meat (cold cuts) is most challenging for householders.
- 5) Householders evoked cultural patterns and values in talking about food waste. Cultural practices and previous life experiences play an important role in how food and meat get wasted, or in how food waste is avoided.
- 6) Many householders were unaware of temperature variations in their fridges and tended not to blame the fridge temperature when meat or food was discarded. However, many participants noted the design of the fridge (deep, narrow shelves) prevented them from having a clear vision of their fridge, leading to forgetting some stored food items.
- 7) The increase in prices of all essential commodities at the time of data collection has made many householders thrifty and more conscious about food waste.
- 8) Householders acquire knowledge about how long to store food in the fridge and how to save food from waste in various ways. These including packaging labels, internet searches and lived experience.
- 9) Many householders were constrained from buying a new or larger fridge by the available space in the kitchen, or in the house, which they believed they required so that
  - a. They could store more food
  - b. Have a 'fancy' fridge (e.g., with a TV, smart capabilities, or with French doors)
  - c. Reduce trips to shops.
- 10) Date labels were used in many ways during shopping: as an indication of freshness, to ascertain how long an item could be stored for, and if near expiry (and on special) buying it to save money. Another common practice was that if the product was not expired, it was bought and frozen to extend its life. Some experimented and used their senses to bypass date labels.
- 11) Packaging was also used in many ways: some participants acknowledged its capacity to keep food fresh, some discarded it immediately after getting home for better stacking and storage results, and some used it for obtaining information about the product.

A quantitative baseline was produced that indicates refrigerator use and performance. These are the primary findings:

- Most (70%) households had one refrigerator unit.
- The main refrigerator unit was, on average, newer in households with multiple units than in households with one unit.
- Fridges had a mean setpoint of 3.4°C, range [-3.0, 8.0], and freezers had a mean setpoint of -17.8°C, range [-23.0, -10.0].

- Fridges were accessed more frequently than freezers, but the data for this finding appears to be unreliable.
- Nearly all door seals were in good condition, enabling them to slow the infiltration of heat, as designed.
- Average temperatures across fridge shelves are different, but they vary together.
- Average fridge temperature had a mean of 4.4°C, range [0.9, 8.9]. Some (17%) fridges had mean temperatures outside of the optimal range.
- Average freezer temperature had a mean of -15.9°C, range [-21.2, -5.1]. Many (43%) freezers had mean temperatures outside of the optimal range.
- Temperature control at some (at least 36%) shelves was imprecise.
- Average humidity across fridge shelves varies together. Average fridge humidity had a mean of 43%, range [31, 60]. Average freezer humidity had a mean of 53%, range [35, 64].

Various parameters were significantly correlated. Any relationships are as expected or are relatively easy to explain; others are difficult to explain.

### Benefits to industry

In generating data about how red meat is wasted and can potentially be reduced, this project contributes indirectly to substantial greenhouse gas savings, with multiple societal and environmental benefits. In this first phase of the project, retailers will benefit from the findings that provide an evidence base of consumer practices. These findings may lead to changes in industry practices through the creation of greater certainty about shelf life, thereby decreasing the marking down discard of products in store. Consumers will also have greater surety that the product they are consuming is still fresh, reducing wastage and contributing to health and wellbeing.

### Future research and recommendations

Sites of intervention/change in practices	Interventions/Research focus	Relevant stakeholders
Meal Subscriptions/ reducing shopping overload on the fridge (due to weekly or fortnightly shopping)	<ul style="list-style-type: none"> <li>• Developing partnerships with packaging companies to ensure less or returnable packaging in meal subscription plans.</li> <li>• Partnering with retailers to improve variety and maintain competitive price point with mainstream grocery shopping.</li> <li>• Support delivery of adequate walkable shopping options.</li> </ul>	Online meal subscription companies, packaging companies, policy makers
Meal planning, shopping, and prepping skills	<ul style="list-style-type: none"> <li>• Support school and community kitchen garden programs that enable children to learn about food – this can help at home as children become equal contributors to meal planning, preparation, and saving food from waste.</li> <li>• Education of adults, community groups and vulnerable groups. For example new</li> </ul>	Primary, secondary and tertiary education stakeholders

	migrants, new parents, and young people just out of home.	
Refrigerator efficiency	<ul style="list-style-type: none"> <li>Encourage improved manufacturer practices such as product stewardship.</li> <li>Encourage management of fridge through manufacturer's continuous engagement with the product.</li> </ul>	Policy makers, product manufacturers and designers, peak bodies
Refrigerator designs	<ul style="list-style-type: none"> <li>Engage community in innovation and rethinking fridge design, layout, and size in relation to fridge and freezer capacities.</li> <li>Support the reduced dependence on freezers as a societal goal through product stewardship.</li> </ul>	Product manufacturers
Sensory evaluation – The 'sniff test'/colour	<ul style="list-style-type: none"> <li>Undertake industry research with community participation on the capacity of 'sniff' tests to determine freshness. This could include the use of chemicals in meat processing that may disrupt or enable sensory evaluation (Flores, Perea-Sanz &amp; Belloch 2021; Ramanathan et al. 2021).</li> <li>Undertake industry research with community participation on improved packaging design and flexibility.</li> </ul>	Policy makers, food and meat industry, retailers
Leftovers	<ul style="list-style-type: none"> <li>Multi-dimensional interventions: encouraging work, school, and university eating areas to provide refrigerators, freezers and microwaves for the use of leftovers (Middha 2020).</li> </ul>	Food and urban planning policy makers, universities
Deli Meat	<ul style="list-style-type: none"> <li>Encourage and support reduction of the use of processed meat, especially refrigerated, through other means of meat preservation and provisioning.</li> </ul>	Meat producers, Government
Knowledge generation about food waste/food storage	<ul style="list-style-type: none"> <li>Encouraging and supporting experiential learning (see meal planning, shopping, and prepping skills).</li> <li>Integrating advice to create trust in a single authority that can provide tailored and specific advice as a one-stop advice platform for storage and use of stored products advice (in the same way that "War on Waste" became a motivator as well as a platform for information).</li> <li>Sharing responsibility to communicate the correct fridge temperature for storage for optimum shelf life</li> </ul>	Peak bodies, policy makers, packaging companies, food producers/manufacturers, Food Standards Australia New Zealand (FSANZ), Fridge manufacturers and retailers.

	<ul style="list-style-type: none"> <li>Integrating and streamlining different packaging instructions (through peak bodies).</li> <li>Including considerations of multicultural attributes of the population in advice on the life of food and storage (for example, specific food items may not be handled in similar ways in different households).</li> </ul>	
Technological interventions	<ul style="list-style-type: none"> <li>Tailor smart fridge technology and design with consumer practices of fridge and freezer use through co-design processes.</li> </ul>	Product manufacturers
Entertainment and parties	<ul style="list-style-type: none"> <li>Research into methods to challenge societal norms. Including elevated hygiene due to COVID-19 and risk of food poisoning, 'what is enough food for parties?' and 'what kind of food ages well in the fridge?'</li> </ul>	Product manufacturers, meat producers, retailers, government

The recommendations are as follows:

- 1) A larger study should be undertaken, which orients around design solutions based on further and longitudinal quantitative fridge monitoring data such as trialling interventions from appliance and packaging suppliers.
- 2) Further research should be undertaken that encompasses in depth, longitudinal and wider scale (country wide) qualitative research to understand Australian consumer practices in a fast-changing economic environment. Additionally, how site and context specific interventions can be collectively implemented at a societal level to change social practices. This further phase of the research would involve industry experts and policy makers to design comprehensive solutions.
- 3) Manufacturers might (re)consider developing and promoting refrigerators that are optimised for storing frozen meat, storing chilled drinks, or other purposes.
- 4) Householder education is a key intervention point. Improvements that rely on households acquiring new refrigerator units (with special technology) would be insufficient because they are limited by the long delay of householders replacing current units.
- 5) Householders should frequently check the seals of refrigerators that are older than about 10 years and address any damage.
- 6) Householders should monitor the condition and life of perishable food, and adjust the setpoint accordingly; FSANZ, manufacturers, and retailers should better communicate the optimal fridge and freezer temperatures for optimum food shelf life; and manufacturers could (re)consider more-robust, more-precise temperature control functions and new alert functions.





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## 1. Background

### 1.1 Introduction

Food waste is an endemic issue in Australia. The Australian National Food Waste Strategy Feasibility Study has identified that Australian households produce 2.46 million tonnes of household food waste, which is 34% of national food waste (FIAL 2021). Approximately 92% of household food waste still goes directly to landfill, which has significant environmental consequences, including air and water pollution and loss of biodiversity (FIAL 2021).

Reducing this waste could save the average family between \$2200 and \$3800 per year (FIAL 2021; Kaur et al. 2018) Furthermore, there is a difference between self-reported food waste and numerous bin audits conducted, indicating that more research is required that identifies this gap and its contexts.

Meat waste is one of the main food waste items in Australian households with 140,300 tonnes of meat wasted per year (FIAL 2021). The greenhouse gas emissions of meat waste going into landfill adds to the energy and resources of meat production and transport as environmental issues to consider (FIAL 2021). In order to reduce meat waste there is a need for better understanding quantitative refrigerator performance in light of modern fridge technologies and energy efficiency standards, and householder practices concerning meat consumption and storage, and how these domains interact.

The project focusses on red meat and has monitored one hundred fridges across Australia. The monitoring of fridges has been measured by IOT devices in different sections of the fridge. Interviews and ethnographic work have accompanied the monitoring phases to generate rich qualitative data to complement and interpret the fridge monitoring data.

New baseline temperature data generated will be applicable to all commodities which require chilled storage (including milk, salad, and fruits). These data can be used for setting new standards for food storage (including extending or shortening best before dates) and provide insights for industry on consumers. These insights will assist in addressing the issues of waste with a holistic fridge/freezer, packaging, and consumer information/ education focussed project for meat.

### 1.2 Previous research

Food waste is currently conceived as an *“end of the pipeline”* issue and householders and consumers are considered one of the main offenders (Evans 2014). The strategies for reducing food waste include changes in attitudes and behaviours of consumers and householders, as well as providing them the choice to change (Shove 2010). Food waste in households comprises up to 50% of municipal waste bins (Verghese, Lockrey & Williams 2014). Much of the research of food waste in Australia has focused mainly on waste management at the public and policy level, or food provisioning at the supermarket level or on consumer perceptions (Verghese et al. 2015) but not on its socio-material context.

There have been a few national, state level and local efforts in Australia to establish strategies and policies for food waste reduction. The National Waste Strategy lays out a few fundamental ways in which the Sustainable development goal 12.3 can be achieved (FIAL 2021). There is some work being done from the consumer side of waste production, currently in Melbourne by the Fight Food Waste CRC that is researching food and associated waste such as plastic packaging through various

perspectives, for example, how and why food is wasted and consumer perceptions of packaging. According to the FFWCRC website, *“Large amounts of household food waste could be avoided through better purchasing and storing of food, cooking the right portion size, eating leftovers, understanding food safety and date labels, and valuing food as done historically”*.

While these are important strategies, not much has been proposed for studying how food is eaten in households and outside, as well as the relationship with other food provisioning channels and practices, especially in the Australian context. In other words, there may be a gap in bringing in understandings of consumption to food provisioning, distribution, and production, that lead to food waste or maybe important for reducing food and associated waste, such as explored in Evans and Mylan (2019), Jackson et al. (2019), Watson and Meah (2012) and Middha et al. (2021) on ‘freshness’, ‘convenience’ or ‘safety’. Key advances in consumption need to interrelate food with the production and provisioning and more research is required to explore how that might happen (Evans & Mylan 2019). This research has also addressed a gap by including leftovers and how they may be produced, used, and become wasted in households.

### 1.2.1 Meat Consumption and Waste

Meat consumption has been related to human induced climate change, rising greenhouse gas emissions and animal welfare issues leading to calls for halving meat consumption (Daly 2020; Leroy 2019). Along with reducing meat consumption, limiting meat waste can be a significant factor that can help maximize the utilization of natural resources and prevent emissions through the decomposition of the waste produced. Moreover, unlike most of the other food waste that can be composted or separately binned for industry and community level composting, some councils in Australia discourage throwing meat waste such as cooked bones into the domestic and some industrial composting infrastructure (Boroondara 2023).

Meat waste occurs during production, processing, distribution, and marketing and at various points of consumption. In order to provide consumers with higher and consistent quality and a distinctive flavour and aroma, several strategies are employed by manufacturers including better packaging, nitrate addition and ageing (Flores, Perea-Sanz & Belloch 2021; Ramanathan et al. 2021). These are expected to prolong the shelf life and experience of meat. For example, a bright-red colour is an indicator of freshness and wholesomeness for consumers. So, in order to understand meat discoloration, which is a natural process resulting from interactions between the physical structure of meat and the oxidation of the ferrous forms of myoglobin, can help to develop innovative strategies to limit meat waste (Ramanathan et al. 2021).

Apart from these chemical and technological interventions, understanding how consumers include the buying, consumption and storage of meat in their everyday lives may help producers and retailers help reduce meat wastage. Scholars have argued for research and policy focus on householders as stakeholders and a need to study the dynamics of social expectations and social networks at the household level (Lane & Gorman-Murray 2011).

### 1.2.2 Fridge and Freezer practices

Refrigerators play an important role in storing and prolonging the life of food. Thus, refrigerators and freezers have been used widely to study food consumption and food waste practices (Farr-Wharton, Choi & Foth 2014; Hand & Shove 2007; Heidenstrøm & Hebrok 2021; Phillips & Waitt 2018). At the same time, refrigeration of food as a practice itself has been shown as a transformation of previous storage practices and implicated in the ratcheting up of needs leading to increasing use of energy (Marshall 2021, 2022). In the post domestic society, where food and meat

is increasingly provisioned from supermarkets (Leroy 2019), domestic refrigerators are an important link in the cold supply chain (James, Onarinde & James 2017). Thus, they become implicated in food waste that occurs along the supply chain as inadequate domestic refrigeration or cooling is frequently cited as a factor in incidents of food poisoning (James, Onarinde & James 2017).

However, how food storage/refrigeration practices become meaningful in everyday life through certain affects, materials and competences has been less explored in food waste literature with some exceptions. This is because the roles of refrigeration are minimised in policy as mundane. However, qualitative fridge studies conducted by Evans (2018) and Heidenstrøm and Hebrok (2021) illustrate how people co-exist with foods and fridges, negotiating storage, refrigeration and binning/ridding practices.

Additionally, refrigerator companies are increasingly showing concern about food waste occurring in domestic settings and thus are trying to make efforts through education and advertisement campaigns (Webster 2021) and advancement of technology and design (Miele 2023). Notwithstanding the issues related to such campaigns, it shows how food and meat waste are increasingly being connected to design and use of refrigerators.

Therefore, it becomes important to supplement measures currently provided to households for minimising food waste such as making shopping lists, storing food properly, and composting rather than binning waste (Port Phillip 2023). What is suggested instead, is to encourage prevention and reduction of waste and designing measures based on understandings of “what discarding food means to people in the context of the routines, rhythms, materiality and sensory knowledge by which they make and remake their home” (Phillips & Waitt 2018, p. 361)

### 1.3 Conceptual Framework

Discard studies (Phillips et al. 2019) have demonstrated that waste is more than just a symptom of an all-too-human demand for meaning or a merely technical problem for sanitary engineers and public health officials (Reno 2015). The starting point that this project takes is that it focusses on understandings of the processes through which food becomes waste.

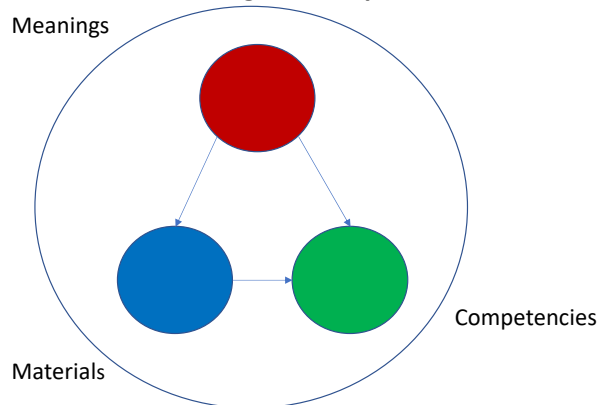
Following lines of inquiry within the work in consumer cultures, material cultures and everyday practices (Bulkeley & Gregson 2009; Gregson, Metcalfe & Crewe 2007; Hawkins 2021), the study adopted a relationalist materialist perspective, which accepts that the matter wasted is itself a part of how it gets wasted (Bennett 2007; Roe 2006). Relational perspectives of food have allied with practice theory perspectives to ask the questions, “*how does matter which is food become matter which is waste?*” In understanding what happens in these moments of change from food to waste, a practice theory perspective helps us look at the ‘doings’ that reveal food waste as occurring within the organization of daily life, both individually and collectively. Studies based on practice theories aim to address and reduce the complexities in analysing food as a material of consumption by making meat-eating as a practice, the smallest unit of inquiry. A practice is an organised set of activities across space and time. The elements of the practice organise the practice and allow it to be reproduced contingently.

Fig. 1 denotes how meat-eating happens as organised through its elements, materials, competencies, and meanings. Social practice theories conceptualize consumption as a ‘moment’ in almost any social practice (Warde 2005). They shift the analytical focus from the purchasing of products and services towards the accomplishment of daily practices such as shopping, eating, or cooking. These practices consist of configurations of elements, which are reproduced and adapted through routine performances (McMeekin and Southerton, 2012). Focussing on the elements and

the links between practices helps decentre humans. However, they are carriers of the practice who reproduce the practice as they are engaged in it.

In the context of researching red meat waste, the application of social practice theories allowed for a comprehensive understanding of meat consumption as part of broader social practices, in the form of intersecting practices. By examining the elements (Fig. 1) involved in red meat consumption, and related practices such as shopping, meal planning, food storage, cooking techniques, portion sizes, and leftover management, we gained insights into the dynamics of waste generation.

**Figure 1: Meanings, competencies and meanings that organise the practice of meat eating/consumption**



## 2. Objectives

The objectives of the project were to:

- monitor household refrigerators to produce updated baseline temperature data for use by industry
- provide an evidence base on consumer practices involving meat consumption, storage and waste in connection with refrigerator use in homes.

New baseline temperature data generated will be applicable to all commodities which require chilled storage (including meat, dairy products, and produce). The data can be used for setting new standards for food storage (including extending or shortening best before dates). The evidence base on consumer practices is expected to provide insights for industry on consumer practices. These insights will assist in addressing the issues of waste that include:

- fridge/freezer design and management
- packaging design and management
- enabling interventions to reduce domestic meat waste.

Both objectives were met over the course of the project, which ran from July 2021 to June 2023.



## 3. Methodology

To understand this social and technical problem which has not been studied in Australia since 1997, a mixed method study was designed for this project. The research was approved by the RMIT University's Ethics Committee (CHEAN 2022-24684-17027) before data collection commenced. Participants were provided material on the project including a plain language statement and consent form prior to data collection. The study involved qualitative interviews with householders about how they buy, store, consume, and dispose of meat (the ethnographic component), combined with retrospective data collection and real-time performance monitoring of refrigerators in Australian households. This approach enabled the performance data to be interpreted using the social, qualitative data generated with households. The interviews took place over two seasonal periods—autumn/winter 2022 and spring/summer 2023—to understand any differences in red meat consumption, use and wastage across different times of the year. Similarly, refrigerator monitoring took place during two seasons—winter 2022 and summer 2022-2023. This captured various practices and activities related to meat in Australian households. The chosen methods were selected to be as efficient and non-intrusive as possible with the minimum sample sizes targeted to create meaningful and robust data.

### 3.1 Qualitative research

#### 3.1.1 Methodology

Ethnographic methods that incorporate visuals are considered valuable for going beyond text-based approaches, which have limitations in fully capturing lived experiences (Pink 2007). In our study, we chose research methods that allowed us to deeply explore participants' ongoing experiences and practices as they interacted with their physical and social environments (Kusenbach 2003). This involved examining not just the objects in their kitchens and surrounding areas, but also how they engaged with different conversations and ideas related to meat and other food. By using visuals, we gained a comprehensive understanding of the participants' experiences and the context in which they made decisions about food.

This research was conceived as "following" red meat consumption through intersecting practices and through household stories and narratives. The purpose was to explore how stuff classified as "food" ends up as "waste" by examining household dynamics and processes. To do that, we chose similar households that may have shared social practices and everyday routines to examine how they connect to market economics and commercial spaces such as supermarkets. We chose households who are couples with children for this study. The aim was for our sample to include the median Australian households based on the most recent ABS data (ABS, 2021). The distribution of family composition in the ABS 2021 survey reveals that couples with children constitute 43.7% of all families, followed by couples without children at 38.8%. While this part of the research was representative in terms of the sample constituents, it was not representative in terms of sample 'size' that is, it's simply a small sample representing the demographic spread of AU.

This part of the project was designed as complementary to the quantitative data. The households interviewed were also part of the quantitative monitoring of fridges.

While ethnographic studies of household food waste provide insights and knowledge, these require long periods of time for observation, data collection and analysis. As this qualitative component of the research was a pilot study we took a shorter but focused approach of studying the movement of

meat through the household, especially the fridge and freezer, called 'efficient ethnography' (Heidenstrøm & Hebrok 2021) through digital modes.

Following Heidenstrøm and Hebrok (2021) this approach gave us an opportunity to ask focused questions and receive focused answers, along with an understanding of related practices of householders. Because fridge focused studies have limitations such as not being able to capture activities beyond the fridge or household (such as shopping)(Heidenstrøm & Hebrok 2021), we combined it with a 'following the thing' method where intersecting practices of householders related to meat (meat storage and use) were also discussed (Hitchings 2012).

This combination of methods provided a deeper insight into the materialities, and practices involved in household's storage, use and disposal of red meat. An accompanying 'fridge rummage' part of the interview provided additional, complementary narratives about food storage and wastage in an efficient manner (Heidenstrøm & Hebrok 2021).

The topics that we explored through the interview and fridge rummage questions included practices and behaviours of food/meat purchasing, storage, and fridge use, cooking and eating, use of leftovers, and perceptions of food safety, freshness, and wastage. Telling the participants beforehand about our intention and interest was intended to put participants at ease. It provided them confidence in what they could offer us and made the interview process go more smoothly. By introducing them to what the questions might be and our line of questioning we aimed to encourage them to talk about seemingly trivial sequences of events and activities, thoughts and emotions, sensory experiences, and the consequences of these in the form of food waste.

### **3.1.2 Methods and tools**

We chose households who were couples with children for this study. The aim was for our sample to be representative of the Median Australian households based on the most recent ABS data (ABS 2022). The distribution of family composition in the ABS 2021 survey revealed that couples with children constitute 43.7% of all families, followed by couples without children at 38.8%. A research marketing company was hired to recruit participants who met the demographic criteria and agreed to participate in the study.

Households were approached and recruited using a stratified random sampling technique to ensure the sample captures the diversity of households across different cities and regions. Households were selected to represent a diverse range of socio-economic backgrounds and geographic locations across Australia.

### **3.1.3 Interviews**

The purpose of the interviews was to gain insights into the everyday practices linked to red meat purchases, storage, consumption, and waste. The interviews were conducted using a semi-structured approach (Brinkmann 2018), with open-ended questions that allowed participants to provide details and elaborate on their experiences and perspectives (interview guides are in Appendix 8.2). The interviews were conducted by trained researchers who followed a semi structures interview guide. We conducted two rounds of interviews. Twenty households were interviewed over two seasons (16 in the second season) (winter 2022 and summer 2022/ 2023) to capture how meat and other food items were provisioned, stored, consumed, and sometimes became waste, in different conditions. The change of temperature and practices in different seasons and the summer/ New Year's holidays were some of the reasons for conducting two rounds of interviews.

### **3.1.4 Winter round of interviews**

The Winter round included interviewing twenty households. Table A1 (in Appendix 8.1) provides demographic information for individuals participating in this study. The participants' ages ranged from 33 to 55, with an average age of 41. Both male and female participants were included in the sample (almost equal numbers). They resided in various regions in Australia, including Greater Melbourne, Regional Victoria, Greater Sydney, Greater Perth, and Greater Adelaide. Most participants owned their homes and were paying off their mortgages, although there are some who were renting. The number of children in the households varied, with an average of two children. A few households also had pets, with the number ranging from none to five. This diverse sample allowed for a comprehensive understanding of residential demographics in different areas and living arrangements.

The householder who was, mainly responsible for shopping or cooking or managing the kitchen was interviewed between July to August 2022. Interviews were conducted online via Microsoft Teams while the householders were at home. Each interview took between 60 to 90 minutes. One or two researchers conducted each interview. A 10 to 15-minute rapid ethnography, called a 'fridge rummage' as explained above was also conducted at the end of each interview where participants showed the researcher their fridge/s and talked about food storage, fridge characteristics, and spatial location of the fridge.

### **3.1.5 Summer round of interviews**

The Summer round included sixteen households out of the twenty we interviewed for the winter round. The purpose of this round was to follow up with the same households and gather additional insights about their practices in a different seasonal context. Interviews were conducted between December 2022 and January 2023 by a team of one or two researchers who undertook the winter round and households were familiar with them. Interviews were online via Microsoft Teams while households were at home to be able to undertake the fridge rummage as well. Interviews took between 25 to 35 minutes.

The findings from the previous components of the study were used to inform the summer data collection to provide a more comprehensive understanding of household practices related to fridge temperature and red meat waste. For example, a question about food spoilage observation was asked of those householders who had temperature anomalies recorded and reported through the first round of quantitative data collection.

### **3.1.6 Data preparation**

The interviews were recorded and transcribed verbatim to ensure accurate capture of participants' responses. Households were coded with a number, denoted as 'HHX'. We used NVIVO software to code the interview data. NVivo was employed to conduct a more in-depth exploration and interpretation of the data. We then transferred our themes to Excel spreadsheets where the whole research team participated in thematic analysis. Tasks such as organising data, creating coding frameworks were undertaken in Excel spreadsheets. Excel also facilitated basic data manipulations, such as filtering and sorting, which aided in the organisation and identification of patterns within the data. The combined use of Excel and NVivo allowed for a comprehensive analysis of the qualitative data, leveraging the strengths of each software tool to gain a deeper understanding of the research topic.

### 3.1.7 Data analysis

The interview data were analysed using thematic analysis (Braun and Clarke 2022), which involved identifying patterns and themes within the questions asked and the responses. We then reanalysed the interviews as a research team looking for themes around everyday practices intertwined with meat consumption and waste.

The results of the data analysis were synthesized to identify potential opportunities for reducing red meat waste in Australian households, and to provide recommendations for future interventions and policies aimed at reducing red meat waste in households. A more detailed explanation follows. The thematic analysis was guided by the elements of the practices and relationships between different practices that were seen to shape or be shaped by meat eating practice.

Six questions derived from the research questions and were reformulated as analytical codes –What are the practices that intersect with meat consumption and disposal in the context of food waste?

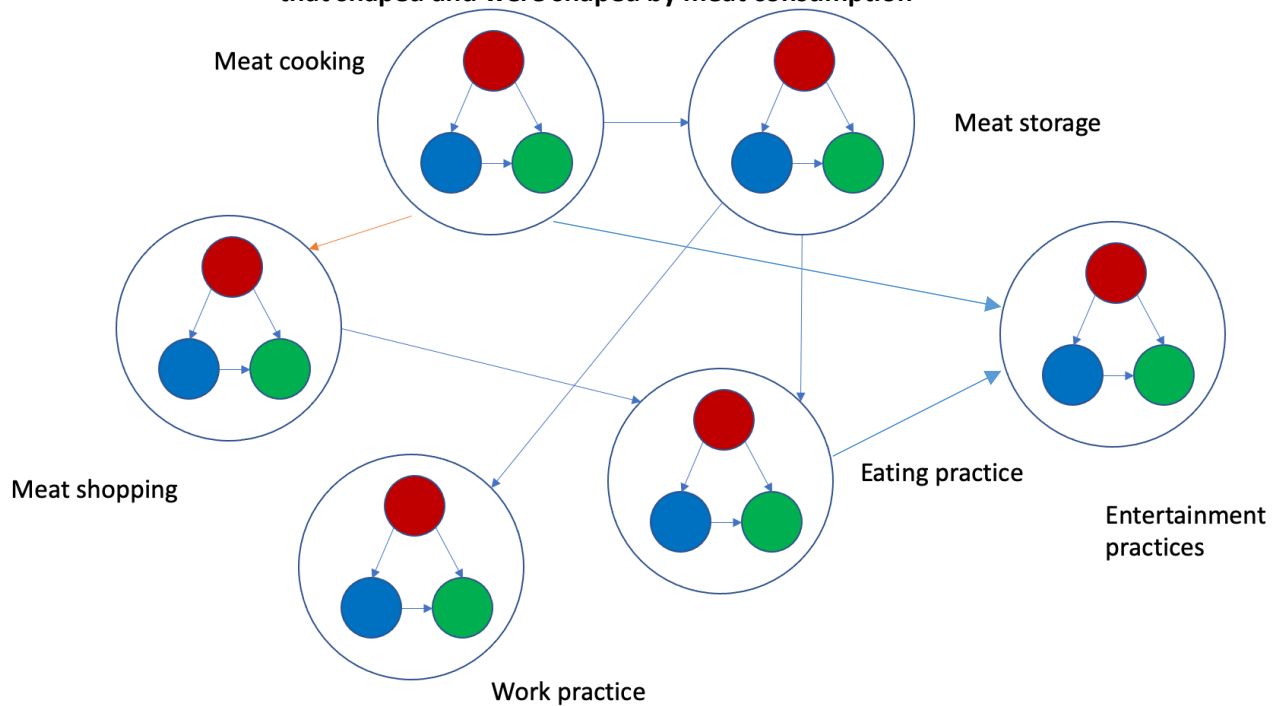
1. How do changing and intersecting practices lead to more or less red meat and/or food waste, e.g., COVID-19, Different living conditions (according to participants)?
2. What is the role of the refrigerator – shopping, cooking, eating, disposal
3. How does packaging influence perception of red meat and other food's longevity and freshness (or other meanings)?
4. How do households reduce red meat and food waste?
5. When and how does meat become waste, and how does that differ from other food items?

An additional theme based on data generated was added:

6. How was knowledge around red meat and other food waste generated?

Thematic questions were grouped under practice and bundles of practices related to meat and food, materials and infrastructures, and meanings of meat eating and waste (Fig. 2). Then, a cross analysis of questions was conducted grouped under these themes. The research team analysed data across all themes and then two specific themes. The themes were brought together for overlapping elements, contradictions, important insights on meat and food waste.

**Figure 2: Following meat eating meant exploring the connections to various interacting practices that shaped and were shaped by meat consumption**



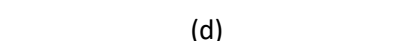
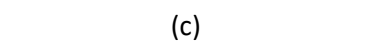
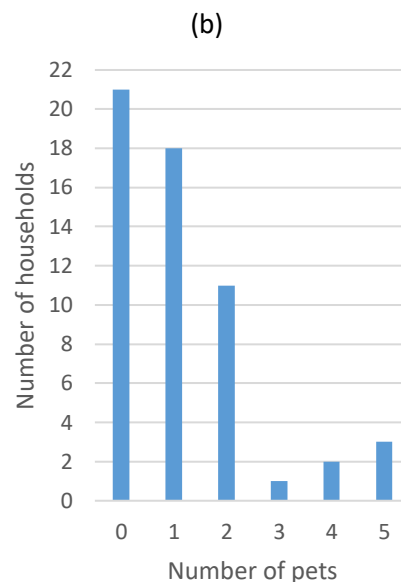
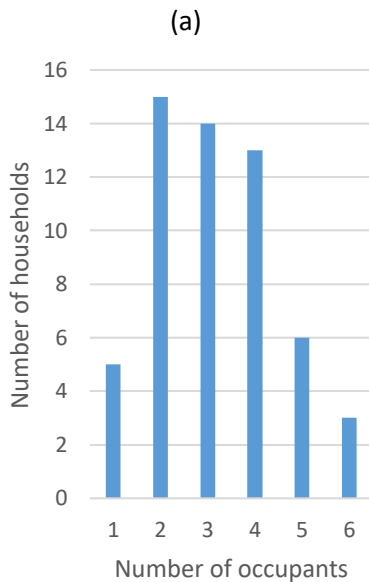
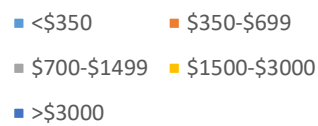
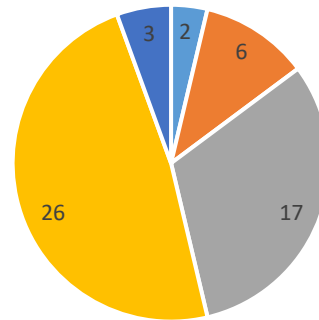
## 3.2 Quantitative Research

### 3.2.1 Participating household

Households participated in the quantitative study during two seasons—winter 2022 and summer 2022-2023. During winter, 2022, 36 out of 40 invited households completed sufficient study requirements. During summer, 2022-2023, 20 out of 39 invited households completed sufficient study requirements. To reduce bias, the categories and proportions of invited households was consistent with those in 2016 (Australian Bureau of Statistics 2019), households from each Australian state and territory were invited, and the recruitment of households was blind (conducted by a research services agency). Fig. 3 shows the categories, proportions, state or territory, and other characteristics of households that completed the study requirements. These households represented each state and territory. The number of residents was a mean of 3.2 persons/household, range [1, 6]. The number of pets was a mean of 1.2 animals, range [0, 5]. The period of monitoring was a mean of 12.5 days, range [5, 31.5]. Only one household monitored its fridge for less than seven continuous days.

**Figure 3: (a) Proportions, by category, (b) weekly income, (c) number of occupants, and (d) number of pets of households that completed sufficient study requirements**

Add charts for household categories, proportions, and state/territory. Awaiting data



### 3.2.2 Data collection

Data sources and data-collection tools comprise the research services agency’s records, a written form (in Appendix 8.3), photographs, and Tive Solo 5G data-loggers and Tive Temperature Beacon data-loggers, shown in Fig. 4. Participants completed the written form and took photographs. The data-loggers were typically arranged in refrigerator units as shown in Fig. 5.

Participants were given instructions for completing the written form, taking photographs, and installing the data loggers. Instructions for installing the data loggers are summarised below.

- Install the data loggers in the main refrigerator unit, the fridge/freezer that is used most often in the household.
- Put the Tive Temperature Beacon near the middle of the freezer and the three Tive Solo 5Gs distributed throughout the fridge.
- Keep the data loggers out of sight or reach of children who might move them.

- Put the data loggers in the main open space in the fridge and the main open space in the freezer. Ignore any door shelves and internal draws, unless the draw is the only fridge or freezer compartment. In that case, treat the draw as a shelf.
- Orient the data loggers (face up or on their sides) to allow for an air gap above its top surface, where the sensors are. Avoid having fridge/freezer items in contact with the top surface. Move the data loggers around to accommodate other food items.
- Leave the data loggers in the refrigerator unit for 7-10 days.

Figure 4: Tive data loggers (Tive 2021)



Figure 5: Typical arrangement of data loggers



The tools were used to collect information and data for the parameters shown in Table 1. Additional parameters were also derived. Data for those parameters were calculated as follows:

- Number of residents = Number of adults + Number of children
- Number of residents and pets = Number of adults + Number of children + Number of Pets
- Daily number of door openings = Number of door openings / Period of monitoring

- Temperature difference from setpoint = Average temperature - Temperature setpoint
- For quantitative parameters indicated with an asterisk (\*), additional parameters based on their descriptive statistics—including the mean, standard deviation, 95% confidence interval, maximum, minimum, and count—were calculated.

**Table 1: Information and data collected, by tool or method**

Information/data	Recruitment record	Written form	Photograph	Data log	Derived
<b>Household characteristics</b>					
Category	✓				
Address	✓			✓	
Weekly income	✓	✓			
Number of adults	✓	✓			
Number of children	✓	✓			
Number (and type) of pets	✓	✓			
Number of residents					✓
Number of residents and pets					✓
<b>Household conditions</b>					
Number of refrigerator units*		✓			
Use of space heating or cooling (while monitoring)		✓			
Unusual events		✓			
<b>Refrigerator unit characteristics</b>					
Make and model		✓	✓		
Gross capacity			✓		
Electrical input			✓		
Year of manufacture or acquisition*		✓			
Number of external doors and draws		✓	✓		
Number of internal fridge and freezer compartments		✓	✓		
Number of internal shelves, draws, bottle racks, etc.			✓		
<b>Refrigerator unit use</b>					
Temperature setpoints		✓			
Number of door openings (light trigger, 5-minute intervals)*				✓	
Daily number of door openings					✓
Damage to door seals (presence of water on the outside of the door seals)		✓			
<b>Refrigerator unit performance</b>					
Temperature (5-minute intervals)*				✓	
Temperature difference from setpoint					✓
Humidity (5-minute intervals)*				✓	
<b>Monitoring characteristics</b>					
Period of monitoring		✓		✓	
Locations of the data loggers (in the refrigerator)		✓			



Other (out of project scope)	✓		✓	✓	
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### 3.2.3 Data analysis

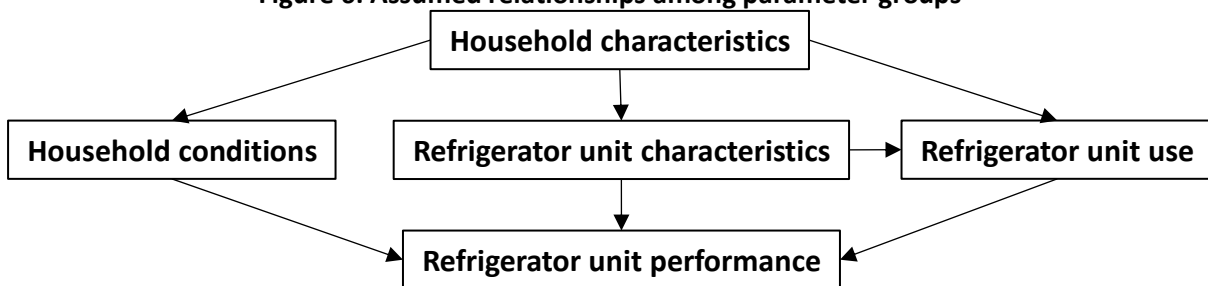
Statistical analyses were conducted on the quantitative data. Analyses comprised the calculation of descriptive statistics using Microsoft Excel and two-tailed, bivariate correlation analysis using IBM SPSS Statistics version 21. The correlation analysis tested for, and identified, significant correlations between all parameter pairs at the 0.01, 0.05, and 0.1 levels.

Quantitative ranges and categorical parameters were coded as follows:

- Weekly income: <\$350=1, \$350-\$699=2, \$700-\$1499=3, \$1500-\$3000=4, >\$3000=5
- Damage to fridge door seals: Yes=1, No=0
- Damage to freezer door seals: Yes=1, No=0
- Use of space heating or cooling: Heating=1, None=0, Cooling=-1.

Parameter groups in Table 1 are assumed to be related as shown in Fig. 6. ‘Household characteristics’ may be considered inputs. ‘Household conditions’, ‘Refrigerator unit characteristics’, and ‘Refrigerator unit use’, may be considered intermediate outputs. ‘Refrigerator unit performance’ may be considered final outputs.

Figure 6: Assumed relationships among parameter groups



Of the parameters, information, and data in Table 1, the following were excluded from the analysis:

- Qualitative parameters ‘category’, ‘address’, ‘type of pets’, ‘unusual events’, and ‘make and model’.
- Quantitative parameters ‘gross capacity’, ‘electrical input’, ‘number of external doors and draws’, ‘number of internal fridge and freezer compartments’, ‘number of internal shelves, draws, bottle racks, etc.’
- Information about ‘unusual events’ and ‘locations of the data loggers’, which was intended to help understand and prepare raw data for analysis. ‘Unusual events’ may include restocking of many groceries, stocking of hot food, stocking of many room-temperature drinks, removal of a data logger, malfunction of a data logger, loss of power to the home, and replacement of the refrigerator unit.
- Data for ‘temperature setpoints’ that were not reported in degrees Celsius.
- Data for ‘number of door openings’ and ‘daily number of door openings’, which appear to be too low, indicating a problem with the data collection procedure. They were included in the analysis for completeness, but the related findings might be unreliable.

## 4. Results

### 4.1 Meat waste: Practices of interest and intersecting practices

These findings provide an in-depth understanding of how and why meat waste occurs within Australian households. The sections follow the themes that were used for coding the interview data. They illustrate the role of the refrigerator, how meat becomes waste, how households save food from waste, and intersecting practices.

To illustrate the main themes from the analysis, two vignettes were developed to illustrate common household narratives about practices of meat shopping, consumption, storage and binning, with fridge use (Boxes 1 and 2). Each vignette presents a narrative that provides a picture of the various ways in which food and meat practices engage with refrigerators and freezers, and how some meat and food waste may occur during these engagements.

#### 4.2 The Role of the Refrigerator:

**What is the role of the refrigerator and packaging in – shopping, cooking, eating, disposal of food, especially red meat?**

The infrastructure and materials used in the storage and transport of meat are many. They shape - and are shaped by - how meat is produced, sold, bought, and eaten. These 'doings' are an important part of the social configuration of meat consumption in households and interlinked with a variety of practices (Shove, Pantzar & Watson 2012).

The fridge and freezer played a key role in all practices involving red meat storage and consumption. The key themes included size of the fridge, fridge temperature, design, freezing capacity, visibility. Packaging also influenced fridge use, as explained below. The centrality of the fridge to red meat practices highlights the importance of understanding how fridge characteristics might affect red meat waste. Not everything comes down to the individual's behaviours, as the materialities and technology at play can have their own impact on waste.

##### 4.2.1 Refrigerator size

Refrigerators and freezers are used to save food and meat from waste - however, the size of the refrigerator governs how much shopping is done (HH1, HH3, HH12). This could imply that larger fridges or perhaps multiple fridges mean that food is more likely to be forgotten and wasted, depending on the size of the family and practices of saving food from waste. In turn, the space provided for the fridge governs the size of the fridge (mentioned by 8 households), potentially having knock-on effects in terms of food saving or wasting. As one householder put it:

*Our fridge from our old house was too big for the nook, for the space. So that was the first thing is it had to fit in the size that we had. So then I was looking at the maximum size I could fit in that space. (HH9)*

##### 4.2.2 Refrigerator temperature

Fridge temperature can drastically affect how long food keeps for, but the households had varied strategies when it came to adjusting it. For example, having the flexibility to change the temperature of the fridge, HH1 changed the temperature to suit the volume of food inside:

*I just guesstimate. So sometimes having more food in the fridge, I turn up the temperature. And whereby there's less volume of food, then I turn down the temperature. (HH1)*

However, many of the participants said they didn't touch the fridge temperature at all, unless something was clearly wrong. HH2 did not think of its impact on bills, even if electricity bills were quite high – they saw it as stingy to change the fridge temperature, and did not connect it to food waste:

*They're [electricity bills] shocking. They're, they're too much for us sometimes, not too much. We afford it every time. It's fine. But they're s\*\*\*, but I would have never thought like on a two-week holiday to come and fix a thermostat on my fridge to save me a buck. (HH2)*

### 4.2.3 Refrigerator design

The design of the fridge is also implicated in how food gets wasted, or at least the perception of it. For HH16 it was 'stupid' to have a deep fridge because items would get forgotten at the back and then would have to be thrown out. Instead, she now has five fridge and freezer combinations to circumvent this problem.

For HH2, their fridge preferences have changed over time – when they were younger, they used to just consider the space in the house and price but are now more concerned with aesthetic, an ice dispenser, and compartments to keep food fresh. HH2 uses compartments to keep meat fresh and be able to see what is there. They would rather buy enough food for the week and waste it, rather than go to the supermarket multiple times.

For HH6, utilising the features of their fridge helped them to keep it organised and keep different items at the optimum temperature:

*So there's like a deli section with a closed lid. And you can actually adjust it, for temperature and bits in it. So we'll put all of the raw meat and everything in there. (HH6)*

HH13 had a warmer than average fridge when it was monitored in the first round of quantitative analysis. When asked about noticing any change in the pace of food getting spoilt, they mentioned design challenges such as the top section getting a little too cold and a slight uneven distribution of moisture. However, they had not noticed food going off:

*That top section that has the little chilled, it's got like a little flap to it. That has issues. It must get too cold maybe. I don't know what causes the moisture, or it'll dry out the cheese on the corners or something. No, not really. Even our milk doesn't go off. We do go through a lot of milk. (HH13, Summer round)*

HH13's case indicated that some households were more likely to think about the design issues of their fridges rather than temperature settings (further details in section 4.2.5).

### 4.2.4 Freezing

Most households (n=14) mentioned using the freezer (and an extra freezer too) to prolong the shelf life of meat, as demonstrated in Fig. 7. For example, for HH5, a kind of dance was set up between the fridge and freezer. Meat that might go off soon, or that had been bulk bought, was stored in the extra freezer in the garage (Fig 7). Later when it became needed, it was moved back to the fridge and then eaten. For them, rules and specific timelines applied to each stage of the meat storage:

*If you're going to use a meat after two days, then it has to be in the freezer. Within the next 48 hours, we can leave it in the fridge. (HH5)*

Freezing practices and routines were entrenched in some households, with date labels being put on frozen items to determine the order in which they would be used. When asked about if raw meat gets wasted, HH3 exclaimed:

*Oh God, only if I don't label it properly in the freezer, and then I've missed the date. Yep. And that doesn't happen too often. Okay. I mean, I just put a sticker with the date that I've frozen it, So I mean, I typically use it within, I think red meats within three months, but we're using it within that month, that time anyway. (HH3)*

**Figure 7: Having a large freezer with enough space to preserve food and keep leftovers for longer time has implication for food waste**



#### 4.2.5 Ignoring the role of the fridge

Fridges were sometimes absent from householders' reflections or actions on food waste. When food went bad and was ultimately thrown out, householders tended to blame themselves (or incorrect use by dates) rather than the fridge. For example, for HH2, the consideration that the fridge may have contributed to food waste did not occur and the use by date was held culprit (which of course, may also have been the case):

*I've felt like there's been an increasing amount of times where I've bought food where it says*

*use-by dates on it and it's gone well before then. Not as much with the red meat, but, when you buy chicken, and its use by is three days away, and you cut it, ready to cook your dinner, and it's off. I've lost a bit of faith in the use-by part of it. (HH2)*

When informed in the summer round that their fridge was warmer than usual, HH2 realised that may be the reason their food was going bad so quickly. They remarked they 'hadn't really thought about it' and professed thanks for being given this information to fix the long-standing issue:

*Well, that's interesting. Because there's been times where, with the food parcels, I've gone, "Ah, I've gotta cook the chicken soon because it's going off,". Okay, I guess I've had a bit of waste. Like if there's a coleslaw mix that's s\*\*\* and I've gotta go buy a new one, or the chicken's slimy. (HH2, Summer round)*

This trend was also observed in participants with colder than average fridges. They also noted that their food gets frozen and wasted in set parts of their fridges, which they blamed on the uneven design of their fridges. For HH8, they found that food in the top shelf becomes partly frozen while the rest of the shelves are fine:

*In the top shelf here at the back, it's freezing. If I put milk, for example, it'll be frozen when I want to use it. Partly frozen, not fully frozen. The rest of the shelves are okay. As you can see, it's actually mostly empty at the back of the first top. I think it's not well designed to have a lower temperature there than the rest of the fridge. (HH8, Summer round)*

Another factor that emerged during the interviews, but was overlooked by participants, is the frequency of fridge door openings. This aspect gained significance when comparing it with the data obtained from the first round of quantitative monitoring, which revealed that four fridges within the groups experienced significantly higher-than-average numbers of door openings. The interview with HH20 in particular aligns with the quantitative data collected from the fridge monitoring. According to the HH20 and HH6 participants, the fridge in their households were regularly opened. This statement further supports the observations made during the Winter round and adds weight to the importance of considering the impact of fridge door openings in the context of the study.

*Ohh God, it's regularly opened. Probably hourly. (HH20, Winter round)*

HH6 mentioned that in their kitchen, the constant demands of their children necessitated frequent access to the fridge.

*The one in the kitchen heaps, just because of the kids are always after something. Ah gosh, it would have to be like 20 times a day for the fridge freezer here all the time. (HH6, Winter round)*

#### 4.2.6 'Contentious' packaging

The packaging of meat is subject to many opinions and preferences related to convenience and keeping it fresh. Certain kinds of packaging may have been thrown away as they did not stack well in the fridge, and the meat was transferred into other containers that meant the meat went off sooner. Opaque packaging may have also led to waste of meats such as in deli items, as the contents were not immediately visible and could not serve as a reminder to eat it.

*I buy my bacon and my deli meats from Woolworths, and it's wrapped in white paper, and I tend to forget what's in the white paper [laughter]. I rely on the son to chew through all the*

*bacon, but I don't have a visual reminder—it doesn't stand out in my fridge that I've got it. (HH20, Summer round)*

During the conversation, HH20 also provided a solution to her issue:

*In a way, because it's a plastic bag wrapped in paper, maybe I should just take the paper off. Just so I can go, "Hey! I've got bacon there." (HH20, Summer round)*

In many ways, somewhat like the fridge, packaging waste was absent from householders' reflection on how much waste they created. For example, stacking the fridge to ensure efficient use of space may be more important to householders than keeping the packaging of the meat.

### 4.3 Red meat waste

#### How does meat, especially red meat, become waste?

Red meat was seen to have many different meanings, values, competencies and infrastructures involved in its consumption, purchasing and storage. This section elaborates on how householder practices reflected these differences. In many cases meat was considered more precious than other food stuff because of higher prices, how meat was cooked or processed also shaped its use and disposal.

#### 4.3.2 Meat as a precious food stuff

Meat was seen as more precious than fruit or vegetables or even bread in many households. Throwing out meat, especially because of forgetfulness, was painful for many householders, such as HH6:

*Time flew and we're like, oh my gosh, I forgot about that meat, then it kills me to throw you know, uncooked meat out that we haven't used.*

Even with the best of intentions, spontaneity or a change of plans, such as going out on weekends, could lead to red meat waste. A change in routine could interfere with meal plans and consumption of leftovers, as per this perspective:

*Saturday, we go out, Sunday we go out and then, by the Monday, oh, we still have this one that we cook on Friday. If we eat it and the taste is funny, only then, we throw. (HH19)*

Householders, such as HH18, considered themselves good at saving meat from waste, and give meat to their pets as a back-up option:

*Look, we're pretty good [with meat waste]. But if...we haven't realized it's been pushed to the back of the fridge or something. Obviously, if it's really gross, we won't give it to the dogs, but if it's still okay, we'll give it to them. (HH18)*

While the winter round of interviews brought up concerns about rising prices of meat and other food items, the summer round expanded that concern to many more of the participating households. For some households at the time of the second interview (in Summer) the price of meat was starting to bite much more and forced changed shopping or eating practices. For HH12, their meat eating had been reduced drastically:

*I feel like the meat consumption is probably down to about half. My husband's English and he was just so used to eating meat every day too. Actually, last time [winter round] was when it [prices] started creeping up a little bit, but now [summer], it's majorly different when you do the weekly shop. Probably another reason why we've changed our eating habits, to be honest. (HH12, Summer round)*

### 4.3.3 Meat types

The materiality of the meat and the food product itself also shaped how meat got thrown away. Deli meat left uncovered or a few days in the fridge gets thrown regularly, for HH13, as with HH5 above as well:

*The only thing I'd probably get rid of is fresh ham salamis because we bought it from the Deli at um, IGA and they cut it all fresh. It just doesn't last, um, probably more than five days, but it usually gets eaten, but if it's going to get thrown out, the dog will know about it. (HH13)*

Many households such as HH15 stopped buying deli meat like salami, due to regular wastage, indicating that households had no solution to stopping wastage:

*We stopped buying salami because it would just sit in the fridge for too long or come back from my daughter's lunch box untouched. (HH15)*

### 4.3.4 Family and care practices

Care practices for families also shaped how and when food gets wasted. Children tended to reject food and extra and separate meals were many a time prepared for them that got wasted. HH10 related how their food waste had changed, for the better, as the kids had grown up:

*From where we were at when our daughter was really young to where we are now because you waste a lot of food with really little kids. They ultimately just won't eat a lot of things. You're tired and cranky or whatever the case may be. You waste a lot more food because they can't communicate at that time. (HH10)*

On the other hand, some households were happy to experiment on themselves but not on the family, using terms like 'cast iron stomach' and 'dumpster' to describe themselves in their efforts to save food from waste by eating food that others might reject. This was the other end of the spectrum to those who tend said, "if in doubt, throw it out". Householders such as HH7 established that they were able to tolerate more stale food than their family and were cautious while feeding them, but were more daring when it came to feeding themselves:

*I think I established it by cooking for the wife something that I'd normally cook for myself and she's not feeling too great, I'm feeling okay, or maybe I'm feeling slightly off because I tried something a bit too hard, pushed it a bit too far. I've noticed she is a lot more susceptible to reactions and so forth than I am. I trust my nose a lot. I don't use use-by dates much. They're a guide. (HH7)*

Aside from care, meat was offered to children as a healthy and nutritious food and as a habit to cultivate. However, the overprovision of meat with this goal, such as for HH6 below, could lead to experimentation and waste, and some guilt about not handling the waste properly (such as composting):

*There's a lot of food wastage with the kids as well. I'd love to do composting and all of that, but it just hasn't happened so far. Probably a lot of meat to be honest with you. And that would be because we always offer our kids meat... my youngest son you know, we just have to put it in front of him and just hope he eats it. (HH6)*

**Box 1.**

Vignette 1: The role of meat in everyday food practices of our participants

Grace, her husband Mark and two kids live in a suburban house in Melbourne. Their older teenaged son is “a growing boy” so they often have steak and red meat, and he is at the age where he will buy his own red meat and cook it for himself. As a family they will go out for dinner occasionally and will generally “balance both meat and vegetables in the dishes”. Grace rummages through the fridge to plan for dinner and finds some sausages one day out of date. She says she is a “stickler” when it comes to use by dates “if in doubt, we always throw it out.” She opens the sausage packet and gives it a cautionary sniff test – seems okay. She tosses the sausages to their dog Rex for his dinner, a special treat. The family have a busy life and often plans change or food gets forgotten. Grace says, “I know we waste a lot of food”. But then again, their rabbit Billy does get the benefit of any lettuce, kale or carrots that might look a bit sad, but are still good enough to eat.

#### 4.3.5 Prioritising fresh food

For many of the participants, the perception and meaning of freshness was the thread that bound together shopping, cooking, storage, eating and waste of meat. For HH5, shopping for the freshest meat ensured that the meat could stay longer in the fridge and eventually not get wasted either. Life experiences of being a meat eater, according to the participants, also helped them determine the freshness of the meat:

*We have grown up eating meat-based dishes so I guess when a meat has gone spoiled, you can smell it. Also, most of the time... my wife prefers to go to Sunshine because those butchers get fresh meat delivered to them a few times a week. We can keep it in fridge for a bit longer. Anything that would be used after three days, it will go in the freezer... (HH5)*

For HH5, if the meat went off as soon as they bought it, in one day, the shop was to blame:

*There have been some instances in the past we have bought a meat from the shop within a day. you can smell it is gone. But then that problem was the shop selling not the fresh meat. (HH5)*

Most of our participants tried to eat fresh food as their main goal, using many ways to determine how freshness was perceived and maintained (including HH7, HH8, HH9 and HH13). For example, as shown in Fig. 8, HH10 tried not to overload their fridge, and if something was close to perishing, they tried to meal plan and eat it quickly:

*We don't want to try and overload the fridge to the point where it actually has to work harder than it needs to as well....If we're talking about food waste and freshness, you'll have a look at that because it gives you those views on a window of time that freshness— because... you want to eat it as fresh as you can. (HH10)*



Time was a crucial factor in determining freshness of red meat for many of our participants, with everyone having different ways to determine the right window of purchase and use. For HH10, it also determined which specials could be bought and incorporated into the meal plan:

*We tend to look at the specials, because they run for a week, so that gives you a window of a week anyway, right? You kind of get a sense of what you can buy and still be efficient, but still know that you'll get the best out of that grocery shop. (HH10)*

**Figure 8: Participants tried not to overload their fridge**



#### 4.3.6 Entertaining etiquettes

Having friends and family over, or taking over platters for parties, was another way that food waste happened. Having enough for everyone was a cultural and social practice that often actually meant having too much, especially when it came to feeding guests. For HH2, talking to us was a revelation of how meat gets wasted:

*I think that we're pretty good as a family about minimizing wastage unless it's salads or strawberries. They go off so quick, but never the meat. Actually, that's a lie. We had some visitors—and we're also platter families. With that, you're buying cabanas and salamis, prosciutto and all those things, but, if you are not eating... so I threw out a couple of things of like salamis, and hams, and prosciutto the other day. (HH2)*

## 4.4 Reducing Food Waste

## How do householders reduce food waste? How is knowledge about food waste generated?

Saving food, especially meat, from waste was reflexive – that is, participants actively thought about what they were doing and why, before acting. Saving food from waste was embodied in householders' practices in many ways. Meal planning, cultural values, practice memories, learning from experiences and knowledge seeking from various sources were all methods utilised by the householders for this purpose, and have been cited in previous literature. The following section highlights how meat was given special attention and, despite these measures, meat did get wasted.

### 4.4.1 Planning, Managing and Cleaning

Planning, managing and cleaning were all cited by participants as important strategies they used to save food from waste. This could mean meal planning or planning and organising the storage, managing how much is bought, and cleaning, tidying and organising the fridge, as per this view:

*I did a clean out of the fridge once a week and then, I would get our shopping and prep the food so that it's getting eaten. It's actually really helped. (HH12)*

Some participants such as HH3, HH12 and HH7 had developed their own methods for testing what works with their family and what doesn't. They did this affectively, viscerally and physically (with material support), usually through trial and error like HH7:

*As I try things with my children, you learn what they eat and don't eat, but it's also learning about quantities. (HH7)*

Processual knowledge generated by experience and trial and error played an important role for some participants. They learned how certain food tastes, certain mealtimes, and their family specific eating routines led to wastage and thus reflexive interventions such as this:

*If you realize that you're buying all your food in a week and then you're wasting it all, then you do something differently, but, I think, also because of the background in health, I have this willingness and happiness for me to eat the same s\*\*\* for lunch every day without it being an issue. If there is extra food that would go to waste, I'll just have that for a lunch instead of the tuna. (HH2)*

Saving food from waste could also mean unlearning cooking and provisioning styles that they learned growing up, such as over catering. Reflecting on how food got wasted, through perhaps tastes or lifestyle, prompted a change in strategy for HH12:

*I was buying a whole shop on the Monday 'cause I was I'll make this, this and this, this week. Then, the kids had hobbies and stuff and maybe that night I didn't make it. Then, a couple of days later it would go out of date. (HH12)*

An individual's approach to food and waste can change over a lifetime or can make rapid changes due to extraneous factors such as the cost of living. Many participants cited changes in prices as a reason they began to save more food from waste as per this perspective:

*Because everything's just getting so expensive, I've changed my whole—it took me 37 years to get to this point. I wish I was like this in my twenties. I would've saved a fortune. I just used to throw things. I didn't care. Now, I think about it a lot more. (HH12)*

Householder, such as HH18, considered themselves good at saving meat from waste, and giving it to their pets as a back-up option – a common practice amongst the households with pets:

*Look, we're pretty good [with meat waste]. But if...we haven't realized it's been pushed to the back of the fridge or something. Obviously, if it's really gross, we won't give it to the dogs, but if it's still okay, we'll give it to them. But normally we try to make a point of eating it because it is expensive. (HH18 Winter round)*

Many participants relied on online shopping due to COVID and started meal planning (as shown in Fig. 9) for efficiency (HH9, HH12, HH20, HH2), but not all directly associated the change with reducing food wastage. Some had resorted to meal planning due to rising costs, and for other participants, not hopping to the market whenever they needed something was a way to control their extra shopping and possibly food waste as was demonstrated here:

*I started doing delivery to boot during COVID. And I've kept that habit. So on Wednesday nights, I sit down, and I do my menu plan from Friday through to Thursday. (HH9)*

When asked if waste had reduced due to that, this participant responded, *I don't think so*, but attributing the program “war on waste” with better recycling of their own soft plastics.

For HH10, rising prices drove meal planning and a general concern about food wastage:

*We're actually buying to make sure that we're cutting down on waste. Probably don't wanna waste too much food obviously. We're very mindful of making lists and preparing what we're going to eat for, more likely, the week, and then we just buy as we need. Because everything's become a little bit more expensive in the grocery aisles. (HH10)*

Householders like HH19 who had a colder than normal fridge stated that the way they stack up their fridge has an impact on food waste and not the fridge temperature:

*Generally, if we don't put too much, as long as it's not super crowded, I think they are fine. Yeah. It is crowded now. (HH19 Summer round)*

Figure 9: Meal planning, and regularly tidying up fridges to reduce food waste



#### 4.4.2 Using expiry dates selectively

Expiry dates were not always used as the final word on when food is off, and a certain amount of “common sense” was used when deciding whether meat is good to eat. For HH3, expiry dates sometimes did not make sense, leading them to use the date in combination with their senses to decide whether to eat meat. However, date labelling was utilised when they were putting meat into the freezer as it shaped if the meat got thrown out or used. In essence, HH3 was selective with how they utilise the expiry date:

*So colour comes first, then you're looking at the date, and the feeling of it not being quite right. Yeah. I think gosh, you know, if you eat it - sick kids, it's just not worth it. (HH3, Summer round)*

Some householders rely more heavily on their senses than date labelling, and to varying degrees are more willing to risk it to ensure meat is not wasted, experimenting with food that may be on the edge of spoiling:

*I'm not a perfect believer of due dates. I use my nose that's what we were given noses for and senses etc. But yeah, if it was well in date. Once it gets beyond a week, I'm the only one who might try it (HH7, Summer round)*

### 4.4.3 Skill management

For HH18, the fact that their partner was a better cook was one way of using meat wisely. HH18 preferred that their partner cook because as they remarked,

*He cooks the meat because he cooks it better than me. But usually, it is me but I just don't trust myself with a steak. I'll just burn it. (HH18 winter round)*

This shows how cooking practices may relate to food waste – burning meat results in wastage so these skills are very valuable. Importantly in this example, tasks can be outsourced to those who have the necessary skills.

Additionally, householders used subscriptions such as EveryPlate and Hellofresh as a support system to reduce waste. This can be an intentional strategy to reduce waste, or unintentional as their motivations are simply convenience and price point. Either way, the planned meals and portioned-out sizes mean there aren't leftover ingredients that may be wasted or forgotten. Fig. 10 shows a participant's fridge with pre-made meals. When asked if they had noticed that the meal subscription had led to reduced food waste, many replied in the affirmative as per this comment:

*Definitely a lot less food waste— actually. So, um, you know, it's kind of weird. For EveryPlate because that doesn't get bagged up; you just have a fridge full of vegetables. And you go, oh, my God, are we ever gonna get through these. And you do; you get through it all and you feel pretty good about yourself. (HH20)*

Box 2.

Vignette 2: The role of meat in everyday food practices of our participants

In Perth, Lily and Adam sit down to eat dinner – a Pad Thai from their HelloFresh subscription - but their baby fusses and throws her food on the floor. They pull out some Bolognese they've saved in the freezer and heat it up – the meal is accepted, and they can breathe. As the young couple are both working, they are often strapped for time and supermarket trips happen only as needed, so they tend to overbuy to make sure they have enough. Lily explains they plan their food so they can eat it for lunch the next day, “we have to be pretty organised!”. On the weekend they have a break from the regimen and host a barbeque with some friends, buying “oodles” of food to make sure everyone has enough. Lily says growing up in Tasmania with a big family taught her to overcater, “if you make enough for everyone to have a bit of everything the maths never adds up, does it?” But at the end of the barbeque, they give away as many leftovers to their guests as they can.

**Figure 10: A participant's fridge full of pre-made meals to accommodate busy lifestyles, limited space, and willingness for waste reduction**



#### 4.4.4 Leftovers

Different food materials and cooking techniques had different skills and knowledge attached to them for deciding if they should be 'binned' by our participants, especially with leftovers. HH7 found it difficult to determine the edibility of leftovers because of the way they were cooked, especially if their sense of smell or sight couldn't be used:

*Leftovers are a little bit harder because often they're flavoured like Indian foods or something like that. We decide by remembering when we got it or cooked it. (HH7)*

In terms of knowledge of how to use leftovers, participants often mentioned what seemed to be a "magic number" for how many days they will keep their leftovers in the fridge before binning it – this ranged from 1 to 3 days. For HH1, meat was always cooked and eaten in two sittings:

*When we buy red meat, we don't buy over. We know we're going to finish that in two eats...normally we cook at night and then, we eat it again the next day in the afternoon. (HH1)*

Often households would speak of systems like this for making sure that everything gets eaten – planning to have leftovers specifically to eat for lunch the next day as demonstrated in Fig. 11. Many householders credited their upbringing that taught them not to be wasteful. HH2 (summer round)

described themselves as a dumpster due to that reason, and he managed the leftovers by simply eating them:

*We're not that wasteful. Maybe it's my culture, but I've transitioned into more of like a dumpster [laughs] for the household. If there's extra food left over, I'll end up just eating it. My partner gives me shit about it all the time, but, yeah, I'm just like the trashcan for the house. (HH2)*

**Figure 11: Leftovers glad-wrapped in one of the participant's fridges to be used within their "magic number" of days**



#### 4.4.5 Purchasing quality

Ensuring a better quality of meat is also a way that participants ensured meat didn't go waste. Unlike other participants mentioned above, HH1 was wary that freezing meat reduced its quality:

*So we don't freeze meat, red meat in particular. Only because I think growing up Mum's always taught us that if you put red meat in the freezer, it tends to degrade the quality. (HH1)*

As shown in Fig. 12, buying quality, fresh meat in the first place is something that participants ensure to reduce wastage, which often means being able to see the meat for themselves to judge its quality. For HH2, they have heard that some lower quality meats can be made to look "inviting" with

the use of a marinade and that pieces might be in fact joined together with glue. So they make a point of being able to see the meat clearly before they buy:

*I think for the most part, red meat's something to celebrate anyway. So, for example, if it's exposed, and it's a good piece of meat, you want to just see the meat. (HH2)*

**Figure 12: Buying quality red meat and using it fresh for the whole family**



#### 4.4.6 Gaining knowledge and experience

The internet was the go-to for food waste information for many of our participants. Internet searches were seen as a quick and everyday way of enhancing, confirming, and assuring participants' knowledge of how food should be stored, used, and binned, as this showed:

*We'll have a look at a variety of different websites and try and get an authority in the area. (HH10, Summer round)*

Sometimes packaging provides information about how to store and use meat as well, in this case:

*IGA have a sticker that has "Freeze me within 24 hours" or something, because it's preservative free. That's handy (HH13)*

Knowledge about reducing food waste was generated in many ways, two prominent methods were learning by doing, and practice memory. When HH2 was asked where the knowledge about food waste came from, they mentioned their past experiences of saving food:

*I think coming from a space of poverty when I was younger, going through uni, and your work, and stuff. It takes a lot to pay the bills, and so a penny saved is a penny earned... You just get better and better and better at all your different things that help you out. That was my experience anyway. (HH2, Summer round)*

What may be interesting to further research is that while advice about meat or food waste may be similar for specific food stuffs, the diversity in fridge designs, size and age of fridge, type of use, organisation of life.



For example, additions to families such as babies, creates complexity in operationalising the advice. Furthermore, a well-used fridge that is warmer may lead to leftovers and other food being spoilt early.

## Intersecting practices

Most practices could be said to have both good and bad sustainable outcomes, and it is the nexus of participation in specific practices that affects the resulting sustainability outcomes of individuals or groups (Maller 2015). Keeping this in mind, in this section, we explore practices that intersect with meat consumption, such as shopping, binning and waste management, and meal planning. This helps to show how meat waste may be an outcome of a certain bundling of practices.

### 4.4.7 Specials and bulk buying

As shown in Fig. 13, supermarket specials and bulk packaging have been known to have ambiguous outcomes for food waste (Tsalis et al. 2021; van Lin et al. 2023) In the case of some households, specials shaped how shopping and budgeting was done, especially keeping in mind the increase in the cost of groceries. HH7 described specials as impulsive buys that go into the freezer for future use:

*“Sometimes our eyes are bigger than our tummies and we just buy too much and don't realize how much. So, if there's a promotion on, yes deliberately buy more with the intention that we freeze one of them” . (HH7)*

For some like HH5, buying large packages of meat (with multiple portions) was implicated in meat waste. They would sometimes get the dance from the fridge to freezer and back wrong, and miss the use by date, which can lead to even more spoiling in summer:

*We store the meat in the freezer and then move it to a fridge, but often we get it wrong...and we notice maybe a couple of times in the warmer month, the meat is not usable. Maybe we left it in the fridge too long or we move it too early... and that is generally the case with the bigger packaging because we bought in bulk..., but if the serving size is just enough then there is very little possibility for those things to happen. (HH5)*

In the case of HH11, buying bulk items was avoided and she only bought portions of meat that was needed. This was partly due to the increased risk of wastage, but mainly because they did not like the unsurety, and complexities associated with frozen food:

*We would never buy big bulk because then it has to end up in the freezer, and then it just gets hidden in the freezer... I find them hard then to defrost well because I'm never quite sure how you do that. Do you do it with running water in the sink? Do you leave it on the bench? Do you try and defrost it in the microwave? Do you try and defrost it in the fridge and then it doesn't defrost for more than 24 hours? (HH11)*

Households expressed distrust and cynicism around how waste was managed by the councils, leading them to be nonchalant about packaging waste and being upset about their labour being wasted. However, generally there was a small sense of belief or at least compliance when it came to advice from local councils, as per this view:.

*Packaging waste, you're feeling good about yourself because everyone was using the REDcycle bags only to find out that was the biggest scam out... I still, even though I know recycling's a scam, I still use the recycling bin the way the council tells you to do it (HH20)*

**Figure 13: Participant's using the freezer for ice-cream, and frozen pizza but not for meat**



#### 4.4.8 Binning food

Practices of binning food did not have a fixed pattern across households. Some households used ad hoc times to bin foodstuff that may have gone bad, preferring to simply bin as they go. For HH7, it happened when they noticed that there was something to clear out:

*I don't really go, "Oh, it's bin night, let's take a look at the fridge." It's more noticing, "Heck, I didn't realise that cream was gone. What else in here haven't we noticed," and then take a look around. (HH7)*

As demonstrated in Fig. 14, others cleaned out the fridge on a schedule aligned with a day of the week, or their shopping schedule (to make space for things). HH16 associated cleaning of the fridge with 'bin night' and would throw out items that were going off or that they thought may not last the week:

*I need to get rid of all that on Sunday night because Monday morning, the bins come and I don't want that to smell left over (HH16)*

**Figure 14. Multiple opened dairy products and leftovers kept in the fridge until bin night**



#### **4.5 Refrigerators: Use and performance of the technology**

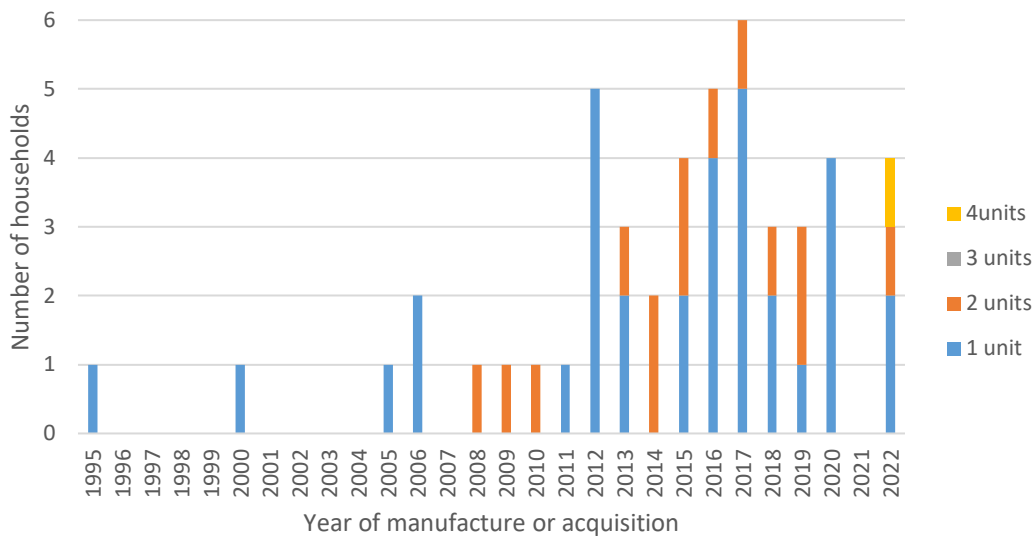
The next findings provide a view into householders' decisions that relate to fridge and freezer technology and the subsequent fridge performance that can affect food waste. The sections follow the sequence of parameter groups presented in Table 1 and Fig. 6.

#### **4.6 Household conditions**

Most (70%) households had one refrigerator unit. Thirty-nine households had one unit. Sixteen households had two units. One household had four units.

#### **4.7 Refrigerator unit characteristics**

The main refrigerator unit was, on average, newer in households with multiple units than in households with one unit. The year of manufacture or acquisition of refrigerator units had a mean of 2014.5, range ['1990s' (assumed to be 1995), 2022], 2012.1 for households with one unit, 2014.6 for households with two units, and 2022 for the household with four units. Apart from two outliers in 1995 and 2000, the other years were from 2005, as shown in Fig. 15.

**Figure 15: Distribution of year of manufacture or acquisition of refrigerator units**

## 4.8 Refrigerator use

Of the 23 refrigerator units for which temperature setpoints were reported in degrees Celsius, fridges had a mean setpoint of 3.4°C, range [-3.0, 8.0], and freezers had a mean setpoint of -17.8°C, range [-23.0, -10.0]. Other temperature setpoints were reported according to a unitless scale (e.g., cold=5, coldest=1) or were not reported.

Fridges were accessed more frequently than freezers. Fridge doors were opened a mean of 1.7 times/day, range [0.1, 7.1]. Freezer doors were opened a mean of 0.5 times/day, range [0.0, 4.6]. These frequencies indicate the expected behaviour that householders access fridges more than freezers, but they appear to be too low to be reliable, especially given that the logged data indicate that many fridge doors remained closed for several contiguous days.

Nearly all door seals were in good condition, enabling them to slow the infiltration of heat, as designed. Only two refrigerator units, manufactured in 2006 (fridge compartment only) and 2010 (fridge and freezer compartments), had wet seals.

## 4.9 Refrigerator unit performance

Average temperatures across fridge shelves are different, but they vary together. Of the 140 shelves with valid data, only two pairs of shelves in two different fridges had similar mean temperatures ( $p < 0.05$ ). Temperatures at various shelves were correlated at 0.01 or 0.05 levels.

Average fridge temperature had a mean of 4.4°C, range [0.9, 8.9]. At any shelf, the highest average temperature was 10.0°C and the lowest average temperature was -1.1°C. Some (17%) fridges had mean temperatures outside of the optimal range. Four fridges had mean temperatures greater than 7°C. Five fridges had mean temperatures less than 2°C.

Average freezer temperature had a mean of -15.9°C, range [-21.2, -5.1]. Many (43%) freezers had mean temperatures outside of the optimal range. Sixteen fridges had mean temperatures greater than -15°C. Five fridges had mean temperatures less than -20°C.

Temperature control at some shelves was imprecise. Of 74 fridge and freezer shelves with valid data, 34% had mean temperatures below the setpoint ( $p < 0.05$ ). Two fridge shelves had mean temperatures that are probably the same as the setpoint ( $p < 0.05$ ). If temperature control is precise, then the temperature is expected to above the setpoint.

Average humidity across fridge shelves varies together. Humidity at various shelves was correlated at the 0.01 level. Average fridge humidity had a mean of 43%, range [31, 60]. At any shelf, the highest average humidity was 63% and the lowest average humidity was 29%. Average freezer humidity had a mean of 53%, range [35, 64].

## 4.10 Correlations

Various parameters were significantly correlated, as indicated in Fig. 16. Green arrows and blue lines indicate positive correlations, meaning that the two parameters varied in the same direction. Orange arrows indicate negative correlations, meaning that the two parameters varied in opposite directions. Dark arrows indicate significance at the 0.01 or 0.05 level. Light arrows indicate significance at the 0.1 level. The arrow heads indicate a proposed direction of causation, consistent with Fig. 6, but the analysis cannot indicate the direction.

Of the correlations that were significant at the 0.01 or 0.05 level, nearly all had a Pearson correlation coefficient of at least 0.3 and may be considered at least moderate (Field 2013); only one coefficient (0.281) was lower. Of the correlations that were significant at the 0.1 level, the lowest Pearson correlation coefficient was 0.23.

The correlation analysis indicates many relationships that are as expected or are relatively easy to explain. The direction of the relationship is assumed.

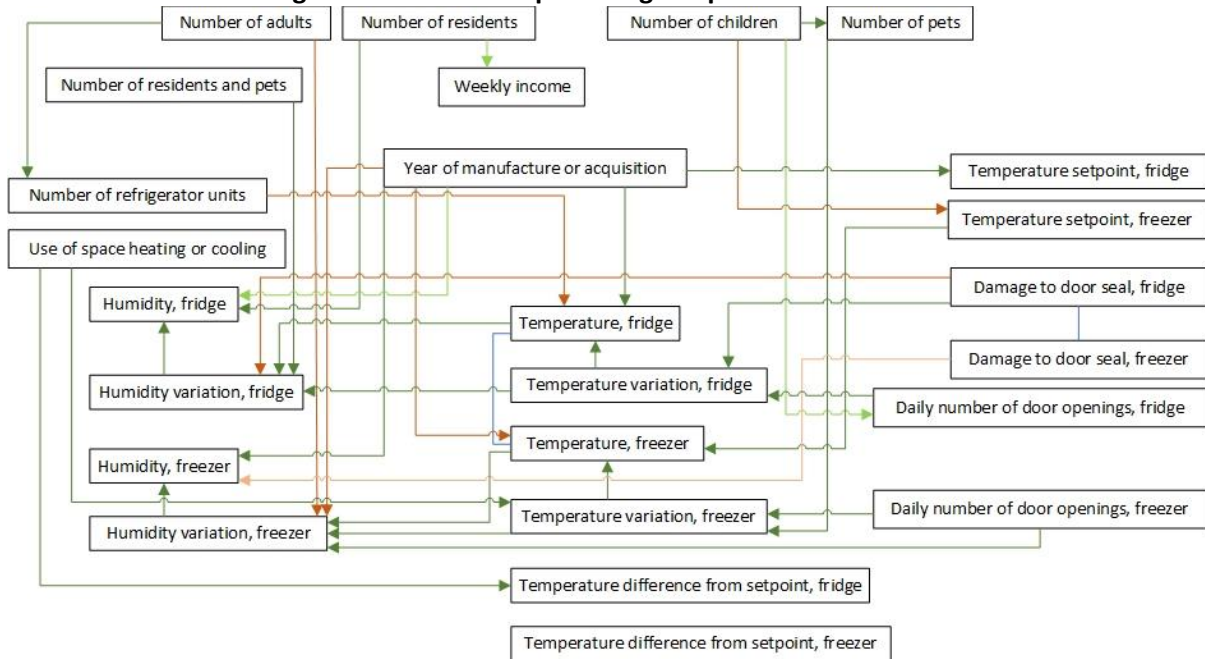
- The number of adults, but not the number of children or pets, drove the acquisition of additional refrigerator units.
- Income had no effect on any other parameter studied.
- The year of manufacture or acquisition, perhaps indicative of the householder's decision to update the main refrigerator unit, was independent of the parameters studied.
- Newer refrigeration units had higher fridge temperature setpoints, higher fridge temperatures, lower freezer temperatures, higher humidity, and lower freezer humidity variation.
- In households with two refrigerator units, the temperature of the main fridge was lower than in households with one refrigerator unit, suggesting that having a second unit enabled a different use pattern for the main fridge.
- For fridges, the use of space heating or cooling drove the difference between the setpoint and actual temperature, and the temperature variation. For freezers, the difference between the setpoint and actual temperature was independent of the parameters studied, other than the temperature parameters in the mathematical formula.
- In fridges, damage to door seals drove temperature variations and dampened humidity variations.
- The opening of doors drove temperature variation, but the data for this relationship was unreliable.
- Temperature and humidity varied together, more so with maximum temperature and humidity, suggesting that the variation was driven by events that increased the temperature and humidity. The minimum temperature and humidity were relatively consistent.
- In freezers, the setpoint temperature drove the actual temperature, as expected, but no such relationship was detected for fridges.

- There was no relationship between temperature setpoints of fridges and freezer, suggesting that householders adjusted the two setpoints independently. The actual fridges and freezer temperatures varied together, though.

The correlation analysis also indicates some relationships that are difficult to explain. The direction of the relationship is assumed.

- The number of adults dampened humidity variations in freezers.
- The number of children decreased the temperature setpoint of the freezer.

**Figure 16: Relationships among the parameters studied**



## 5. Conclusion

Many practices play a role in how meat gets wasted in domestic settings. Our data illustrates the relationships between practices that produce meat and food waste despite householders acquiring knowledge from various sources, reflecting on their actions and some organised interventions.

Our data illustrates that saving meat from waste is a reflexive practice for many householders. Reflexive activities embody certain skills and competencies, availability of specific materials and most of all reflect how householders thought about saving food, especially meat from waste. The strategies that are reported above are from those householders that have successfully reduced their waste (self-reported) and therefore reflected mechanisms that had been generated under real-world circumstances. Whether these strategies can be reproduced in other households or society-wide is ambiguous and needs to be further explored. Listed below are some points that summarise the reflective and dynamic nature of attempts to save meat from waste.

1. Giving food and meat to pets is seen by many participants as saving food from waste. This practice highlights the complexity of food waste and brings into the discussion how the upcycling and downcycling of food while being saved from landfill, or even composting, shapes food waste production.
2. Using marked specials on meat and other food: Our report has shown that retailer practices like specials or bulk discounts have varied and ambiguous results in terms of food waste. While bulk buying saves people money, and freezing extra food saves food from expiring too soon, events such as forgetting things in the bottom of the fridge or reduced quality due to freezer burns, especially for meat, have been reported to lead to food waste. Some householders who regularly bought specials had specific ways of re-packaging their meat to better stack the freezer and avoid freezer burn. This resulted in ambiguous results for packaging use.
3. Hygiene and health concerns, as raised by many other studies, have a wide range of meanings and practices attached to them. Depending on microbial action, sensory perception, and cultural values, meat and other food is moved from edible to waste. So much so that a strong foul smell renders it useless for pets as well. The challenges of varied sensory perceptions illustrates that many practices may be hard to shift without societal interventions.
4. Leftovers are an important site of intervention as they are produced intentionally (for example for the next day's lunch) and unintentionally, for meat as well as for other food products. Safety is understood through time and smell for leftovers, except when the meal itself has a strong smell it becomes complex to ascertain spoilage, and meat waste is shaped by these decisions. Leftover raw ingredients are another potential site for intervention, as portion sizes of meat must fit into recipes and leftover ingredients might be thrown. Varied portion sizes and practices that promote using all ingredients may shift wastage here. In terms of knowledge of food waste and leftovers, participants mentioned "magic numbers"

around how many days they will keep their leftovers in the fridge before it goes to the waste, ranging from 1 to 3 days.

5. Price points and the economics of consumption and wasting: Evans (2011) talks about thrift and frugality, differentiating between them to understand the long-term effects of price points and how they eventually have a limited effect on food consumption and waste. This point is important to note as in the summer round (Dec-Jan 2022-23), our participants were more worried about buying and wasting extra food than previously. These activities or concerns may range from thrifty, that is primarily economic, to frugal ways related to care and compassion. At this point with limited longitudinal data it is difficult to determine whether this is long term change or short-term austerity.
6. An organised fridge is valued by many of our participants – size and shape and the visibility of food is another aspect of refrigerator design (as shown by other research as well) that may involve coordination between various entities and actors – such as house and apartment design, kitchen design, fridge efficiency, refrigerator design, and pricing of fridges. Material arrangements such as fridges and freezers that are flexible but also perform the main aim of efficient cooling and delay food spoilage. Here we encounter how food storage and saving food from waste are sometimes strongly connected, while other times the use of the fridge is to merely store foods, efficiently and for a longer time.
7. Fridges and freezers are implicated in food and meat consumption in vastly different ways. This complexity of 1) ratcheting of needs (bulk buying/cooking, better/fancier fridges) 2) quality of meat (freezer burn) 3) convenience of use to save food from waste (forgetfulness and ambiguity around best before dates) sometimes contradict but at other times support each other.

Food borne illness is frequently caused by insufficient food temperature control (James, Onarinde & James 2017) . Many researchers have also asserted that temperature control in refrigerators may be inadequate (James, Onarinde & James 2017). Our findings suggest that controlling the fridge temperature or adjusting shelves, and other measures to ensure food waste doesn't occur, does not form a part of many householders' everyday storing and meat consumption practices. Instead, freezers are most frequently used to control meat or other food storage and to ensure food waste is minimised. This may mean that while the refrigerator is an essential infrastructure in householders storage practices, the meanings behind the use are only loosely connected to saving food from waste. Or more simply refrigerator practices do not include changing the temperature and/or monitoring the temperature to save food from waste.

We also found that not many householders knew the temperature of their fridges or tried to control it, seasonally or due to other reasons (being too full) apart from a few. A review conducted in 2016 found that in 30 years from the previous surveys, not much had changed in householder practices of refrigeration, fridge temperature controls, apart from energy efficiency labelling of fridges. Various information strategies, recommendations on storage and handling have largely been ignored nor included in daily practices.



Previous research (James, Onarinde & James 2017) demonstrates that despite decades of standards and recommendations that fridges operate between 0 and 5 degrees, the arithmetic mean temperatures of fridges in their study was 6.1 degrees C indicating 50% of fridges were operating at the wrong temperature. At the same time, France has had mandatory thermometers inside refrigerators, which have had very less impact on how refrigerator temperature is monitored in homes, with only 4% more fridges being monitored by the householders, after the regulation was implemented (James, Onarinde & James 2017). This indicates that mere regulatory, technological, or behavioural interventions may not be enough to ensure that refrigerators operate at recommended temperatures. Manufacturer practices such as product stewardship, alternative practices of storage, and a shift in shopping, eating, cooking and/or storage practices, change in perspectives towards meanings of waste and its production may be some sites of intervention.

If meat and other food waste and spoilage is directly related to how refrigerators are used, temperature-controlled and designed, then other food and non-food practices may need to be changed to make this connection visible or effective to reduce food waste.

These include interventions at household level, such as reducing bulk buying or multi week shopping to urban planning interventions where adequate and affordable food is available at walking distance to prevent overbuying. Retailer practices of specials and bulk discounts may need evaluation as well.

## **5.1 Key findings summary**

This research has aimed to understand the effect of everyday practices and their interrelationships on the consumption and wastage of meat in Australian households. More importantly, the contexts of food especially meat waste, and refrigerator use and performance, have been studied. Interventions to reduce food waste may be applied in these areas. Similar to the WRAP UK findings (Quested et al. 2013), we have found that food waste is an outcome of a set of complex relationships. As a unique contribution and to provide an in-depth insight into these complex relationships, we 1) focussed on meat consumption, instead of meat waste, 2) explored the specific relationship between meat consumption and waste, and refrigeration and freezing practices, and 3) investigated the use and performance of refrigeration unit, the primary tool for preserving meat for consumption. This has enabled us to highlight connections between everyday routines especially related to food and storage to reduce meat waste and effectively use chilled storage.

This research helps to elucidate how and why meat waste occurs, leading potential avenues for future interventions. The results illustrate how the practices around meat of cooking, storing, shopping, and eating, as well as seemingly less connected practices of entertainment and work, interact. Key findings are:

1. Householders find saving food and meat from waste challenging but experiment with novel and established ways to save food, especially regarding saving meat from going into landfill. This includes feeding it to their pets and composting.
2. Freezers are used to save meat from expiring at the date provided on the packaging. This practice is sometimes used deliberately to buy meat close to the expiry date, thus saving money on specials.

3. Quality of meat is regarded by some householders as reduced by freezing, and may lead to binning, or freezing meat is avoided completely (because of concerns about freezer burn)
4. Managing leftovers from cooked meals and deli meat (cold cuts) is most challenging for householders.
5. Householders evoked cultural patterns and values in talking about food waste. Cultural practices and previous life experiences play an important role in how food and red meat gets wasted, or food waste is avoided.
6. Many householders were unaware of temperature variations in their fridges and tended not to blame the fridge temperature when meat or food was discarded. However, many participants noted the design of the fridge, such as deep, narrow shelves, prevented them from having a clear vision of their fridge, leading to forgetting some stored food items.
7. The increase in prices of all essential commodities at the time of data collection has made many householders thrifty and more conscious about food waste. However, as this a short-term study, no strong conclusions can be drawn from this.
8. Householders acquire knowledge about how long to store food in the fridge and how to save food from waste in various ways, including on the packaging, from the internet and by lived experience.
9. Many householders were constrained from buying a new or larger fridge by the available space in the kitchen, or in the house, which they believed they required so that:
  - a. they could store more food
  - b. have a 'fancy' fridge (for example, with a TV or smart fridge, or with a French door), and
  - c. reduce trips to shops.
10. Date labels were used in many ways during shopping: as an indication of freshness, to ascertain how long an item could be stored for, and if near expiry (and on special) buying it to save money. As mentioned above another practice was that if the product was not expired, it was bought and frozen to extend its life. Some experimented and used their senses to bypass date labels.
11. Packaging was also used in many ways: some participants acknowledged its capacity to keep food fresh, some discarded it immediately after getting home for better stacking and storage results, and some used it for obtaining information about the product.

12. Given that many households had multiple refrigerator units, each having a different purpose, manufacturers might (re)consider developing and promoting units that are optimised for storing frozen meat, storing chilled drinks, or other purposes.
13. Given that the mean age of refrigerator units was approaching 10 years, householder education is a key intervention point. Improvements that rely on households acquiring new refrigerator units (with special technology) would be insufficient because they are limited by the long delay of householders replacing current units.
14. Given that the refrigerators with damaged door seals were older than the average refrigerator, householders should attempt to frequently check the seals of refrigerators that are older than about 10 years and address any damage.
15. Given that, for some fridges and freezers, temperatures were different to the setpoints and mean temperatures were outside of the optimal range, householders should monitor the condition and life of perishable food, and adjust the setpoint accordingly; Food Standards Australia New Zealand (FSANZ), manufacturers, and retailers should better communicate the optimal fridge and freezer temperatures for optimum food shelf life; and manufacturers could (re)consider more-robust, more-precise temperature control functions and new alert functions.

In the fight for waste minimisation, “innovation and commercial ventures are the more promoted solutions” (Hobson 2020, p. 108). However, everyday activities are ripe for intervention. Our results clearly show the interwoven nature of household practices that both promote *and* minimise meat waste, which are again interconnected with the broader material, commercial and cultural aspects of meat and meat waste. At the same time, saving food from waste is not merely about householders’ attitudes, behaviours or choices that may result from better designed packaging or fridges. In addition, this research has shown how various organisations and interrelationships of elements and practices either produce meat waste or prevent meat waste from happening.

In this pilot project, the qualitative study has contributed deep and rich insights, and the quantitative study provides a view at a national level. Further research that addresses some limitations would help to extend the findings.

- While the qualitative study represents the largest demographic household type, the results are not generalisable due to the small sample size. As is common with ethnographic inquiries, relationships and connections between everyday routines, materials and understandings have been highlighted and emphasised in this research that need further research to inform design and policy solutions.
- In the quantitative study, the statistical analysis determines correlations rather than causation; alternative methods are required to confirm causation. A larger sample size would enable analyses of subgroups (e.g., household categories, and states and territories) and seasonal effects. More-reliable data about the number of door openings would increase the reliability of the related findings; data about the duration of door openings would provide further insights into the behaviour of householders.

- Data collection through interviews and the written form is open to social desirability bias, the tendency of householders to provide answers that are viewed favourably by others. To reduce this potential bias, most interview questions were open ended and most details sought on the written form were facts about the household's state rather than householders' behaviours.

## 5.2 Benefits to industry

The recommendations in this report are relevant to key stakeholders, including householders, policy makers (food, community building, urban planning, education, waste); product designers; product manufacturers; packaging companies; marketers of food and red meat, retailers of meat, food, readymade and pre portioned meals and meal ingredients; online meal subscription companies; peak bodies; and researchers pertaining to red meat and food. The sites of interventions that are proposed are based on analysis of household experiences of where food waste and particularly meat waste occurs. The statistics are drawn from

This project has contributed to the following key impact areas:

- **Food waste reduced:** This project has contributed knowledge in achieving the overall Food Waste CRC 2030 industry goal of reducing consumer waste of red meat by 50%. If half of the food wasted by households requires refrigeration (1.25 MT) there is a potential to reduce waste by a minimum of 10% (125,000T) (Arcadis 2019). For the meat sector (Meat, Poultry, Smallgoods) the waste is reported to be 471 tonnes, there is a potential to reduce by 50% (230 tonnes) resulting in 2,474 tonnes CO<sub>2</sub>-eq saving (Arcadis 2019). Note that waste reduction will be dependent on the adoption of the data from this project by retailers, and regulators.
- **Industry profitability gained:** Any potential reductions of meat waste that will be achieved will lead to greater profitability for retailers and brand owners due to more certainty on shelf life and most likely longer time on the shelf. This means that there will be fewer markdowns on shelf and reduced amount of product discarded in store. It has been estimated to return \$16.3 million for industry in the domestic market (Kaur et al. 2018).
- **Greenhouse gas emission savings:** For the meat sector (meat, poultry, smallgoods) the waste is reported to be 471 tonnes (Arcadis 2019). There is a potential to reduce waste by 50% (230 tonnes) resulting in 2,474 tonnes CO<sub>2</sub>-eq saving (Arcadis 2019). This saving is probably an underestimate because it excludes retail, transport, household refrigeration, and waste disposal; and the additional processing for the smallgoods.
- **Improved retail and production practices for consumers:** Consumers will also have greater surety that the product they are consuming is still fresh, reducing wastage, possibly reducing excess fridge and freezer usage and contributing to health and wellbeing.

## 6. Future research and recommendations

Waste minimisation is complex, and studies and strategies so far have focussed largely on developing new technologies and businesses rather than attempting to change producer and consumer practices. Furthermore, binaries of separating production from consumption miss the central role and entanglements of daily lives with livestock farming, agriculture, industrial production, waste services and materials, and the implications of change in these sectors.

Design solutions that design out waste have also received attention. However, the technological focus tends to leave the ‘social’ out of design and consumption interventions, ignores how “we both make and are made (as social entities) by our material worlds” (Hobson 2020, p. 108). Our study has highlighted how practices (household, industry, and policy) can change only when the social, material, technological, and cultural configurations align. For example, the dependence on and use of freezers for saving money and preventing meat from going waste leads to subsequent issues, such as buying multiple fridge/freezers, reduced quality of meat, and doubling up of packaging. Thus, societal change, such as minimising meat waste behaves a larger scale and multi-sited intervention rather than mere householder behaviour changes and reflexive actions based on choice and information. Furthermore, future research could investigate how diversity in families and schedules may align with different fridge designs to make better recommendations. More research is required into retailer practices, especially of specials and bulk discounts to evaluate how it may shape meat and other food waste.

### 6.1 Recommendations and future research pathway

This report makes recommendations regarding future sites of intervention and research focus areas. These recommendations are premised on the notion that merely informing householders about food waste is not an adequate strategy to bring about change in everyday routines and activities. Interventions that enable change within the complex and interwoven lives that people live are required, as current models are not designed for multiple, complex behaviours (Quested et al. 2013). Therefore, these recommendations are relevant to key stakeholders, including policy makers (food, community building, urban planning, education, waste); product designers; product manufacturers; packaging companies; marketers of food and red meat, retailers of meat, food, readymade and pre portioned meals and meal ingredients; online meal subscription companies; peak bodies; and researchers pertaining to red meat and food. The sites of intervention are based on analysis of household experiences of where food waste, particularly meat waste, occurs. As a pilot red meat waste project, we have endeavoured to focus not solely on meat and meat products in our investigation. This has resulted in interesting and unique insights about the difference in understandings about meat consumption from other food categories as well as a comprehensive picture of how refrigerators and freezers are used specifically for meat and generally for all other food products. However, we have designed the recommendations in Table 2 to particularly suit meat waste but also be relevant to other food waste categories, primarily chilled food.

**Table 2: Recommendations for reducing meat and other food waste**

Sites of intervention/change in practices	Interventions/Research focus	Relevant stakeholders
Meal Subscriptions/reducing shopping overload on the	<ul style="list-style-type: none"> <li>Developing partnerships with packaging companies to ensure less or returnable packaging in meal subscription plans.</li> </ul>	Online meal subscription companies, packaging companies, policy makers

fridge (due to weekly or fortnightly shopping)	<ul style="list-style-type: none"> <li>Partnering with retailers to improve variety and maintain competitive price point with mainstream grocery shopping.</li> <li>Support delivery of adequate walkable shopping options.</li> </ul>	
Meal planning, shopping, and prepping skills	<ul style="list-style-type: none"> <li>Support school and community kitchen garden programs that enable children to learn about food – this can help at home as children become equal contributors to meal planning, preparation, and saving food from waste.</li> <li>Education of adults, community groups and vulnerable groups. For example, new migrants, new parents, and young people just out of home.</li> </ul>	Primary, secondary and tertiary education stakeholders
Refrigerator efficiency	<ul style="list-style-type: none"> <li>Encourage improved manufacturer practices such as product stewardship.</li> <li>Encourage management of fridge through manufacturer's continuous engagement with the product.</li> </ul>	Policy makers, product manufacturers and designers, peak bodies
Refrigerator designs	<ul style="list-style-type: none"> <li>Engage community in innovation and rethinking fridge design and size in relation to fridge and freezer capacities.</li> <li>Support the reduced dependence on freezers as a societal goal through product stewardship.</li> </ul>	Product manufacturers
Sensory evaluation – The 'sniff test'/colour	<ul style="list-style-type: none"> <li>Undertake industry research with community participation on the capacity of 'sniff' tests to determine freshness. This could include the use of chemicals in meat processing that may disrupt or enable sensory evaluation (Flores, Perea-Sanz &amp; Belloch 2021; Ramanathan et al. 2021).</li> <li>Undertake industry research with community participation on improved packaging design and flexibility.</li> </ul>	Policy makers, food and meat industry, retailers
Leftovers	<ul style="list-style-type: none"> <li>Multi-dimensional interventions: encouraging work, school, and university eating areas to provide refrigerators, freezers and microwaves for the use of leftovers (Middha 2020).</li> </ul>	Food and urban planning policy makers, universities
Deli Meat	<ul style="list-style-type: none"> <li>Encourage and support reduction of the use of processed meat, especially refrigerated, through other means of meat preservation and provisioning.</li> </ul>	Meat producers, Government
Knowledge generation about	<ul style="list-style-type: none"> <li>Encouraging and supporting experiential learning (see meal planning, shopping and prepping skills).</li> </ul>	Peak bodies, policy makers, packaging companies, food

food waste/food storage	<ul style="list-style-type: none"> <li>Integrating advice to create trust in a single authority that can provide tailored and specific advice as a one-stop advice platform for storage and use of stored products advice (in the same way that “War on Waste” became a motivator as well as a platform for information).</li> <li>Sharing responsibility to communicate the correct fridge temperature for storage for optimum shelf life</li> <li>Integrating and streamlining different packaging instructions (through peak bodies).</li> <li>Including considerations of multicultural attributes of the population in advice on the life of food and storage (for example, specific food items may not be handled in similar ways in different households).</li> </ul>	producers/manufacturers, FSANZ, Fridge manufacturers and retailers
Technological interventions	<ul style="list-style-type: none"> <li>Tailor smart fridge technology and design with consumer practices of fridge and freezer use through co-design processes.</li> </ul>	Product manufacturers
Entertainment and parties	<ul style="list-style-type: none"> <li>Research into methods to challenge societal norms. Including elevated hygiene due to COVID-19 and risk of food poisoning, ‘what is enough food for parties?’ and ‘what kind of food ages well in the fridge?’</li> </ul>	Product manufacturers, meat producers, retailers, government

It is hoped with research and related changes as per those above, that meat waste is minimised into the future to the benefit of industry, society and the environment collectively.

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## 8. Appendix

### 8.1 Participant demographics

Table A1: A summary of participants demographic characteristics

HH Interviewed for winter	Interviewed for summer	Type of temp anomaly	Age	Gender	Area	Living arrangements	Number of children	Number of pets
HH1	Yes		46	Male	Greater Melbourne	Own - paying off mortgage	1	0
HH2	Yes	Warmer Fridge	35	Male	Regional VIC	Rent	2	1
HH3	Yes		49	Female	Greater Sydney	Own - paying off mortgage	2	1
HH4	Yes		36	Female	Greater Melbourne	Own - paying off mortgage	1	0
HH5	Yes		37	Male	Greater Melbourne	Own - paying off mortgage	2	1
HH6	Yes		35	Female	Greater Perth	Rent	2	1
HH7	Yes		44	Male	Greater Adelaide	Own - paying off mortgage	2	2
HH8	Yes	Colder fridge	46	Male	Greater Melbourne	Own - Fully	3	2
HH9	No		46	Female	Greater Sydney	Own - paying off mortgage	1	0
HH10	Yes		44	Male	Greater Brisbane	Own - paying off mortgage	1	1
HH11	Yes		55	Female	Greater Melbourne	Own - paying off mortgage	1	1
HH12	Yes		36	Female	Greater Brisbane	Rent	3	1
HH13	Yes	Warmer Fridge	37	Female	Greater Melbourne	Own - paying off mortgage	3	4
HH14	Yes	Colder fridge	35	Female	Greater Melbourne	Rent	2	0
HH15	Yes		33	Male	Greater Melbourne	Own - paying off mortgage	1	2
HH16	No	Warmer Fridge	47	Female	Greater Sydney	Own - paying off mortgage	4	1
HH17	No		40	Male	Greater Sydney	Own - paying off mortgage	2	0
HH18	No	Colder fridge	34	Female	Regional VIC	Rent	2	5
HH19	Yes	Colder fridge	36	Male	Greater Melbourne	Rent	1	0
HH20	Yes		49	Female	Greater Perth	Own - paying off mortgage	3	0

## 8.2 Interview guides

### 8.2.1 Winter data collection questions

#### Eating practices

1. What kind of dishes, cuisines or recipes do you like to cook and eat in your household?
2. What kind of dishes do you like to make with meat? (Prompt: What kind of food containing red meat do you cook and eat?)
3. What does a weekly routine of eating look like for you? Prompt: Do you usually have three meals a day or another pattern of eating?
4. How do you eat differently during the week compared to the weekend? How often do you go out to eat? (Prompt: What types of meals do you usually eat: Cooked meals, restaurant meals/take away/eating together etc)
5. How often would you say you cook and eat meat/red meat? (when participant mentions poultry or other meat than red meat – record the type). (Prompt: everyday, weekly, monthly or a different frequency?)
6. Who mainly does the cooking? Is it divided between family members and if so, how and do they like to cook different types of meals? Do they use red meat?
7. [Add question if not already answered above in Q6: Do you cook the same meals for everyone all of the time, or do some people in the house have dietary requirements so that you need to cook different types of meals for them? ]
8. Have your cooking and eating patterns changed during COVID-19? Do you eat less or more red meat now? Do you cook different types of meals?

#### Food Shopping

9. Who does the grocery shopping in the house? How often? (Prompt: Do you use a car/public transport/walking?) (Prompt: everyday, weekly, monthly or a different frequency?) Do you buy in bulk?
10. How often do you go meat shopping and where? Do you buy specific kinds of meat from different places? E.g. specialist butchers, farmers' markets, online? How often do you buy meat from each of these places? (Prompt: everyday, weekly, monthly or a different frequency?) Do you buy in bulk?
11. What are the main things you look for when you buy red meat? Are there specific things that matter to you when you buy meat/red meat? (Prompts: colour/date/cut/labels/price/sustainability/food miles etc.)
12. What kinds of portions of red meat do you buy? Do you buy enough for each day or week or do you bulk buy for longer periods of time?
13. Do you think about packaging when you buy meat? Do you have any preferences for packaging? If yes, what are they and why? (Prompt: recycling/ sustainability, health, cost). Does packaging influence what red meat you buy?
14. Do you buy quality red meat for any pets in the house? (i.e. not food specifically produced for pets, and do you buy any red meat to feed to wildlife?) (Prompt: mince for magpies/crows/butcherbirds)

15. When you return from shopping, who puts the groceries away? (Prompt: Can you say more about why?)
16. Has COVID changed the way you shop for food/meat? (Prompt: Online shopping? Frequency changes in shopping?)

### **Food storage**

17. How many fridges/freezers do you have? How did you decide to buy these (Prompt: purchasing decision – brand, energy efficiency) What about any future fridge/ freezer purchases?
18. Where do you keep them, and how do you use them? (Prompt: do you use different refrigeration appliances for different types of storage of food products? Bulk buy, drinks etc)
19. What do you do with red meat once you arrive home? E.g. do you divide up into portions, do you freeze some? Do you cook it straight away?
20. Where do you store raw red meat in your fridge/freezer? Which part of the fridge or freezer? Why? Refer to the photos, if possible.
21. How long do you usually keep red meat, uncooked in the fridge/freezer before you cook with it?
22. How do you know if it is still fresh/safe to use? Are you concerned about meat/other food going bad? Have you had prior experience/read something about the risks?
23. When cooking, do you usually use the whole cut of meat or do you trim some of it off? What happens to the trimmed parts, are they disposed of/composted or do you use them for something else (e.g. stock, feed to the dog/cat?)
24. What do you do with leftovers from your meals cooked with red meat? Do you re-use them in other meals/store/freeze them?

### **Food waste/disposal**

25. In general, do you think your household wastes much food? Do you know which food items get wasted most? (Prompt: or food items that tend to go waste more (raw or cooked))
26. Does much meat get wasted? If yes, how? Why do you think this is? And if not, what are the other items that get wasted?
27. How do you decide that food will be wasted/ be thrown out or discarded? Is it by smell, taste, sight, palatability or something else?
28. What kind of waste disposal systems do you have in your house/apartment building? (Prompt: Rubbish bins, recycling, food waste/compost?)
29. Have you noticed a change in waste production in your house during COVID? (Prompt: Food, packaging, what kind of food/packaging?)
30. Is there anything else you would like to tell us about food waste, red meat or the way you use your fridge (or fridges/freezers) that we may have missed out.

**Questions for the fridge rummage (involves opening the fridge and having a chat about fridge contents/setting etc):**

1. Can you tell us what kind of fridge this is, anything specific you might want to add about it/UX/ you have and how long have you had it?
2. Do you have any specific things/aspects/features that you like in your fridge?
3. Do you have any specific things/aspects/features that you don't like in your fridge?
4. Can you tell us if you have a system for where you store things in the fridge? Vegetables, meat, leftovers, other chilled products, such as milk, cheese etc.
5. How often do you think you open the fridge in a day? For what purposes? Does this differ during weekends?
6. How do you decide about the fridge/ freezer temperature setting?
7. Let's talk about you buying meat (whatever form they buy/source it in), can you describe its journey from shops (or source) to cooking?

**8.2.2 Summer data collection questions**

Opening question: What has changed since we last spoke?

1. How are you planning to cook with red meat for yourself and your guests this summer? Will there be changes in the way you shop, store and cook? Has the seasonal change affected the way you are shopping/cooking/eating now?
2. What has changed in your general essential shopping habits this year? What about red meat shopping/eating/cooking?
3. Where do you normally/mostly get your information about keeping food fresh, food waste, packaging and fridge efficiency from? (if they said that they have general knowledge and that is enough, ask: where does this knowledge come from?) Do you use this information and in what way?
4. What information about food waste, packaging and fridge efficiency or design would you like more of?
5. Would different sorts or arrangements of packaging help you to minimise red meat waste in your household? Why?

Specific questions tailored for each household as tail end

**Fridge rummage**

Prompts: what is your cleaning-out/rearranging frequency, changing shelves around?

If money or space was not an issue, what is your ideal fridge? Why?

Households with anomaly in fridge data will be asked extra questions to better understand this fluctuation. For example: Have you noticed food going off frequently? What happens to food that gets frozen by chance in the fridge? Which part of your fridge do you notice spoils food most?

## 8.3 Written form

### Basic details

#### Monitoring

*We'd like to identify the data that matches your monitoring period.*

Monitoring devices placed in fridge/freezer:      Date: \_\_\_/\_\_\_/\_\_\_      Time: \_\_\_:\_\_\_ a.m./p.m.

Monitoring devices removed from fridge/freezer:      Date: \_\_\_/\_\_\_/\_\_\_      Time: \_\_\_:\_\_\_ a.m./p.m.

On the next page, please note any unusual events, their dates, and their times.

#### Participant and devices

*We'd like to correctly compile your data from this form and the monitoring devices.*

Your name: \_\_\_\_\_

*We'd like to identify the devices that you put in each location. Please write the codes (e.g., G80644).*

Fridge top shelf: \_\_\_\_\_

Fridge middle shelf: \_\_\_\_\_

Fridge bottom shelf: \_\_\_\_\_

Freezer middle shelf: \_\_\_\_\_

#### Fridge/freezer photographs checklist

*We'd like to compare fridge type with fridge use and performance.*

- Fridge from the outside, showing the arrangement of external doors and draws.
- Model tag (often a sticker located on the fridge's inside wall or below the bottom draw), which states fridge details such as make, model, voltage, current, and date of manufacture.
- Fridge on the inside, showing the locations of the monitoring devices on the top, middle, and bottom shelves.
- Freezer on the inside, showing the locations of the monitoring device on the middle shelf.



#### Refrigerator details

*We'd like to compare fridge type and age with fridge use and performance.*

Make and model: \_\_\_\_\_      Year of purchase or manufacture: \_\_\_\_\_

Number of external-door compartments: \_\_\_\_\_      Number of external-draw compartments: \_\_\_\_\_

Number of fridge compartments: \_\_\_\_\_      Number of freezer compartments: \_\_\_\_\_

Temperature setpoint of fridge: \_\_\_\_\_      Temperature setpoint of freezer: \_\_\_\_\_

Is the outside of the door seal wet (an indicator of seal damage)?     Yes, fridge     Yes, freezer     No

**Please turn over.**

## Household details

We'd like to compare household characteristics with fridge use and performance.

Number of adult residents: \_\_\_\_\_ Number of child residents: \_\_\_\_\_

Number and type of pets: \_\_\_\_\_ Number of refrigerator units: \_\_\_\_\_

Weekly income of household:  <\$350  \$350-\$699  \$700-\$1499  \$1500-\$3000  >\$3000

Which of the following did you use during the monitoring period?  Cooling  Heating  None

**Thank you for your participation.**

## Unusual events

Please note any unusual events, their dates, and their times. Unusual events might be:

- someone removed the *fridge bottom* device
- you noticed that the *freezer middle* device was off and contacted us
- the power to your home went out
- you replaced your fridge
- etc.

Event start: Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ Time: \_\_\_\_:\_\_\_\_ a.m./p.m.

Event end: Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ Time: \_\_\_\_:\_\_\_\_ a.m./p.m.

Description: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Event start: Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ Time: \_\_\_\_:\_\_\_\_ a.m./p.m.

Event end: Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ Time: \_\_\_\_:\_\_\_\_ a.m./p.m.

Description: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Event start: Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ Time: \_\_\_\_:\_\_\_\_ a.m./p.m.

Event end: Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ Time: \_\_\_\_:\_\_\_\_ a.m./p.m.

Description: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_