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FINAL REPORT

DIRECT Commercialisation

ENDFOODWASTE COOPERATIVE RESEARCH CENTRE

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End Food Waste Cooperative Research Centre is funded through the Australian Government's CRC Program administered by the Department of Science, Industry and Resources.

Panel Review Statement

End Food Waste CRC recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard. The author(s) confirm(s) that this document has been reviewed and approved by the Project Leader and Industry Partner.

This project has also been evaluated by the End Food Waste CRC publication review panel. These reviewers evaluated its:

- Methodology articulated clearly
- Positioning of findings within the current literature
- Acknowledged compliance with food safety standards
- Conclusions against results
- Relevant human and/or animal ethic approvals obtained

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Industry Partner Foreword

Empauer is a technology-driven sustainability business focused on delivering innovative solutions within the global food and beverage industry. We collaborate with businesses worldwide to leverage data-driven insights, creating strategies that address environmental and economic challenges, and enhance sustainability initiatives and resource efficiency.

Our diverse client base spans multiple sectors, including food production, packaging, retail, hospitality, logistics, and waste management. This diversity presents both opportunities and challenges as we work to identify and implement solutions that are effective across different industry verticals. It also underscores the vital role of collaboration and shared knowledge in advancing sustainability goals. Recognising the critical role that cross-sector partnerships play in achieving meaningful impact, Empauer is committed to fostering deeper industry engagement and collaboration.

In 2017, we took a significant step by partnering with RMIT University to address the global issue of Food Loss and Waste (FLW). This collaboration led us to become the first industry partner of the Fight Food Waste Cooperative Research Centre (FFW-CRC, now the End Food Waste CRC, EFW CRC), playing an active role in its foundation.

The key achievement of our partnerships with RMIT and the EFW CRC was the development of the Dynamic Industry Resource Efficiency Calculation Tool (DIRECT), based on a methodology refined by RMIT since 2012. DIRECT is recognised as a leading decision-support tool, quantifying the volume and economic impact of FLW across the supply chain, highlighting hotspots and opportunities for improvement. For Empauer, DIRECT aligns with our mission to empower companies to take actionable steps toward sustainability based on quantifiable data.

This report is a testament to our commitment, providing valuable insights that will inform, educate, and inspire our clients and partners to take decisive actions against FLW. The research findings of the project reaffirm our belief that through strategic innovation and targeted interventions, significant progress can be made both globally. It also underscores the importance of detailed research in driving world-changing initiatives.

Empauer will leverage these insights to guide our efforts, ensuring that our clients remain at the forefront of reducing FLW and contribute to a more sustainable future via data-driven insights.

Victor Barichello

CEO

19 August 2024

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Executive Summary

To reduce food waste, you must first measure it. This concept is increasingly prominent and being acted on worldwide as the vast scale and complexity of the problem has been estimated. Now is the time to move past estimation, and the world needs the right tools to meet global targets like SDG 12.3, which aims to reduce food waste by half by 2030 and is a little over half a decade close. Even as quantification of food loss and waste (FLW) scales up and progress towards standardisation continues apace, varied approaches to measurement persist today so business can benefit from clarity and compatibility in the approaches they take to the problem.

As the data collected regarding food waste expands, so does the need for software that can be used to analyse, display and interpret this data. These software-enabled decision support tools (DST) are increasingly prevalent. Still, their impact has been limited, generally and concerning FLW reduction, as they have tended to underdeliver both on providing a data overview that managers can effectively utilise to support their decisions and on integrating into their reporting of financial costs with environmental impact insights. DIRECT aims to be the DST that fills that gap to assist businesses in the accelerating fight against food waste, enabling them to judge financial and environmental returns. DIRECT was developed through over a decade of rigorous research, resulting in a cloud-based decision-making tool that can map and visualise data in multiple ways to help organisations make informed decisions concerning their food production, both towards minimising non-product/waste outputs and identifying opportunities for valorisation. DIRECT enables an approach that accounts for the financial and environmental costs of waste.

Accounting for the financial is where DIRECT makes perhaps its most innovative contribution to the world of FLW through its tracking of the ‘true cost of waste’ by considering factors such as overheads, personnel and lost profitability alongside the more obvious costs of lost material and waste disposal, in alignment with the principles of Material Flow Cost Accounting (MFCA). By aligning to international standards (and providing guidance on quantification approaches), DIRECT delivers a system that enables the mapping of data flows that can be easily collated with other data sets to estimate larger scale figures of FLW more accurately. In the past, data collection methods and metrics varied wildly, meaning that industry-wide, nationwide or worldwide statistics have relied on patched-together data with multiple different conversion methods. DIRECT provides a mass balance approach that standardises the destinations of material flows in alignment with the FLW Standard. Hence, data mapped by DIRECT can be exported by businesses and confidently be used by agencies to comparably track and report on the progress of large-scale food loss and waste interventions.

DIRECT’s development included an extensive FLW quantification literature review that examined research in areas such as the precise definition of food waste, techniques used by international studies to extrapolate existing food waste data, and global standards developed to measure and compare FLW. This was followed by expert 'user needs' interviews that covered analysis of the existing DIRECT spreadsheet tool to identify areas for optimisation, as well as best practice and trends for FLW quantification with a panel of experts drawn from business, research and governmental agencies. A new cloud-based interface was then developed following iterative design workshops. Instruction manuals and training modules were developed alongside the DIRECT tool. The resultant DIRECT online decision-making tool was then run through alpha, by the project team, and beta testing/piloting with industry - with the tool refined after each of two phases of piloting.

During the piloting, DIRECT was used by multiple organisations to test its effectiveness. Diverse groups, such as potato and almond producers, a leading quick-service restaurant chain, and another research project based in the End Food Waste Cooperative Research Centre (CRC), utilised DIRECT in a mutually beneficial way. These organisations got early, free access to this state-of-the-art food waste decision-making tool, while the DIRECT project was able to test its interface in real-world scenarios.

The following report is a rich resource for information concerning how food waste has been accounted for internationally. It outlines the iterative, industry-focused design process that created the DIRECT decision-making tool. This can be used as a best practice model for industry-focused research. The outcomes of the DIRECT project are not only a rigorously researched piece of cloud-based software, but they are also a set of reports and articles that outline the way forward when it comes to the standardisation of the measurement of and accounting for food loss and waste within a triple bottom line framework.

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1. Introduction

During the past decade, the world has witnessed a sharp uptick of interest in food loss and waste (FLW). Research has highlighted the vast scale and complexity of the problem across the entire food supply chain and has begun to identify the drivers of such loss and waste (Gustavsson et al. 2011; Hegnsholt et al. 2018; Lewis 2019; ReFED 2016; WRI et al. 2016a). Globally, USD $1.2 trillion of food is lost or wasted per annum, equivalent to 1.6 billion tonnes of material. Unless significant reduction measures are introduced, this figure is projected to increase to 2.1 billion tonnes by 2030 (Hegnsholt et al. 2018). In Australia, recent research estimates that 7.6 million tonnes annually of food are lost and wasted across the entire supply and consumption chain. This equates to 312 kilograms per person, at an estimated cost to the economy of $36.6 billion per annum (FIAL 2021).

The prominence of the food waste issue has been elevated by its inclusion in the United Nations Sustainable Development Goals, under Goal Twelve – Responsible Consumption and Production. Goal 12.3 sets the target of halving global food waste by 2030 (United Nations n.d.). This goal has been taken on by the End Food Waste Collaborative Research Centre, in line with the parameters and policies of many regional and national governments. At the same time, global climate change issues are prompting governments worldwide to take strategic actions towards minimising the pressure on natural resources across all sectors to achieve net zero by 2050, as per the Paris Agreement (Nations 2015).

The world is now faced with how best to achieve these targets, particularly as there has been a marked lack of accurate and transparent FLW data. Quantifying food waste is integral to waste prevention and reduction efforts by organisations (Rajic et al. 2021). This is for two major reasons. Firstly, accurate quantification of food waste is essential to develop a business case for waste reduction. Placing a cost on food waste gives a quantitative indication of the impact on the financial element of individual organisations (Lee et al. 2013; Verghese et al. 2018) which provides an obvious and immediate lever for change. Secondly, accurate measurement is necessary to demonstrate trends in food waste management over time, allowing organisations to both show progress towards achieving targets and assess the efficacy of given interventions. This knowledge is needed to guide business decisions around selecting appropriate food waste reduction strategies. This is important because as of 2017, interventions aimed at reducing waste were taking place at a greater rate than the quantification of supposed waste (Lipinski et al. 2017), and as of 2022, although many businesses were measuring and publicly reporting their food waste, significant gaps in data still existed (Lipinski 2022). Such lack of data means that efficacy of interventions cannot properly be measured (Lipinski et al. 2017). Organisations are left not knowing how effective their food waste strategies are, an obvious impediment to reaching sustainable development goals.

While the need to address food waste through measurement is widely acknowledged, and progress towards standardisation has been substantive - building on the work of multi-stakeholder partnerships such as the European FUSIONS project (Tostivint et al. 2016) and the global food waste protocol - varied approaches to measurement persist today. For example, food waste quantification measurements in academic studies have varied in terms of the source data used, how that data is collected, analysed and reported, the chosen metric, the system boundaries dictating what is included in the measurement, and specific definitions of what is counted as food waste. Such differences in approach can cause significant variation in the results obtained from any given study, with Bräutigam et al. (2014) demonstrating a three-fold difference in results based on the same source data when two different approaches to quantification were enacted.

Today's businesses have the potential to access far more food waste data through contemporary technological innovations. Targeted software, scan technologies, the Internet of Things, and sensors can and will soon be used throughout the supply chain to reduce the manual burden of data collection, entry, collation and analysis, with sophisticated resource orchestration systems being a distinct possibility (Amaral & Orsato 2022). Organisations could use such technology to facilitate measuring food waste, and to identify and monitor hotspots.

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As the data collected regarding food waste expands, so does the need for software that can be used to analyse, display and interpret this data. Software-enabled decision support tools (DST) can highlight efficiencies and drivers of food waste, including new opportunities to act, while at the same time assisting leaders in making more informed decisions by better assessing inefficiencies and barriers to adopting better practices in their organisations (Somlai 2021). Overall, however, there has been both an underutilisation and a mismatch between expectation and reality of the usefulness of such decision support tools, which has limited their uptake (Allen et al. 2017). Such tools have tended to underdeliver both on the provision of a data overview that managers can effectively utilise to support their decisions, and on the integration into their reporting of financial costs with environmental impact insights (Somlai 2021; Verghese et al. 2018).

This gap in the market is what the DIRECT project worked to fill. By creating a decision support tool that allows data to be analysed and visualised in several ways, the DIRECT tool increases transparency and efficiency in food waste management. It identifies the 'true cost' of waste and enacts a standardised measurement process for tracking waste to allow food waste benchmarking and cost accounting in line with international standardisation.

1.1 What the final DIRECT tool does

Dynamic Resource Efficiency Calculation Tool (DIRECT) manages food processing data and provides the assessment framework organisations need to effectively identify and map material flows and costs and thereby understand the impact of FLW in the food and beverage sector. It does this by helping businesses map and understand:

- Material inputs, costs and outputs across the food and beverage supply chain
- The product and non-product/material loss destinations of material flows
- Associated business costs contributing to the 'true cost of waste'
- Mass and cost hot spots in and between production processes/life cycle stages
- Methods to calculate resource efficiency
- Methods to identify the business value of improving resource efficiency and food waste reduction

Armed with these data, organisations can efficiently make real changes for the better. This can drive change by understanding exactly where material loss occurs and how much it costs to **not** turn material inputs into products. DIRECT could also be linked to product life cycle management and financial software suites such as Xero, SAP or Microsoft Dynamics empowering business with cloud-based tracking, dashboards, and assessment tools.

DIRECT operationalises the Food Loss and Waste (FLW) Standard and implements the approximation of the monetary cost of material flows of food waste.[1] Firstly, DIRECT captures and manages material mass flows and all their associated costs. Then DIRECT calculates and maps both product and waste/material loss flows based on a mass balance approach – that is, measuring the mass of both edible and non-edible food material inputs as well as non-food inputs (such as packing or packaging materials) before they are processed/handled, and then comparing them to the mass of products produced after manufacturing, while taking into account the efficiency of conversion of materials into products.

[1] This is in line with aspects of the MFCA ISO 14051, and its derivative/affiliated ISO standards 14052 and 14053.

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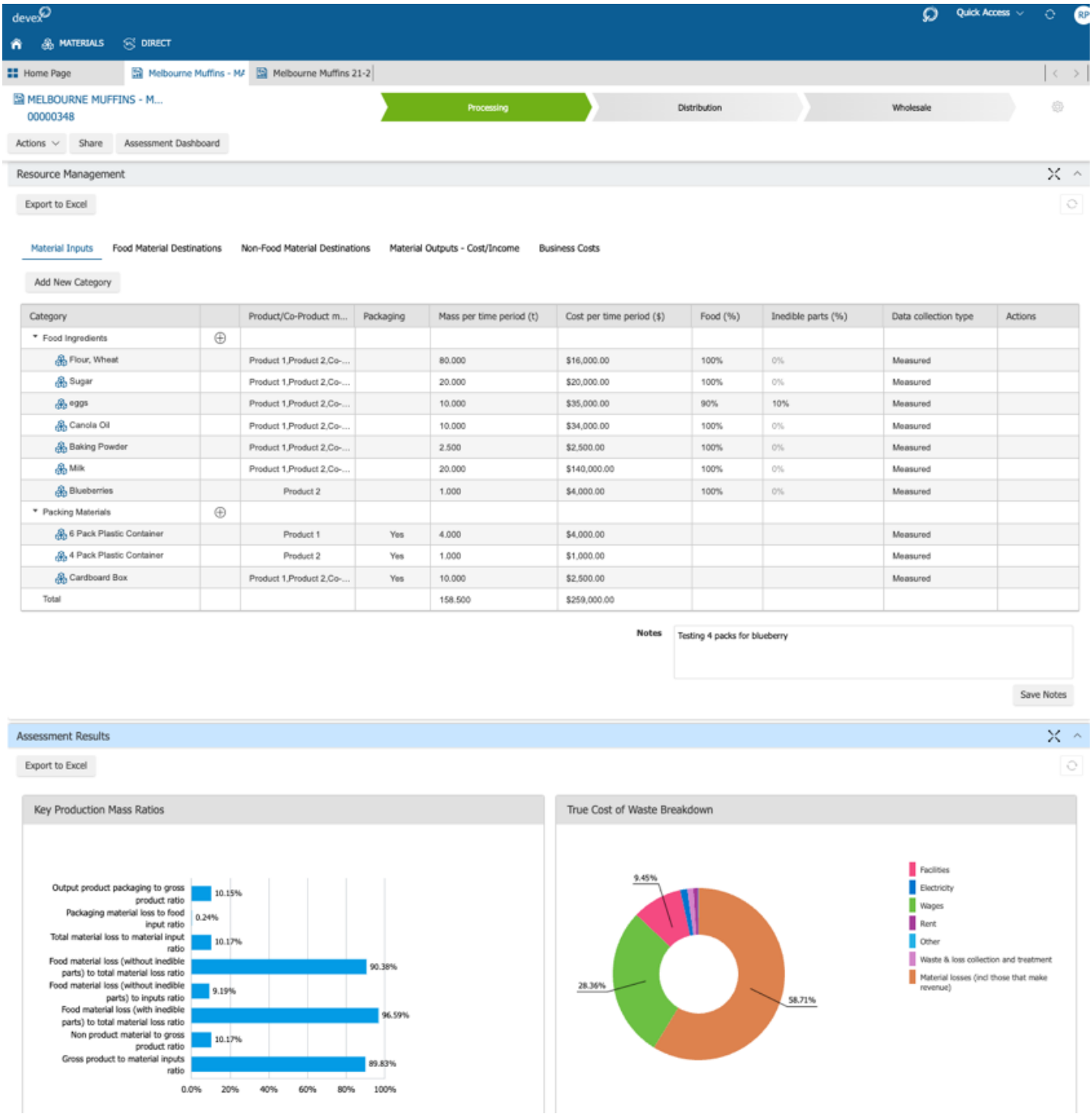

Figure 1 DIRECT Interface

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DIRECT apportions costs to material losses as a proportion of the mass of material inputs that flow into material losses/non-product outputs. This is used to calculate the indirect business costs related to material losses. DIRECT makes plain the indirect 'hidden' costs of losses through expenditure on infrastructure, labour, transportation, energy, and so on, thus showing that the true cost of waste goes beyond the cost of any raw / and or processed material lost. DIRECT also shows the cost of ***not*** transforming 'waste' material into revenue-generating products.[2] By doing this, DIRECT identifies the most critical targets for waste reduction within a business.

The data analysis model that DIRECT uses, allows businesses to create with their food supply chain data is called an assessment. This can cover one or multiple life cycle stages. Assessment data is entered across clearly defined sections: general information, material inputs, material destinations, material outputs cost and revenue and business costs. Figure 1 shows the DIRECT interface with examples of recorded data and charting for an assessment, with many of the tabs discussed below visible. *Industry Report - DIRECT Commercialisation* (Hill et al. 2023) contains further detail of each tab/feature described.

On the **material inputs- cost/income** tab, components of the food process (including liquids) being assessed can be classified as food or non-food ingredients - such as packaging and packing materials, water, emulsifiers, etc – thus allowing businesses to account for their material flows accurately. Material inputs may be unprocessed 'raw materials' or fully processed 'products' depending on what life cycle stage is being accessed. Food ingredients are then able to be accounted for, as per the FLW Standard material type, as percentages of food and inedible parts. Mass and cost per time period values are captured, as well as the ability to see/reassign the master data collection type for the assessment.

Material destinations of food and non-food materials are captured/displayed (on separate tabs), where rows for each material input must have destinations add up to 100% to ensure mass balance.

The material outputs tab is where DIRECT tracks the output cost (as related to material loss) incurred specifically in the disposal, handling and transport of the material/non-product output to that waste destination. This can include additional costs for the management and movement of co-product and food rescue, as well as other waste collection and treatment costs, all of which are considered material losses. Here DIRECT also allows businesses to keep track of any income for the material that flows to each destination. For products and co-products, this would include income from sales. For multiple life cycle stage assessments, this income should represent the market value of the product as it passes from one stage to another. Other materials that are sent to animal feed, food rescue or other destinations may also generate an income. For example, inedible parts of a food material input may be sold as animal feed or food rescue may have tax offsets attributed to them.

The business costs tab is where DIRECT accounts for the standard operations associated with the production process being modelled. This includes overheads such as fuel bills, wages, rent, equipment purchase/repair, asset depreciation, electricity, gas, rent, wages, management, facilities, storage and freight. If modelling for the whole organisation, all related business costs would be entered. However, if modelling only a specific product or facility, only the business costs relating to the modelled process should be entered.

The **assessment result** section reports and displays DIRECT's results including potential hot spots. This displays summary information in charts and tables across four key metrics:

- Key production mass ratios

[2] The term 'true cost' is not the 'full cost' accounting notion which includes a wider range of hidden costs and externalities – such as upfront, back-end, environmental and social costs (Bebbington et al. 2001).

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- Key production financial ratios
- True cost of waste breakdown
- Food material losses – per destination

The **true cost of waste breakdown** accounts for hidden the cost of waste, by looking above and beyond the cost of material loss and disposal. From a mass balance perspective, comparing the materials brought into a process, such as manufacturing, to the mass product shipped, the true cost of waste is significantly higher than wasted materials and the management of their disposal. The flow of this wasted material absorbs expenditure on infrastructure, labour, transportation, energy, and other business costs. DIRECT accounts for these indirect costs as well as offsetting any non-product or material loss income.

The **Food material losses - per destination** displays the mass of non-product food material losses (excluding inedible parts) stacked as a nominal hierarchy of destinations. Starting with destinations that prevent food materials from leaving the human food supply chain (such as co-products and food rescue), the hierarchy then descends (from high to low valorisation) down the list of (potential FLW) destinations that leave the human food supply chain.

DIRECT also allows users to compare assessments and readily identify hot spots via an **assessment dashboard** that aggregates assessment results across all product life cycle stages. The assessment dashboard allows organisations to compare aggregated results across up to four assessments.

The **assessment dashboard – true cost** tab displays summary information divided into the following four segments:

- Material loss costs and mass across life cycle stages
- True cost of waste
- Key production ratios comparison assessments
- Key financial ratios comparison assessments

The **assessment dashboard – food material losses** tab displays summary information in tonnes per destination across two metrics: including and excluding inedible parts. The addition of an **inedible parts only** results allow organisations to track and compare their inedible parts, which is useful for those organisations that choose to target inedible part loss reduction.

Through this collation, visualisation and comparison of material cost flows and implications, DIRECT helps managers and other decision makers increase process efficiency and reduce FLW. The next sections detail how DIRECT was developed to this level, and what the value of the tool is going forward.

2. Methodology and Project Structure

DIRECT was developed through co-design with industry. It reconciles theoretical research with sustainable government policies and industry practices.

The project began in 2012 when RMIT University's School of Design worked on the development of a decision support tool to assist businesses in addressing food waste as part of a triple bottom line. This initial stage developed over two years through to 2014, with the RMIT research team and food manufacturers co-designing processes and methods to develop a fit-for-purpose resource efficiency tool. The initial stage of the project was undertaken by the Centre for Design at RMIT, delivered through the Plenty Food Group (PFG, now the Northern Food Group) in Melbourne, and funded by Sustainability Victoria's 'Beyond Waste Fund'.

Initially, the aim of DIRECT was to quantify and identify the causality of food waste within food manufacturing operations. The project's scope then expanded to include other resources, such as energy and water, thus enabling better tracking and understanding of the

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financial and environmental 'true cost' of waste (Lee et al. 2013). Following the launch of the spreadsheet version of DIRECT, RMIT was commissioned to undertake new research projects using DIRECT between 2015 and 2018, examining new product supply chains and packaging systems, including on-farm operations (Verghese et al. 2018).

The DIRECT project in its current form was further developed through End Food Waste CRC from 2019, via Project 1.1.1. This development took the form of a four-year project with industry partner and co-investor Empauer, a sustainability firm that provides companies with services and tools to better assist businesses meet their sustainability goals, via techniques such as reporting, supply chain review and carbon foot printing. This period saw further iteration of the tool, with the spreadsheet version being transformed into a cloud based online version, to underpin its commercialisation. With support from the End Food Waste CRC student program, two PhD students, Roland Somlai and Jack Heatherington, provided input into the development of the tool itself, contributed to the scholarly literature on the scope and value of sustainability decision support tools attempting functional commercialised cloud version of DIRECT.

The project and its key phases are laid out throughout this report under the following sections:

3. A desktop literature review and user needs interviews
4. Scope enhancements, coding and interface development for pre-existing iteration of DIRECT
5. Building, piloting and refining DIRECT online
6. Refining and further developing supporting materials for DIRECT
7. Development of communication materials, launch and marketing
8. Case studies and real-world applications

3. Desktop literature review and user needs interviews

3.1 Literature Review

The literature review for the DIRECT development, since 2012, has been done in several stages, as the project expanded in scope and ambition. Literature in this space was first reviewed for the article resulting from the initial development of the DIRECT tool *'DIRECT, a tool for change: Co-designing resource efficiency in the food supply chain'* (Verghese et al. 2018). At the start of Project 1.1.1 further literature was reviewed, much of which was summarised in a confidential internal technical report produced in February 2020 (Rigbye et al. 2020). However, the key overview of the literature can be found in the Project 1.1.1 industry report (Hill et al. 2023), which is summarised below.

The literature that informed DIRECT's development was primarily focused on capturing recent food loss quantitative measurement definitions, metrics and methods, and the global move towards measurement reporting and standardisation. It covered literature from academic and industry sources, including academic database literature searches, industry websites, industry/sector mailing lists, and knowledge compiled by members of the academic team/co-authors in prior research (see for example Lockrey et al. 2019). This cross section of sources was used due to each of them containing forms of data relevant to examining food loss quantification and reporting. For instance, most food waste standards are developed and published by not for profits/ governments, whereas many methods of food waste quantification are applied in academic studies. The literature relating to decision support tools (DST) and Material Flow Cost Accounting (MFCA) was not examined in significant detail until later in the Project 1.1.1, although ISO 14051 was flagged as important in the technical report (Rigbye et al. 2020).

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3.2 Frameworks Review

What follows is a rundown of the data collection methods and frameworks used in major studies of food waste by relevant organisations, as of 2019, to set the scene for the direction taken with DIRECT. First, the following core studies, roadmaps and benchmarks are examined:

- Food and Agriculture Organisation (FAO) 2011 Global Food Losses and Food Waste and the subsequent 2013 Methodology reports (Gustavsson et al. 2011; Gustavsson et al. 2013);
- the Waste and Resources Action Programme (WRAP) and their The True Cost of Food Waste within Hospitality and Food Service report (Lee et al. 2013);
- Ju et al. (2017) mass balance approach to tracking FLW in Japan;
- ReFed's "Roadmap to reduce US food waste" (ReFED 2016);
- "Food Loss and Waste in Food Supply Chain Material Flow Analysis", the analysis of Canadian food waste undertaken by Value Chain Management International Inc. (VCMI) and Second Harvest (Gooch et al. 2019); and,
- The Australian National Food Waste Baseline (ARCADIS et al. 2019).

This is followed by a rundown of two key standards: the Food Use for Social Innovation by Optimising Waste Prevention Strategies (FUSIONS) project and the FUSIONS Manual (Tostivint et al. 2016), and the FLW Protocol's Food Loss and Waste Accounting and Reporting Standard (FLW Standard)

3.2.1 Core studies, roadmaps and benchmarks

The 2013 Food and Agriculture Organisation methodology report documents how the FAO used production statistics as a data source for modelling and waste estimation in their 2011 report (Gustavsson et al. 2013). They make a distinction between loss and waste, where loss is not intentional and happens in production & processing, and waste is intentional and happens at retail and consumption stages. Despite the authors stating that their results should be taken with "great caution" due to uncertainty and gaps in both the FLW quantification and cause data, their work continues to be referenced by many other studies/ papers.

The Waste and Resources Action Programme (WRAP) is a UK not-for-profit, which works with organisations, governments and citizens to increase the sustainability of resource use through various initiatives. It aims to maximise the value of waste and reduce the amount ending in landfill in the food and drink, clothing and textiles as well as other sectors. For their 2013 study (Lee et al. 2013), WRAP considered various inputs to the production of food and thus food waste in the hospitality and food service sectors, including food purchase, waste collection, energy and water use, wages and transport. Food waste was represented in several ways, including cost of food waste per meal, total food waste mass, and separation of what was categorised as avoidable or unavoidable waste.

ReFED is a not-for-profit with a network of executives from businesses, NGOs, and governments. One of the key actions of the group was developing the "Roadmap to reduce US food waste" (ReFED 2016). This sets out the baseline, impact of FLW, and provides twenty-seven solutions for reducing food waste. A graphical representation of these solutions, which can be viewed from various perspectives including financial benefit, emissions reduced, and jobs created, is available at refed.com.

ReFED used existing data in their model, such as wastes from particular operations such as landfill and on-farm losses, and then extrapolated this to a national level. Waste rates were calculated per food type. Data quality for the baseline here seems to be high - inputs for various models were taken from industry, other experts and previous research, and were checked. In order that multiple sources supported each input, as well as being compared to the results from other studies. ReFED also captured the destinations of waste. ReFED reported waste figures in mass, then also used these figures to report on greenhouse gas emissions, water use and

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job creation. ReFED also identified a proportion of waste they describe as “addressable”, which is related to best-case FLW reduction scenarios given various system constraints. ReFED places emphasis on economic models of food waste costs and potential savings by estimating the potential savings and comparing it to the potential capital outlay and ongoing costs of implementing the FLW solutions proposed. Through this process they identified prevention solutions that had the best savings potential.

“FLW in Food Supply Chain Material Flow Analysis” (Ju et al. 2017) documents a Japanese study which constructed a mass balance system for food and food waste as it progressed through the supply chain. Input data was taken from national production statistics, and waste factors were applied at each stage. Conversion factors have been used to separate the edible from the inedible waste mass, with different coefficients for different food types. There are some broad assumptions made here to cover the gaps in data: for example, hospitality food waste rates are set at double the household waste rate. Inedible food fractions have been classified here as “unavoidable”, all other types of food waste are, by default, deemed to be “avoidable”.

The “The Avoidable Crisis of Food” report (Gooch et al. 2019) documents a collaboration between Value Chain Management International Inc. (VCMI) and Second Harvest, which culminated in a whole supply chain analysis of Canadian FLW. This study is intended as a guide to reducing FLW in the whole of Canada, identifying many of the drivers of waste, and proposing some solutions. The results are quantified in terms of total mass, percentage of production and economic value. Primary data regarding food waste and disposal was sourced through industry surveys, advice from an industry advisory group, interviews and informal discussions. The data were then validated using focus groups, supplementary data and comparison to third party data. Total quantities were calculated using a mass balance. A baseline was developed of food availability, at primary production, in metric tonnes, with that baseline being equal to the total volume of food that was grown, caught, harvested, and imported into the Canadian food system. Loss rates estimated and calculated from the survey input data were then applied to form a total snapshot of food waste in Canada. The base data for this study was still heavily dependent on self-reported estimates. Recommendations included using waste audits, and to design sample sizes allowing statistical significance within a 95% confidence interval.

The National Food Waste Baseline (ARCADIS et al. 2019) is a high level but detailed quantification of the state of food waste in Australia. It looked at different supply chains and food type sectors. The finest resolution in this study is at an industry level. The National Food Waste Baseline took guidance from the FLW Standard in setting up the parameters for its study. such as definitions and system boundaries, but customised some elements, such as waste destinations, specifically for the Australian context. Primary data sources were diverse, with data collected from industry, companies, as well as various inventories and sector profiles.

3.2.2 FLW Standardisation

There has been a move towards standardised approaches to food loss quantification that aims to achieve comparability between studies, and so to allow the creation large datasets that offers more global indicators of the state of food waste, The two key standards that shaped the development of DIRECT - FUSIONS Manual and FLW Standard - are covered next.

Food Use for Social Innovation by Optimising Waste Prevention Strategies (FUSIONS) was a project working towards a more resource efficient Europe by significantly reducing food waste. The project ran for 4 years - from August 2012 to July 2016 - had twenty-one partners in various EU countries, including universities and businesses, and was funded by the European Commission Framework Programme. One of the key deliverables of the FUSIONS project was the Food Waste Quantification Manual to Monitor Food Waste Amounts and Progression (‘FUSIONS Manual’ Tostivint et al. 2016). A key focus of this manual was whether waste is categorised as either food or inedible material, and the destination of the food waste, such as animal feed or landfill. Entities must account and report for as much as they know about the destination of their waste. If destination is unknown, entities must report at a minimum how the FLW gets to the destination. If the destination is known, entities must report which destination(s) are included in inventory, and if known, the amount by weight as well as the destination’s valorisation of FLW. The FUSIONS Manual was written in collaboration with the authors of the FLW Standard, and the quantification approach is in harmony between these two documents. However, the FUSIONS Manual is more focused on supporting EU Member States specifically in their FLW quantification efforts

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"using agreed definitions of food waste and supply chain sectors, and to report results in a manner that is coherent with the global Protocol (sic) and consistent between" member states (Tostivint et al. 2016, p. 9).

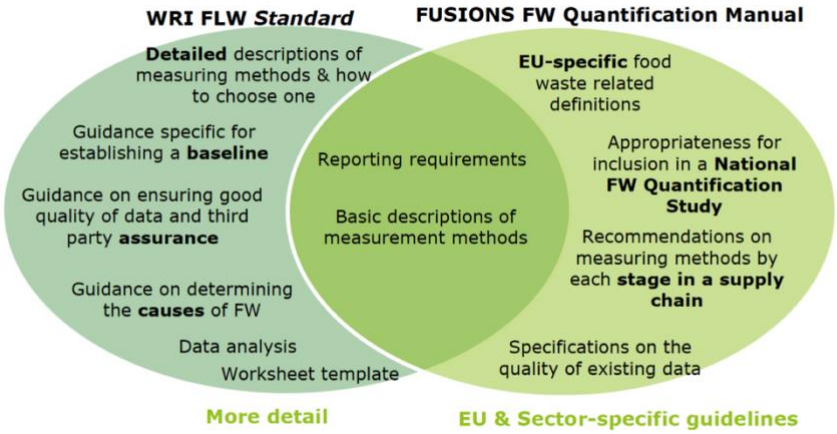

Figure 2 FLW Standard vs. FUSIONS [Figure 5 from Bajzelj (2016, p. 17)].

The Food Loss & Waste Protocol is the multi-stakeholder international partnership, which developed the global Food Loss and Waste Accounting and Reporting Standard ('FLW Standard' WRI et al. 2016a; 2016b, the second of which is quantification guidance). As the FLW Standard is what DIRECT was aligned to, it will be covered in detail below. However, it is worth first comparing it with the FUSIONS Manual. A useful document produced by REFRESH (Bajzelj 2016), compares and contrasts the FLW Standard and the FUSIONS Manual while providing food waste quantification guidelines aimed at food businesses - see Figure 2 for a visual breakdown of this comparison. This document notes that the two standards have a significant amount of common content while covering slightly different grounds. For example, the FLW Standard contains more detailed information about the FLW measurement process, while the FUSIONS Manual contains more targeted and prescriptive information. The FLW Standard was the first coordinated collaboration to develop consistent terminology and approaches and, as compared to the FUSIONS Manual, contains the most comprehensive information as well as the most flexible approach, encouraging the user to set their own scope and parameters for FLW quantification.

3.2.2.1 Focusing on the FLW Standard

The FLW Standard's allowance for modular definitions of FLW and the requirement of a clear and detailed statement of scope is a pragmatic solution to offer limits on quantification consensus. This provides a good balance between the use of standardised definitions for comparability across different measurements and a flexible framework. Such flexibility is essential to encourage widespread uptake of the FLW Standard's methods by catering to individual needs and allowing users to match definitions to their available data (WRI et al., 2016a). However, it should be noted that there is still significant room for interpretation of definitions, such as in the case of edibility or water content. The inclusion of the specifics of these definitions as part of the scope of a study means that there is a lessened danger of inappropriate comparisons. The problem remains that if too many participants use diverse definitions, there may not be enough similarities for comparison. For this purpose, a more prescriptive approach to standard definitions and frameworks (such as the food services sector specific 'tree structure' framework advocated by Eriksson et al. (2018) could be warranted.

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While the FLW Standard (WRI et al. 2016a) suggests possible quantification methods, it does not prescribe the use of a specific method. The FLW Standard aims for accuracy where possible – with transparency as the main goal, as accuracy is more difficult to achieve. Transparency is achieved by requiring a defined and detailed scope, stating assumptions and describing data gathering and processing methods that are included as an integral part of the results of any study. The FLW Standard specifies that the scope should include:

- the stated aims of the study
- the timeframe
- the material type, be that food only, inedible parts only, or both
- the destination of the FLW when it is removed the food supply chain; and
- the boundaries set in the study, be they the type of food, a particular geographical region or a particular organisation.

Quantification methods can either be based on measurement or approximation of FLW, such as through direct weighing, counting, assessing volume, waste composition analysis, records, diaries and surveys, or based on inferring amount of FLW through calculations such as mass balance, modelling or proxy data. The FLW Standard developed an online tool, which is available for entities to select the most appropriate method: see flwprotocol.org.

Within the FLW standard, an inventory must also meet the following requirements:

- Account and report on principles of relevance, completeness, consistency, transparency and accuracy.
- Account for and report FLW by weight.
- Define and Report on the scope of the inventory.
- Describe the quantification method(s) used.
- Provide qualitative or quantitative assessment of FLW inventory results.
- If sampling and scaling of data are undertaken, provide information on these.
- If assurance on FLW inventory is undertaken, create an assurance statement.
- If tracking amount of FLW or setting a reduction target, select a base year and identify the scope of target.

The FLW standard also developed a recommended overview of the steps required to be able to effectively account for and report FLW, which is as follows.

Figure 3 Overview of Steps in FLW Accounting and Reporting - (Figure 3 from WRI et al. (2016))

While outside the requirements of the FLW Standard, the supporting documentation provides recommendations for reporting alternative units of measurement other than weight, such as environmental impacts, nutritional content and financial costs/implications (see Appenddix D in WRI et al. 2016a). The FLW Standard provides “technical considerations”, describing

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instances where FLW has been discussed from the alternative unit perspectives and provides resources, in the form of calculators, tools and International Standard Organisation standards. For measuring environmental impact, the FLW Standard recommends including energy use and greenhouse gas (GHG) emissions, water use and land use. With regards to nutritional implications, the FLW Standard highlights that this aspect may be even more important than FLW weight comparison, especially for governments, sectors such as retail, or where food security or malnutrition is a concern.

In terms of measuring financial data, the FLW Standard recommends including various elements including the price of the product, the price of ingredients, the price of other inputs, the price of labour, the value of lost revenue, the costs associated with collecting FLW, the costs from disposing/ treating FLW, and the costs associated with environmental impacts (greenhouse gas emissions, for example). Importantly, it underlines that distinctions must be made between edible and non-edible parts of food, as although financial information generally refers to a whole food (for example, an orange), most of the financial value is generally extracted from the edible part (for example, the flesh). Entities should also be clear about which financial implications are considered, and the proportion of those costs associated with FLW. Possible revenue from FLW (such as animal feed), whilst smaller than the cost, must also be included for accurate quantification. Costs to society can also be included, for example environmental externalities.

3.2.2.2 Uptake of the FLW Standard

Uptake of the FLW Standard by governments, researchers and institutions has occurred, with multiple high-level publications presenting modelling and quantification of food waste according to a specific method detailed in the report's technical appendix (see CEC 2017; Corrado et al. 2019; Gooch et al. 2019; IGD & WRAP 2018; Wesana et al. 2019) The UK food surplus and waste measurement and reporting guidelines are explicitly consistent with the FLW Standard (IGD & WRAP 2020). Furthermore, FAO and UNEP are founding members of the FLW Protocol steering committee, alongside the UK's and EU's FUSIONS, and the UN's SDG 12.3.1 FLW indicators are in modular alignment with and have built upon the FLW Standard (FAO 2019; UNEP 2021). The European Commission's Delegated Decision 2019/1597 (2019), also builds upon the work of FUSIONS, and both WRAP and UNEP have subsequently stated that the European Commission's FLW definitions and methods are in alignment with their own and, by extension, the FLW Standard (IGD & WRAP 2020; UNEP 2021).

Multiple studies have been undertaken using all or part of the FLW Standard (see Ambiel et al. 2019); Baker et al. (2019); Gooch et al. (2019); Gunders and Bloom (2017); (Lewis 2019); Neff et al. (2018); (Principato et al. 2019; Tostivint et al. 2017). The Australian National Food Waste Baseline took guidance from the FLW Standard in setting up the study, using some definitions and system boundaries, customising some elements for the Australian context (ARCADIS et al. 2019). Given the increasing uptake of the FLW Standard, future studies and tools which use and are aligned with it will produce data that is valid and comparable to other research around the world, helping to build a more accurate overall picture of the state of FLW globally.

The push for FLW standardisation (and the incentivisation to utilise standard approaches) continues. For instance, the International Organisation for Standardisation has assembled a working group for the purposes of "standardization of FLW, providing a framework for food organizations throughout the food chain, to work actively and effectively with measuring and reduction of food loss and waste" (ISO 2021b). Furthermore, local jurisdictions have their own complementary FLW standards under development with one currently being developed with Standards Australia (pers comm).

Overall, the FLW Standard is an indispensable resource for a business audience and beyond – providing instruction and guidelines on practical considerations in food waste parameters and data collection methods applicable in various contexts to suit the diversity of stakeholders within the food supply chain. Additionally, demonstration of compliance with the FLW Standard will show that a business is not only committed to appearing to reduce food waste, but also to be accurate and transparent in their efforts.

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3.3 The parameters of FLW studies

Understanding the reasoning behind differing approaches is crucial in designing a targeted strategy for measurement of FLW, as decisions regarding definitions are often informed by the aim and scope of a particular study. For example, Australia's first National Food Waste Baseline (ARCADIS et al. 2019) supports policy aiming to reduce food going to landfill; therefore, it does not consider food diverted to other destinations, such as food rescue or animal feed, as food loss or waste. In quantification studies concerned with food security, edible fractions of food waste are the most important quantities to capture (FlanaganLipinski et al. 2019; WRI et al. 2016a). However, if a study's aim is to address overall resource efficiency and waste management in the food supply chain, then inedible parts are worth measuring as well – production, processing, transport and disposal all consume resources and have environmental effects (Alexander et al. 2017; Hartikainen et al. 2018; WRI et al. 2016a).

Previous FLW studies also varied in their definitions of what they see as 'food', where waste is disposed of, what metrics should be used, and the data sources and analysis methods used, an overview of which follows.

3.3.1 Material type definitions – What is food?

'Material Type' definitions set out precisely what kind of waste materials will be regarded as 'food' so that measurements of waste can then be taken for FLW quantification. Sources reviewed differed in terms of whether they included or excluded 'inedible' parts of foods, such as bones and rinds. Furthermore, studies varied as to whether they included liquid wastes that are disposed of in sewers.

The rationale for exclusion of inedible parts of food are that they are not intended for consumption, and therefore their disposal is inevitable (WRI et al. 2016a). This is logical if the goal of the FLW measurement is to identify opportunities for increasing the amount of produced food that ends up being eaten – especially from a food security standpoint. This may also help to avoid misleading results. For example, if inedible parts are included, a process involving a food item with a significant quantity of inedible parts (such as beef production from carcasses) may appear as less efficient or more wasteful than another process where inedible parts are negligible (such as fresh berries). Similarly, a household consumer food waste student by van Herpen et al. (2016) includes only edible food waste, as it is argued this makes it easier to disregard the effect that a specific diet may have on a household's waste output – especially given some items contain a much higher proportion of inedible matter than others.

The terms 'edible' and 'inedible' are sometimes used interchangeably with 'avoidable' and 'unavoidable', where unavoidable food waste is treated as inedible, and avoidable parts as edible (Elimelech et al. 2018; Gooch et al. 2019; Ju et al. 2017). However, unavoidable food waste can mean either waste that was not edible, or the waste of food that could not practically be avoided, for instance, due to the limitations of manufacturing processes. Sometimes this also represents somewhat closed thinking as to what could be potentially edible, and how processes could be modified beyond what is currently done to address these practical issues. To remedy this, Gheoldus et al. (2017) uses the term 'potentially avoidable' to refer to items of subjective edibility.

Providing guidance in choosing distinctions between 'edible' and 'inedible' is an example of how the FLW Standard helps users to make material type decisions to best suit their aims and specific circumstances. The FLW Standard addresses the problem of material type by requiring the user to account for and to describe the definition used for their measurement as an integral part of the results. The user is ostensibly directed to choose to include either edible parts, inedible parts or both edible and inedible parts – though the FLW Standard substitutes the word 'food' for 'edible'. Broad definitions of what to include as either 'food' and/or its associated 'inedible parts' are provided; however, it is also acknowledged that edibility can be subjective based on factors such as cultural norms and context as well as individual preference (Baker et al. 2019; Chaboud & Daviron 2017; Elimelech et al. 2018; Nicholes et al. 2019) with vegetable peels and offal being two noteworthy examples. The FLW Standard also notes that in cases where a waste stream is very heterogenous, for example in a household or hospitality setting, edible and inedible fractions are much more difficult to separate than a food manufacturing business, whose output and waste may consist of only one type of food item. Therefore, practical considerations may also factor into the decision to include or exclude inedible parts. For more heterogenous waste streams, edible

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amounts of food waste can be separated from inedible waste by using set factors – "[f]or example, carrots contain 89% edible material, thus for each ton of carrots wasted, 890 kg can be considered edible" (Tostivint et al. 2016, p. 54).

Aside from the potential difficulty in quantifying the edible quotient of a mixed waste output, there are other arguments for the inclusion of inedible parts in a FLW definition. Firstly, the production and management of waste material consumes physical and financial resources regardless of its edibility (FLW Standard, (WRI et al. 2016a)). This includes the direct costs of waste management as well as costs incurred in transportation, storage, refrigeration and other overheads and production costs, all of which factor into the 'true cost of waste', as described by Lee et al. (2013) & Verghese et al. (2018). Therefore, the edibility of produced waste can be less relevant when addressing resource efficiency. Secondly, just as edibility can be subjective, material that is not edible in its current form may be processed into another, usable form. This could include rinds used for animal feed, organic matter being processed into fertiliser (Zucchella & Previtali 2019) or biogas feedstock (Rajic et al. 2021). Including this material in overall waste amounts may facilitate the identification of new opportunities for the development of co-products (Amaral & Orsato 2022).

Another significant factor in FLW definitions is the inclusion or exclusion of 'liquid wastes' (Corrado & Sala 2018). It is difficult to track liquid waste as it may be disposed of through channels other than main waste management such as sewers and combined with water from preparation or washing of food. The moisture content of food and waste can also change, either increasing or decreasing through processing, preparation, cooking or storage (Corrado et al. 2019; Corrado & Sala 2018). Corrado and Sala (2018) suggest circumventing this by qualifying any figure as to whether it is expressed as a wet or a dry mass or giving mass figures with accompanying moisture content figures. They further assert that measuring FLW as dry mass might give more consistent results, but the water content incurs costs and consumes resources in itself – for example, transportation of a wet mass is more costly and resource intensive than that of a dry mass. The FLW Standard requires reporting the mass of FLW with the water content it had at the time the waste was produced, with any assumptions or calculation methods used to determine this amount to be included as part of the scope of the study (WRI et al. 2016a). There can be issues with the FLW Standard approach, as it requires knowledge of this water content, which may be challenging for heterogeneous waste streams and it does not account for the changes in resource consumption incurred, due to an increase or decrease of water content, as the waste is managed. So even when well defined, the issue of measuring liquid wastes can be problematic. In the case of a business looking to address the financial impacts of FLW, the approach proposed by the FLW Standard is likely to best capture the costs associated with liquid wastes – and sufficiently accurate liquid waste quantification may be possible when water consumption data is known.

3.3.1.1 Material destinations – Is it waste material, or a wasted opportunity?

Waste material can be defined by the very fact that it is disposed of, or it may be characterised as a non-product output. From many perspectives, the concept of 'waste' is primarily based on a loss of value (Zucchella & Previtali 2019). Within the FLW literature, the term 'material destinations' is used to define where this 'valueless' material ends up. When the motivation for food loss or waste quantification is to reduce "environmental impact in terms of waste management or the removal of upstream natural resources", only food ending up in landfill is considered waste (Chaboud 2017, p. 192). For initiatives aiming solely to minimise the amount of food waste going to landfill, it is then logical to disregard the portions of waste that end up being used for other purposes such as animal food and biofuel (WRI et al. 2016a). However, if "removal of upstream natural resources" and their associated environmental impact is to be considered, it could be argued that food is still wasted if it goes to animal feed or food rescue because "redistribution does not encourage a shift in practices that led to the surplus in the first place" (Flanagan et al, p. 43) and represents extremely poor resource efficiency. In the case of primary production, "even when crops are turned under or composted on the farm to nourish the soil, the result is high-input compost that relied on considerable water, energy, labour, and manufactured inputs such as fertilizers" (Neff et al. 2018, p. 2).

The FLW Standard also requires that a user specify which food and loss destinations are to be included in the definition of waste for any given study, again guiding the user to make these decisions based on their aims and circumstances (WRI et al. 2016a). However, the FLW Standard states that food sent to food rescue destinations should not be regarded as FLW. From the social and

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environmental sustainability perspective of the FLW Standard, this is justified given that this food is not removed from the food supply chain. However, it disregards the consumption of resources in transporting, storing and redistributing rescued food as well as the potential loss of revenue to business.

3.3.2 Metric selection

FLW can be quantified by many different metrics, including but not limited to mass, cost, nutritional content and environmental impact. Although they are related, the source/input metric – the quantity that will be directly recorded as input data, may differ from the reporting/output metric – which is the quantity that will be used to describe the results. These dimensions of FLW management are discussed below.

3.3.2.1 Source metrics

Waste may be quantified by weighing, using mass as the source metric. This mass may then be used to calculate the cost of the waste, in which case cost is the output metric. The metric chosen may reflect either the intention of the study, or the availability of data.

Mass is the most common input metric for FLW studies and seems to be the obvious choice for quantification. The Sustainable Development Goal 12.3 target aims to reduce total waste mass, and waste is often reported as a tonnage, or a percentage of production based on mass measurements. One drawback to using mass as a waste metric is that it is greatly influenced by water content, which can vary over time and life cycle stage due to evaporation, drainage, absorption, cooking or processing (discussed above under 'Liquid Wastes') (Corrado & Sala 2018; Elimelech et al. 2018). If water is separated or added during various stages, the true amount of waste may be misrepresented by reports of total waste tonnage.

Metrics may also be selected for practical reasons – particularly data availability. If an entity evaluating waste has access to information such as a unit number of discarded products, a certain number of bins that were collected, or ingredient purchase compared to sales data, this may be more useful than physically weighing produced waste. These methods may also circumvent issues with water content, and an extrapolation to mass may also be implemented to align to a certain target or protocol, such as SDG 12.3 or the FLW Standard.

3.3.2.2 Reporting metric and hotspot identification

Reporting metric choice may reflect the existing concerns of those doing the study but may also be selected to achieve a particular purpose. Identification of the most critical targets for waste reduction, commonly referred to as 'hotspots', can depend heavily on the choice of reporting metric. For example, in their analysis of waste from Swedish supermarkets, Corrado et al. (2019) found that fruit and vegetables were the most wasted food type by mass, making up 86% of the total waste, compared to 3% for wasted meat. When the waste was characterised in financial terms, fruit and vegetables accounted for 72% of waste, meat 12%. When characterised by environmental impact – regarding the potential for greenhouse gas emissions based on the resources embodied in the different food groups – fruit and vegetable waste accounted for 48% of the waste, whereas meat was responsible for 30%. Therefore, in this case, when taken by mass, the priority for FLW reduction would be to prevent the waste of fruit and vegetables. However, if environmental factors were the chief concern of the study, a reduction in the comparatively small mass of wasted meat would, in turn, result in a large relative change in the overall environmental impact (Rajic et al. 2021). Therefore, the utility of chosen reporting metrics is key to how a study may provide value and influence business decisions.

Another reporting metric worth considering for FLW is nutritional content. Quantifying waste in terms of nutritional content makes sense when quantification aims to address food security or health issues but may also have additional benefits. Addition or subtraction of water during cooking, manufacturing or waste management processes does not change nutritional content. Therefore, using a metric such as calorific content avoids some of the issues inherent in using mass as a metric. FlanaganLipinski et al. (2019) note that

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when reported in calorific content, cereals represent the largest volume of FLW globally, which is of greatest concern for food security. Hence including nutrition loss in reporting can shed light on what foods represent considerable food security challenges. It may also be beneficial to characterise waste in calorific terms when assessing the potential for the development of co-products from a waste stream, with examples including diversion to animal feed and biofuel potential.

FLW volume may also be reported in terms of cost, which may be more effective in driving behavioural change to reduce waste and may prove that investment in waste reduction is desirable from a financial perspective as well as an environmental one. The roadmap produced by ReFED (2016) places a heavy emphasis on reporting and evaluating FLW reduction in dollar terms while representing FLW in environmental terms. The FAO (2019) suggest that 'hotspots' of FLW in economic terms are often more critical to identify than mass 'hotspots' (p. xiii). Characterisation of waste volumes in robust cost terms is necessary to assess the efficacy of waste reduction efforts. Importantly, it can also directly contribute to a business case for investment in waste mitigation measures, for example, in the form of upgraded equipment, improved processes or better resourcing.

3.3.3 Data sourcing and analysis methods

Data sourcing and analysis methods have been shown to impact a study's results significantly. This was illustrated by Bräutigam et al. (2014) in a study that compared the results obtained from two different projects (reported on in Monier et al. (2010); Gustavsson et al. (2011); Gustavsson et al. (2013)) aiming to calculate FLW waste volumes in the EU. The Monier et al. calculations rely on a mixture of data: such as EUROSTAT-data, national surveys and extrapolations by the authors, whereas Gustavsson and her collaborators used FAO's Food Balance Sheets. A comparison of the results showed major discrepancies between the two methods, such as a three-fold difference in the waste amount produced in Italy.

Broadly speaking, within the literature reviewed, there were two approaches taken to produce estimates of FLW volumes:

- A 'bottom up' approach – direct measurement or estimation of FLW material itself, which is then often contextualised by comparison to the total amount of food produced or the size of a population. This approach may also make use of existing data, for example, where waste management data is available that directly shows waste quantities.
- A 'top down' approach – starting from overall production volumes, usually sourced from existing data. Mass balance or waste rates are then used to calculate the tonnage of FLW by taking a percentage of overall production. Waste rates may be sourced from existing statistics or in consultation with industry.

The 'bottom up' approach, including waste composition analysis or direct weighing, can be highly accurate. However, such an approach is also costly (Corrado et al. 2019; Elimelech et al. 2018; van Herpen et al. 2016; WRI et al. 2016a) and can either measure total waste, or a sample, such as that used in field measurement (Johnson et al. 2018; Tostivint et al. 2016). Similarly, counting units and using known weight to convert units to tonnage, can provide accurate, but lower cost results (CEC 2017; Tostivint et al. 2016; WRI et al. 2016a). Although only reported in a household waste context, van Herpen et al demonstrated that visual estimation of waste volumes can be comparable in accuracy to direct weighing of waste but is much cheaper (2016).

The FLW Standard's companion document, *Guidance on FLW Quantification Methods* (WRI et al. 2016b), offers detailed information on a range of measurement options, including discussing advantages, disadvantages, cost and level of expertise required for each choice (WRI et al. 2016b), and suggests that methods should be determined by an entity's goals and resources. Eriksson et al. propose the FLW Standard be used as guidance to strike an appropriate balance between resource investment in FLW quantification, and "relevance, completeness, consistency, transparency or accuracy" (p. 192). Corrado agrees, stating that there is a balance to be stuck between "robustness", relying on primary data with validation and controlled uncertainty, and "feasibility", dependent on cost, data availability and time. Additional considerations may be repeatability, scalability and potential for bias. The FLW Standard recommends that its FLW Quantification Ranking Tool, developed in conjunction with WRAP, be used to make decisions regarding this balance. This tool, which is in the form of an excel spreadsheet, asks the user questions about their requirements in terms of accuracy, data availability, the nature of the waste stream to be quantified, and returns a list of quantification methods ranked from

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most to least appropriate ((WRI et al. 2016b). In short, the FLW Standard is a valuable resource in a business looking at these practical considerations related to primary data measurement options.

The 'top down' approach, which uses of statistics and existing records (with or without mass balance) was a prevalent method in the literature reviewed, as it is a low-cost, easily available data source. However, its use as a source for FLW quantification invariably comes with caveats about the quality of the data, as it often involved the combination of large, heterogenous datasets, and the patching of holes with estimates, proxy data and extrapolations (ARCADIS et al. 2019; Gustavsson et al. 2013).

3.4 Material Cost Flow Accounting (MFCA)

Material Flow Cost Accounting (MFCA) is an environmental management accounting (EMA) and assessment method that tracks the flows and stock of materials, in the processes of organisations, by accounting for both the physical movement and transformation of mass (and energy) and the associated monetary costs of those material flows (Christ & Burritt 2015; Jasch 2009; Kokubu & Tachikawa 2013). Specifically, MFCA applies cost accounting to those materials input, the energy consumed and the in-house system costs of a process, as well as additional waste management costs. MFCA goes beyond traditional cost accounting by dividing costs into those 'good' costs, which can directly be attributed to the final products, and those 'bad' or 'lost' costs that result in the output of non-products / non-product outputs (Guenther et al. 2017). The benefit of such apportionment of cost is that hidden costs of a process are made visible to management as a decision support tool that compliments and goes beyond the mass balance approach of material flow analysis for waste and resource management (Allesch & Brunner 2015). By demarcating the costs associated with intended (product) and unintended (non-product/material loss) outputs, "the transparency of material flows and the associated costs increases considerably; inefficiencies concerning material and energy consumption are revealed, and hidden costs uncovered" (Walz & Guenther 2021, p. 594). By applying MFCA, and the integrated plan–do–check–act continual improvement cycle, businesses can benefit by simultaneously identifying inefficiencies and being motivated to make decisions that reduce both costs and waste – facilitating management action towards meeting their organisation's goals. As Kokubu and Tachikawa argue, in many cases, an organisation is unaware of the full extent of the actual cost of material losses because data on material losses and the associated costs are often difficult to extract from conventional information, accounting, and environmental management systems. However, once available through MFCA, both in physical and monetary units, this data can be used to reduce material losses, improve efficient uses of material and energy, and reduce adverse environmental impacts and associated costs (Kokubu & Tachikawa 2013, p. 352).

In 2011, the first of the three existing MFCA International Standards Organisations standards was released,[3] which was followed by two more released in 2017 and 2021 (ISO 2017, 2021a). The latter two ISOs were developed to make the implementation of MFCA even more practicable, as they outlined how to cooperate with supply-chain partners and how small and medium-sized enterprises could begin their MFCA journey by utilising a more simplified approach. The development of standard 14053 explicitly linked MFCA to the drive to achieve the UN's Sustainable Development Goals in particular SDG 12 (sustainable consumption and production) *(ISO n.d.)*.

[3] *14051:2011 - Environmental management - Material flow cost accounting - General framework* (ISO, 2011)

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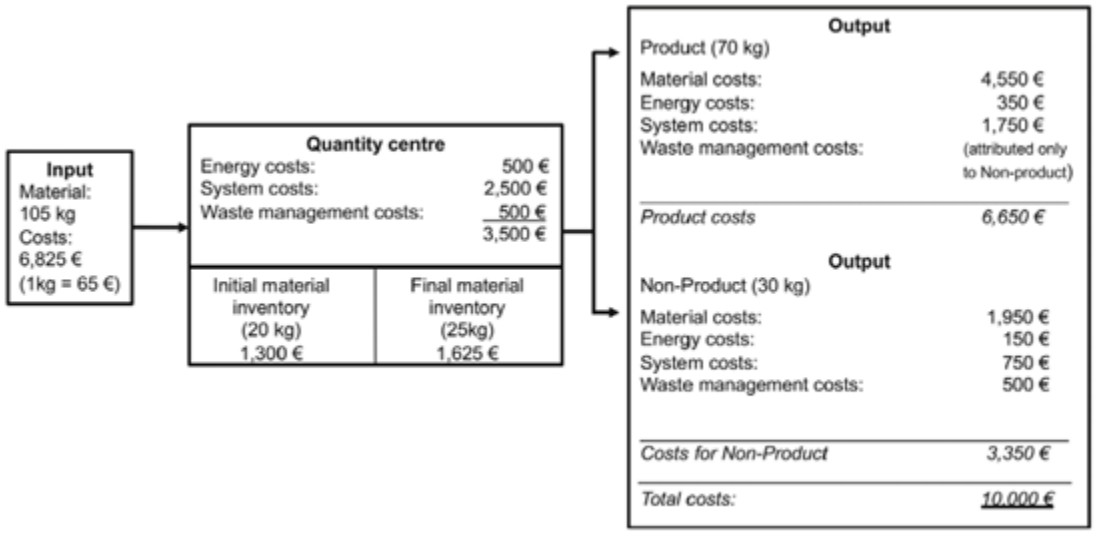

Figure 4 Principle of material flow cost accounting as adapted from ISO 14051 [(Guenther et al., 2017; Walz & Guenther, 2021)]

3.4.1 Applying MFCA

Figure 4 shows the basic approach of MFCA. In contrast to traditional cost accounting, MFCA not only allocates operational costs to the products produced by organisations but also to the material and energy losses accrued. For each step of a production process, the material (and, where relevant, also energy), system, and waste management costs are distinguished and assigned as either product or non-product/material loss outputs of what is known as a 'quantity centre', later renamed a 'process' in ISO 14053. To support decision-making, "all costs caused by and/or associated with the material flows entering and leaving a quantity centre should be quantified and assigned or allocated to those material flows" (ISO 2011, p. 6).

Material losses can cover more traditional production waste and emissions, but also those non-products that can be repurposed, reused, recycled, or sold off as co-products. System costs are costs related to in-house processes such as labour, maintenance, transportation, or depreciation costs. Waste management costs are those attributable to managing the material losses output from the quantity centre and are applied to the non-product outputs only, whereas material, energy and system costs are generally apportioned by the relative weight percentage of product and non-product outputs (70% and 30% accordingly in the approach exemplified in Figure 3 – with an overall 66.5% of operational costs adding product value, once waste management costs are considered). As this apportioning of costs is determined linearly, it is a significant simplification of reality, and therefore, as noted by Guenther et al. (2017), MFCA results should be viewed as an approximation. Though ultimately aiming to have a theoretical value of no non-product/material loss output, the realistic aim of MFCA is to reduce the approximated ratio of non-product costs as efficiencies improve.

Christ and Burrit have documented the general processes organisations need to undertake to implement MFCA. After first agreeing on an appropriate system boundary (including time period, and quantity center(s)), they then need to construct a flow model to map the flows of material and energy and assign values to those flows. Next, they should ensure that mass is conserved, and energy and

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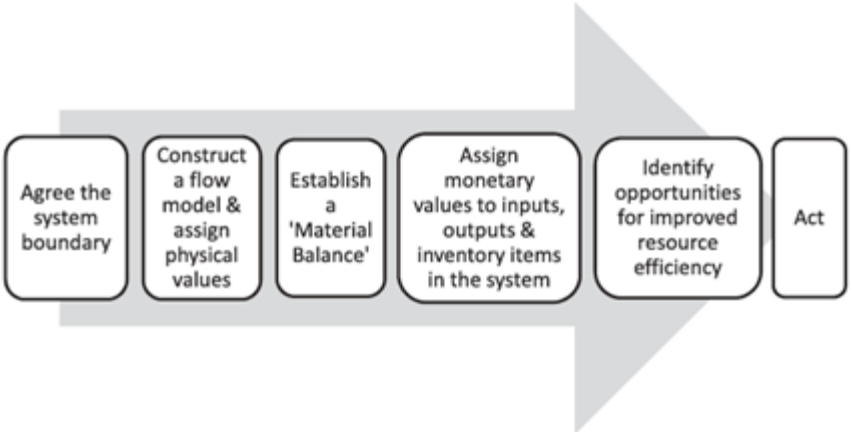
mass are never lost by establishing a material balance as they flow through a quantity centre – that is, achieving mass balance of



inputs and outputs. Then they must assign monetary values for every input and output contained for each step in the flow model (that is, for material, energy, system, and waste management costs). This data will need to be summarised, evaluated, and interpreted by management to identify opportunities for improvement and then act to implement those improvements (see Figure 5).

Figure 5 Process of Implementing MFCA [Figure 1 from Christ and Burritt (2015, p. 1381)]

3.4.2 The importance of financial accounting as a lever for change

Most business resource materials that exist in the food waste space are focused on addressing food waste from a sustainability perspective, written for an audience chiefly concerned with corporate social responsibility. However, a case can be made for the reduction of FLW from a financial perspective. An environmental case can also be made (i.e. waste reduction, carbon reduction, etc), addressing the problem as a matter of resource efficiency, as "[w]aste… indicates a material traded at a negative price" (Zucchella & Previtali 2019, p. 278). There are therefore benefits in addressing FLW on each of the economic, social and environmental aspects that the concept of the triple bottom line attempts to manage, measure and report on for businesses (Milne & Gray 2013).

The implications of failing to tackle FLW affects every aspect of the triple bottom line (Somlai 2021). Covering financial losses for businesses, governments and consumers (CEC 2017; Hegnsholt et al. 2018; Lee et al. 2013), lead to social detriment by endangering food security (ReFED 2016), and negative environmental effects – including the release of greenhouse gas emissions – impacts on land and water use, and ecosystem/biodiversity impacts (FlanaganRobertson et al. 2019). Tension between these triple bottom line elements is in most cases, a multi-objective optimisation problem, requiring innovative and adaptive management strategies (Somlai 2021). However, the problem of food waste is perhaps unique in that balancing the objectives of the triple bottom line is not a zero-sum game. Reduction of food loss has financial, environmental and social benefits: that is, greater resource efficiency reduces costs and improves sustainability while positively impacting food security.

It is such multiple gains that is used in the sales pitch for the software Crisp (https://www.gocrisp.com/about). AI powered programs, like Crisp and those offered by others such as SWARM Engineering (https://swarm.engineering/platform-overview), can reduce food waste by more accurately predicting supply and demand. While such innovations show promise in increasing efficiencies when it comes to production, distribution and end of pipe food waste, they do not focus on the issues of waste within manufacturing process itself as DIRECT does via the principles of MFCA.

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3.5 Literature learnings and goals for DIRECT

This wide-ranging literature review led to the identification of several learning and goals for DIRECT including:

- The FLW Standard should be the primary reference point for the development of the DIRECT tool as it gives the most consistent yet flexible framework for measuring food waste.
- At times, DIRECT needs to build upon the FLW Standard. For example, DIRECT elaborates on the destination of the material waste stream. Where the FLW Standard uses destination to demarcate where food and/or the associated inedible parts go when removed from the human food supply chain, DIRECT includes product(s), co-product(s) and food rescue as material destinations that are intended for human consumption, for mass balance. DIRECT also goes beyond the FLW Standard, and facilitates mass balance, by tracking materials that are recycled and lost to the environment (such as through evaporation).
- The selection of source metric for a business should be informed by the nature of the waste stream, access to data, and availability of records.
- There is a distinct need for a visual tool that shows users where benefits of reducing FLW lies
- The variation in the language used to separate waste types is often confusing. For example, sometimes the same waste could be categorised as either ‘addressable’ or ‘edible’. In alignment with the FLW standard, DIRECT classified FLW as either edible or inedible.
- The type of economic modelling such as that undertaken in ReFED has value to show food waste costs and potential savings, and this was already a key functionality of early iterations of DIRECT. Such business costs have been included in DIRECT to account for the standard operations associated with the production process(es) modelled in an assessment. DIRECT business costs bundle together ISO 14051’s ‘energy cost’ and ‘system cost’.
- The **true cost of waste breakdown** in DIRECT highlights the associated 'true costs' as per the WRAP report (Lee et al., 2013). This is collectively equivalent to ISO14051 material, energy, system and waste management material loss costs of material flows within the process/life cycle stage assessed. So, ensuring that the calculations for the true cost of waste aligned to the principles for calculating non-product/material loss costs in IS14051 is imperative.
- Data used in many studies examined is highly extrapolated and so does not always create a realistic data set for food waste comparison. This distinct lack of granular data on food waste means that there is a market opportunity for a tool such as DIRECT to be used as a standardised input to a high-level study like the National Food Waste Baseline. By introducing a standardised tool, a greater accuracy of aggregated data across industry can also be achieved.
- Multiple modes of analysis are useful to account for the different drivers that lead organisations to examine their food waste. This could include the cost of food waste per meal, total food waste mass, and separation of what was categorised as either edible or inedible waste. Such modality has been included in the final iteration of DIRECT, with assessment results allowing organisations to look at FLW results either including or excluding inedible waste.
- Standardised conversion fractions that show what proportion of a particular ingredient end up as waste have great utility. This has been integrated into DIRECT, with the key production mass ration metric being included in assessment results.

3.6 Expert 'user needs' interviews

In September/October 2019, a series of stakeholder 'user needs' interviews were undertaken with experts representing (at the time or previously) organisations such as CSIRO, the World Resources Institute (WRI), WRAP, FUSIONS/REFRESH, VCM International,

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Sheffield and Karlstad Universities and the End Food Waste CRC. The insights from these interviews were summarised, alongside those from the concurrent literature review, in the confidential internal technical report produced in February 2020 (Rigbye et al. 2020).

After ethics was approved by RMIT (CHEAN B 22362-08/19) in August 2019, respondents were recruited and prior to being interviewed were sent, alongside a detailed plain language statement and consent form, a copy of the DIRECT article 'DIRECT a tool for change' (Verghese et al. 2018) and a 2014 slide presentation about the Beta version of DIRECT. They were asked a series of questions covering what they would be looking for in a FLW tool for industry and government benchmarking, what protocols and standards to align to, what level of flexibility they'd like to see in the tool, how the supply chain should be defined in the tool and the necessity of including upstream and downstream waste in DIRECT. There were nine respondents all together.

This research involved a 30–60-minute audio-recorded in-person or telephone/VoIP video interview where interviewees were asked a range of open-ended questions concerning food supply chains, where the relevant data exists within organisations for FLW; necessary workflows for FLW data capture and synthesis; and relevant methods for comprehensive and repeatable reporting of FLW.

Along with the plain language statement and consent form, a discussion guide was developed for the research team for the 'user needs' interviews. Questions included in that guide are listed in APPENDIX B – Supporting Material(s).

The respondents suggested features to be retained from the spreadsheet version of DIRECT. As well as noting institutional barriers to collecting and sharing data both within and between organisations that may impact the future use and uptake of the tool (not to mention potential issues of collusion and confidentiality), the experts suggested a range of enhancements to DIRECT too.

4. Scope enhancements, coding and interface development from pre-existing iteration of DIRECT online

4.1 Scoping Sessions

After the expert interviews were completed, RMIT researchers, Empauer and industry experts undertook a three-day workshop, of DIRECT design scoping sessions, in December 2019, in which they:

- Reviewed the insights from the user needs interviews and literature review
- Considered two use scenarios for DIRECT:
    - by an individual business or organisation to analyse their own FLW; and,
    - The use of the tool to produce a benchmark measurement for national FLW tracking
- Determined and examined the commercial imperatives and viability of the tool.
- Looked at how to simplify and what to prioritise for the first iteration of DIRECT online
- Utilised stakeholder mapping to map out and analyse relationships between stakeholders of DIRECT. Separate stakeholder maps were created for:
    - Business/ Organisation Benchmarking and Strategy; and,
    - National Benchmarking
- Mapped user journeys/touchpoints to create service blueprints, bringing processes and connecting points of interaction into the same diagram, for both Business/ Organisations and National Benchmarking

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- Mapped the DIRECT online graphics user interface (GUI) and schema (of data flows).

The outcomes from scoping sessions are set out in the concluding discussion of the confidential internal technical report produced in February 2020 (Rigbye et al., 2023). The discussion identified elements that should be retained from the previous version of DIRECT, as well as enhancements and additions that were recommended for inclusion in the next and future iterations of the tool. The following are stakeholder maps and service blueprints, which were created by workshop participants during the scoping sessions and refined afterwards. Examples of the design outputs from the scoping session are included as Figure 6 and Figure 7.

This work culminated in a revised online DIRECT tool graphic user interface (GUI) and schema, that is, a schematic diagram of the new tool architecture, prioritising the development of a Business/ Organisation version of the tool for DIRECT.

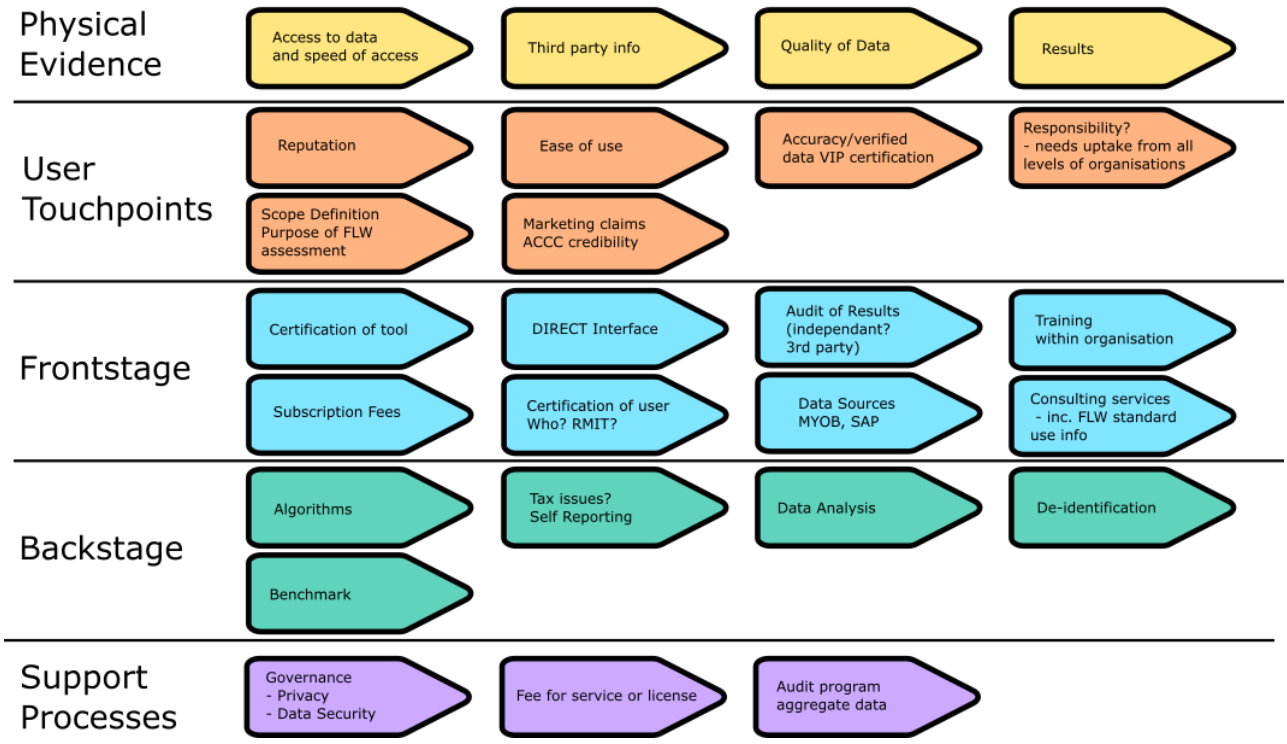

Figure 6 Design Output - Business / Organisations Service Blueprint

5. Building, piloting and refining DIRECT online

Following on from the scoping sessions, Empauer and RMIT worked together to build the cloud version of DIRECT.

This prototype design and functionality included:

- Schema development
- UX and product architecture conceptualisations and refinement
- Service mapping (for DIRECT product and support consulting services)

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- Database design
- Algorithm definitions and development
- The development of approaches to analyse data and develop new insights
- The implementation of security and encryption protocols to protect company data that is entered.

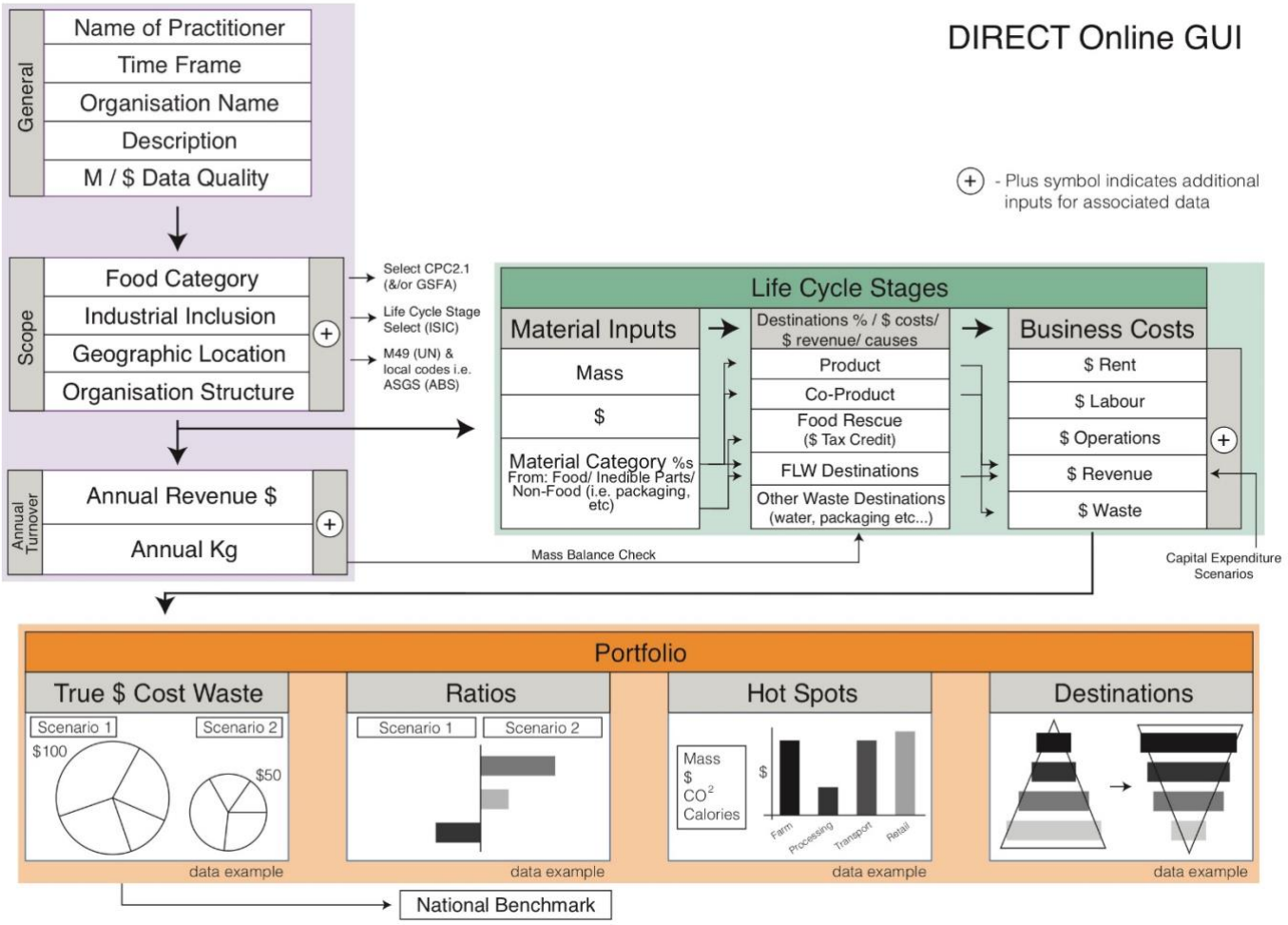

Figure 7 Design Output - DIRECT Online GUI

5.1 Alpha Testing & Supporting Materials

Extensive alpha testing was conducted for the first iteration of the cloud version of DIRECT. This step helped to identify and address bugs, improve interface functionality, and refine the overall user experience. For example, issues such as mislabelled ratio tables, and inconsistencies in chart labels were identified and corrected. Feedback also led to the addition of new options, such as the 'Estimated' data collection type, and modifications to existing elements to improve clarity and usability. This included revising the

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definitions and titles for various mass ratios to ensure accuracy and better user understanding. The alpha testing process also identified bugs, such as issues with the wizard navigation where required fields were incorrectly flagged as incomplete. Additionally, visual issues in charts were resolved, such as updating ratio tables to reflect accurate metrics and updating labels for clarity.

Specific points of feedback used to refine the tool also included:

- Providing an introduction outlining necessary steps and information for users, explaining search functions and required field indicators.
- Ensuring terms were consistently spelled and used throughout the tool.
- Auto-filling and providing clear instructions for entering names and product details, using specific prompts for classifications and time frames.
- Clearly defining reporting levels and specifying geographic locations.
- Offering lists for material destinations and life cycle stages, including options for data collection types.
- Clearly defining and accurately reporting income and production metrics related to the assessed product.
- Permitting entries with zero cost inputs where applicable.
- Ensuring that percentage breakdowns for material destinations total 100%.
- Allowing edits for output costs and clarify related terminology.
- Updating cost categories and labels and adding an "Other" option for additional business costs.
- Standardising labels across the tool for clarity and consistency.
- Including detailed headers and tables for cost breakdowns, ensuring pie chart labels are clear and toggleable between percentage and dollar values.
- Reorganising the dashboard for better flow and clarity, splitting tables into categories like production ratios and financial ratios with matching charts.
- Providing clear labels and tables for reporting material losses, including food and non-food categories, and include hotspot graphs for loss mass and costs across life cycle stages.
- Ensuring fields are user-friendly, allowing easy edits and navigation aids like tabbing through cells

In parallel to the alpha testing, the RMIT team developed supporting documents to accompany the tool for them to be used for the beta testing/piloting as well as form the basis for the supporting documents of the final/commercialised tool. These supporting documents included:

1. A detailed user guide: Step-by-step detailed guidance to assist users with the DIRECT tool. To assist organisations to collect the right data required by DIRECT, this guide includes a pre-assessment checklist which covers the tool's data and input requirements.
2. "Training decks": A high-level four slide deck presentation overview of the tool and its key sections. These documents were used to brief organisations during the pilot process.

More detailed information about these materials is provided in Section 6 'Refine and Further Develop Supporting Materials'

5.2 Beta Testing/ Piloting Phase 1

After alpha testing and resulting first stage of enhancements were complete, DIRECT was then piloted with several agricultural, food, and food service organisations. This was the Pilot Phase 1. These organisations were recruited through professional industry networks as well as through End Food Waste CRC.

This stage of the project was a key part of Project 1.1.1's research-industry co-design process and was reciprocally beneficial to both DIRECT 's development and pilot participants. Organisations were able to trial DIRECT, assess their own FLW practices, map

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material flows across their food supply chain, quantify the 'true cost of waste' and undertake scenario comparisons to their reduce costs and increase resource efficiency. For the tool development, the organisations acted as 'beta –testers' who provided feedback on the tool and their interaction with the interface, processes and supporting documents. A summary of each of these organisations' piloting outcomes is provided in Section 8 'Case studies and real-world applications' of this report.

After ethics was approved by RMIT (CHEAN A 22750-03/20), in April 2020, phase one of piloting occurred between August 2020 and November 2020 with three organisations: Sweet Potatoes Australia, Olam Orchards and The South Australia Potato Company. Representatives from each organisation were either commercial or sustainability managers. Pilot participants were provided with a plain language statement, consent form, access to the DIRECT tool, supporting documents (for example, the user guide, training decks and copies/summaries of standards) and a confidential participant briefing document {Rigbye, 2020 #1444} – the latter of which included a summary of the DIRECT development process, an overview of its current form, and its alignment to key standards (FLW Standard and ISO 14051/MFCA).

The pilot program consisted of organisations being supported to use DIRECT to model their own supply chains and scenarios. It included three sessions on Microsoft Teams with the RMIT research team, which were delivered across approximately a three to four-week period. These sessions included:

1. Briefing Session: The research team explained the purpose of the DIRECT pilot phase, discussed data requirements, ran piloting users through DIRECT tool.
2. Check-in session: This session gathered initial insights and users' feedback on the tool, as well as provided an opportunity to support, advise and guide the piloting organisation users through any questions regarding their assessment(s).
3. Debrief session: The purpose of this session was to extract insights and feedback on the tool and accompanying supporting documents (namely the user guide) as well as to discuss the organisation's assessment results and implications for the company.

The research team was also available to support participating organisations throughout this period via email and phone, and additional check-in sessions were made available if needed. Apart from the plain language statement and consent form, an outline guide for the piloting was also used to guide the research team in their interactions with pilot participants (this remains confidential due to the commercial sensitivities of the working of the tool).

5.3 Refining DIRECT online to be business-ready

Feedback received from piloting companies in phase one was reviewed and prioritised by the RMIT research team and Empauer into high priority (immediate), lower priority (later/ post launch).

The major enhancements implemented as a result of piloting phase one included:

- Enabling of export of inventory post-assessment wizard, expanding beyond results tables to include a spreadsheet (xl)s file download.
- Incorporating an option to pre-populate/carry over product mass and cost across life cycle stages in the model.
- Modelling multiple products or co-products within one assessment to mirror real-world scenarios.
- Allowing the addition/removal of life cycle stages and material destinations at any data entry point in the tool.
- Including comment sections for business costs and resource management windows for user notes.
- Permitting an entry of zero in all fields for consistency across data entry points.
- Implementing autosave function for entries in the wizard to prevent loss of work.
- Adding functionality for users to add custom business costs and select different timeframes for assessments

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- Refining assessment results explanations

These enhancements were implemented in the first half of 2021.

5.4 Refine and Further Piloting (Phase 2) /Review

From September 2021 through February 2022, the second phase of piloting occurred – this time with a fruit grower and a fast food/Quick Service Restaurant chain.[4]

This second round of pilots utilised the same structure, documentation and support as Phase 1: that is, participants were provided access to DIRECT and the pilot program was delivered across three sessions (briefing, check-in, and debrief) held over a 3–4-week period with the DIRECT research team.

It is worth noting that both phases of the piloting occurring during COVID-19 lockdowns and rapidly changing government restrictions, which had broad ranging impacts on the both the participating organisations as well as the DIRECT research project and pilot – for instance, all sessions were held over Microsoft Teams, and operational challenges for participating organisations meant that pilots and sessions were delayed.

The major enhancement highlighted and implemented from this round of piloting was the need to limit the value per tonne of the co-product (and other non-products) to be less than the product(s). This change was necessary because DIRECT uses the income from non-product materials to offset the costs of material loss. By ensuring the value of the co-product is less than the product, the true cost of waste can be accurately reported. This helps in accounting for lost margins when materials don't turn into products, and it ensures that the offsets effectively reduce the true cost of waste based on the income per tonne of the non-product compared to the product. The pilots also identified future enhancements to be implemented in the longer term.

5.5 Peer Review

In early 2021, an open peer review of DIRECT was undertaken regarding the robustness of the alignment to standards of the enhanced online version of the tool.

Two sets of reviews were gathered, one from Brian Lipinski (World Resources Institute), an expert in the FLW space and author of the FLW Standard. The other review was from academic experts in sustainability accounting (including material flow cost accounting), Dr Katherine Christ (University of South Australia) and Honorary Professor Roger Burritt (Australian National University). Reviewers were asked to provide feedback on their general impressions of DIRECT, to give an assessment of alignment to the standard they have expertise in (i.e. the FLW Standard or ISO 14051) - with a 'statement of alignment' as to if and how and/or what is further required to align the tool to the standard in questions and to give recommendations for further improvement of the tool, in relation to the standard in question and in general. They were also given the opportunity to give miscellaneous feedback.

The peer reviews used a similar structure, documentation and technical support as the pilots. Reviewers had DIRECT demonstrated to them, and they were given access to the tool (with additional support provided by RMIT where required). This enabled the reviewer to review the flow, look and feel of the tool, as well as its alignment to the standard in question. Reviewers were not expected to undertaker a full review of the accuracy of DIRECT but were encouraged to run some data analysis - via the tool - sense checking as well as testing if the algorithms in the tool align with the data collection and allocation, as recommended in the standard in question.

The major points of peer review feedback were as follows:

[4] Organisation names are withheld. The piloting with the fruit grower was conducted solely with a university researcher collaborating with the fruit grower. After issues with the value of co-products became evident, and no data on business costs was able to be procured, the fruit grower pilot did not produce data useful for a marketing case study. However, the tool proved useful for understanding the implications of the trials they were conducting.

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General impressions of DIRECT:

- While DIRECT enables scenario comparisons, lack of easy comparison of assessments over time limits its effectiveness in assessing improvements or changes in resource efficiency.
- While the tool emphasises the Australian context, DIRECT may benefit from broader industry coverage to address multi-country or multi-industry scenarios.
- Consideration should be given to include stocks of materials, energy, and waste, especially in contexts like pandemics and climate change.

Minor recommendations for improvement, as well as minor functional/syntax/label issues picked up, including building guidance that is currently in a separate user manual directly into the tool.

The peer reviewer's assessment of alignment with the FLW Standard was as follows:

- Overall, DIRECT aligns very well with the FLW Standard, but a couple of minor tweaks could provide further alignment including:
    - tweaking the label to avoiding confusions with the recycling destination label that was only aligned with non-food; and,
    - Allowing inventory to be automatically carried over to the next life cycle stage (reducing date entry labour and potential double counting).

Their assessment of DIRECT's alignment with ISO 14051 was:

- DIRECT and ISO 14051 are based on a similar premise related to differentiating product and non-product output (termed waste in DIRECT) and relating this to costs. In line with ISO14051, DIRECT breaks systems costs down into individual categories which can provide useful information for decision makers. However DIRECT could give greater consideration to cost accounting principles and issues with product costing and cost allocation more specifically:
    - Clarification is needed on how system costs or overheads are allocated in DIRECT. This is crucial for meaningful data interpretation and alignment with ISO 14051;
    - There is a lack of provision for carrying over output from one process/quantity centre to the next, a feature present in ISO 14051; and,
    - Terminological discrepancies between DIRECT and ISO 14051, such as the use of "true cost," necessitate clear explanations to avoid confusion among users.

There were also major commercial in confidence recommendations for future Improvement of DIRECT made by the reviewers.

In May 2022, RMIT officially responded to the ISO 14051 review and then had further discussion with Dr. Christ and Professor Burritt. RMIT responded to specifics in the review and pointed out several upgrades and amendments (including updated support documentation) to the tool since they submitted their review in February 2021, as well as future amendments that could further address some of the concerns raised in the review. RMIT also specifically sought feedback on the lost-margin offset feature that reduces the 'true cost of waste' and advice on the suitability of this, in the first instance, versus other accounting approaches, such as a direct cost offset-based credit that reduces the 'true cost of waste'.

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6. Refine and Further Develop Supporting Materials

During the alpha phase of the project the RMIT team developed supporting documents to accompany the tool and support its users. Throughout the beta testing (piloting) and following resulting enhancements to the DIRECT tool, these documents were updated and further refined before being finalised and prepared for commercial use after the launch of the tool.

6.1.1 User Guide

As the primary support document, the DIRECT user guide provides comprehensive and detailed guidance and instructions, covering an overview of DIRECT's key features and a pre-assessment checklist that lays out data requirements for the tool. The user guide also explains data entry procedures, has step-by-step guidance on entering data for assessments, explains DIRECT interface navigation, and includes detailed explanations on interpreting assessment results and comparing assessments, including benchmarking and scenario comparison. The user guide also includes an extensive glossary of significant terms and labels used in DIRECT, for ease of clarification.

6.1.2 Training Modules

Training 'modules' were also simultaneously developed and refined - with accompanying slide training decks for each module. These modules provide bite-size overviews of key aspects of the tool and its use and are beneficial to both the trainers and the trainees in the way they section off the relevant information into manageable components. Figure 8 shows the flow of what is covered in the modules.

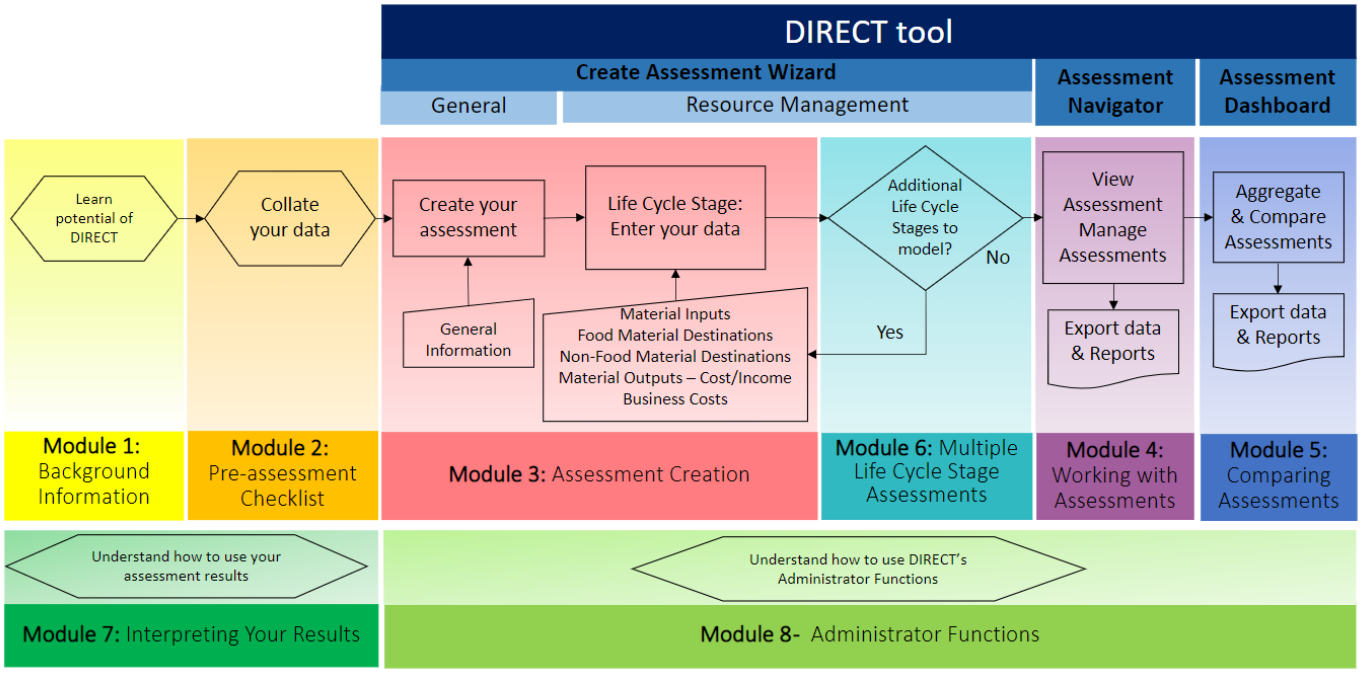

Figure 8 Flow chart of training modules

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Modules developed are as follows:

1. Background and Introduction to DIRECT
2. Pre-assessment Checklist
3. Assessment Creation
4. Working With Assessments
5. Comparing Assessments
6. Multistage Assessments
7. Interpreting Results
8. Administrator Functions

An outline guide for training/delivering the modules was created as well, listing supporting docs and noting how to set up training folders, overviewing the modules, making suggestion which modules to run in training sessions, as well timing of each module. Other documents prepared/collated to assist the delivery of the training modules included:

- The user guide (with extracted/additional copies of the pre-assessment checklist and glossary),
- Spreadsheets of exemplar assessment data (a complex 'Melbourne Muffins' data set also used for demonstrations of the tool and a simple 'Bobby Biscuits' example)
- Various documents and presentations/guides/reports covering the key standards (FLW Standard and ISO 14051/MFCA), as well as a document estimating edible parts in various food products.

In addition to this, a detailed list (including copy and steps) of potential videos that could be generated and embedded in and/or used to support training on the tool was developed.

7. Development of communication materials, launch and marketing

In late 2020, a short promotional video “Do you know the true cost of waste to your operations?” was posted on YouTube, providing an infographic overview of the DIRECT tool’s capabilities (Fight Food Waste CRC 2020). Six months later DIRECT, was amplified by the BBC globally by way of the ‘Better Lives Through Better Business’ film series (BBC Story Works 2021). The episode featuring DIRECT “Giving Companies the Tools to Fight Waste“ demonstrated how DIRECT helps food companies identify food waste reduction opportunities so that their personnel can achieve environmental and financial goals. The film was launched to CEOs and Executives of the likes of Walmart, Aldi and Tesco at the Global Summit of the Consumer Goods Forum in June 2021. In the film project leader Simon Lockrey demonstrates and discusses aspects of the tool and food waste for 5 minutes. The BBC promoted the film throughout 2021 through social media and www.bbc.com, estimating it garnered around 60 million unique impressions from audience segments such as business leaders; grocery shoppers; manufacturers; millennials; and the eco-conscious. Simon Lockrey also promoted the tool on the CPG Innovation Podcast and The Food & Drink Business Podcast in March and July 2021 respectively (Berry 2021; Tripologos 2021).

Prior to launch in late 2021 a brochure was developed in partnership with Empauer, “Uncover your true cost of waste with DIRECT” (Empauer 2021d). This document was centred around the concept of tracking waste in order to either eliminate it or transform it into

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other products. Pitched at businesses, the narrative is centred around tying financial benefits to creating greener, more efficient businesses (see Figure 9).

Figure 9 Pages from DIRECT launch brochure

Marketing for DIRECT also included three blog posts: “Why it’s so hard to see the true cost of waste”, “Transforming waste into opportunities” and “The DIRECT approach to averting a $1.5 trillion problem”, which were all centred around the notion of transforming business through the true cost of waste.

In November of 2021, DIRECT was launched online via a webinar, with CEO of End Food Waste Australia, Dr Steve Lapidge, saying “DIRECT is a powerful tool and our hope is that the Australian food industry incorporates it into their operations to realise the impact it can have on their management of food waste” (https://endfoodwaste.com.au/new-software-tool-to-provide-direct-benefits-in-the-fight-against-food-waste/) (Fight Food Waste CRC 2021). This launch emphasised the importance of measuring waste to the process of minimising it. It presented a number of case studies (including the three outputs from piloting phase 1) that demonstrated the financial benefits of fighting food waste, and also ran through how the program functioned and the graphic interface of the data (see Figure 10).

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Figure 10 Slides from DIRECT launch

Ongoing public promotion of DIRECT has been implemented via a webpage embedded on Empauer's website (as well as various other mediums such as podcasts, promotional videos and webinars (see for example Empauer 2024; End Food Waste Australia 2024; Robertson 2023)): https://empauer.com/solutions/direct/

8. Case studies and real-world applications

As detailed in prior sections of this report, several agricultural and food service organisations piloted DIRECT as part of the beta testing phase of this project. These organisations were supported to use DIRECT to map their material and cost flows for selected processes, while providing feedback on the tool for refinement. From mid-2020 to early 2022 five organisations participated in the piloting, including Olam Orchards, Sweet Potatoes Australia, South Australia Potato Company, a fruit grower (kept anonymous), and a fast-food / QSR chain (kept anonymous). While significant learnings were fed back into the refinement of the tool, both implemented and flagged for the future, the case studies output from the piloting were focused on marketable insights. DIRECT was also used as part of an End Food Waste CRC project around whole of meat supply chain waste mapping and interventions, which utilised the tool to estimate and measure the cost of losses.

Three of these organisations have their case studies included in Section 7 of the DIRECT Industry Report (Hill et al. 2023) representing the post-harvest (Olam Orchards), processing (FFW CRC Project 1.1.4 – Meat Supply Chain Mapping), and food service (QSR chain) life cycle stages. Four of the pilots also have the results of their piloting published as case studies available on the DIRECT website (see https://empauer.com/solutions/case-studies/ for full details and Figure 11 for an example page). The 5 case studies produced during the course of Project 1.1.1 are also summarised below. The piloting with the fruit grower provided significant insights for the project and prompted enhancement to the tool but did not procure relevant data to produce a marketing case study.

8.1 Case study one: Sweet potatoes

Sweet Potatoes Australia, based in the Bundaberg region of Queensland, supplies domestic and international markets year-round. The largest producer of sweet potatoes in Australia, the company focuses heavily on data, sustainability, and transparency to bring consistent quality to consumers. Forecasting scenarios is one strategy Sweet Potatoes Australia leverages to make business decisions. Without a complete understanding of the true cost of waste, the company was unable to map out accurate alternatives to current processes. Until waste resources were fully analysed, there was no way for Sweet Potatoes Australia to tabulate and

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demonstrate waste's impact on bottom-line. This limited the availability of opportunities and presented enterprise-level challenges as it relates to capital expenditure.

In 2020, Sweet Potatoes Australia participated in a pilot study that utilised DIRECT to capture process data and built out the scenarios they were looking to model. Able to model their value-add facilities, where product is placed into different weighted bags, the company could see the impact of different approaches and know which value-add products were best. The straightforward interface made it easy for Sweet Potatoes Australia to assess their true cost of waste.

To communicate the value of business decisions to key internal stakeholders, Sweet Potatoes Australia utilised the power of DIRECT to validate a variety of data-based decisions. Paired with the ability to present a variety of scenarios or products which reduce cost and waste, the company could more readily illustrate the value of capital expenditure.

DIRECT's assessment results revealed that while waste was minimal, 5-percent of all sweet potato material inputs ended up in non-income destinations. A substantial portion of their true cost of waste was attributable to business costs. By redirecting the materials wasted in their manufacturing chain to higher value destinations, such as animal feed or food rescue, and extracting nutrients from leaves and vine waste, Sweet Potatoes Australia could begin to transform waste into additional income (Empauer 2021c).

8.2 Case study two: Quick Service Restaurant (QSR)

The food service provider that took part in these piloting case studies was a multinational fast-casual/quick-service dining restaurant chain specialising in meat products. This chains' insights into the FLW were limited by the capabilities of their systems, which had made it difficult to track the material efficiency of processes. The system previously used provided overall volume and cost information, however, unlike DIRECT, it did not provide insights around where material losses occurred in their processes. The food service provider was attracted to DIRECT for its ability to pinpoint these waste hotspots, as well as for the tool's visual representation of data. The chain used the DIRECT pilot as an opportunity to map and develop a more intricate understanding of the front and back of house processes in order to determine where, why, and how much wastage was occurring.

Results from the DIRECT trial formed a baseline of data that illustrated the possibilities of strategic and streamlined operational processes, reducing, and diverting waste responsibly. Even without the added nuance of business cost data (that was not able to be ascertained for the pilot) DIRECT's results pinpointed hot spots in the processing stage. The hot spots showed the QSR chain where it could adjust operations accordingly for improved resource efficiency. The pilot also assisted in identifying opportunities for new income streams by diverting and repurposing food currently going to waste streams.

Three clear insights were identified as a result of running DIRECT's assessments in the pilot (Empauer 2023):

- I**mproved operational processes.** With a clear picture of processes within its restaurants, the QSR chain identified a significant food waste hotspot in its food service processing stage, namely that their ordering system and cook plan were not being utilised effectively and that they needed to bolster the operational processes in restaurants;
- **Optimal food waste destination.** DIRECT results also identified breakdowns in processes impacting food waste destinations. In one restaurant, all materials were ending up in landfill when much of it could be donated to food rescue, while at the other restaurant, DIRECT highlighted that a greater variety of SKUs could be donated than were currently; and,
- **New product income streams.** DIRECT's ability to track multiple products and identify how additional costs could be offset by turning material loss into new product income streams could support the food service provider in entering the food innovation space. Products currently wasted (such as herbs, spices, bastings, bread) could be transformed into a product (such as soup base or soup stock) to be sold in restaurants or donated to food rescue partners.

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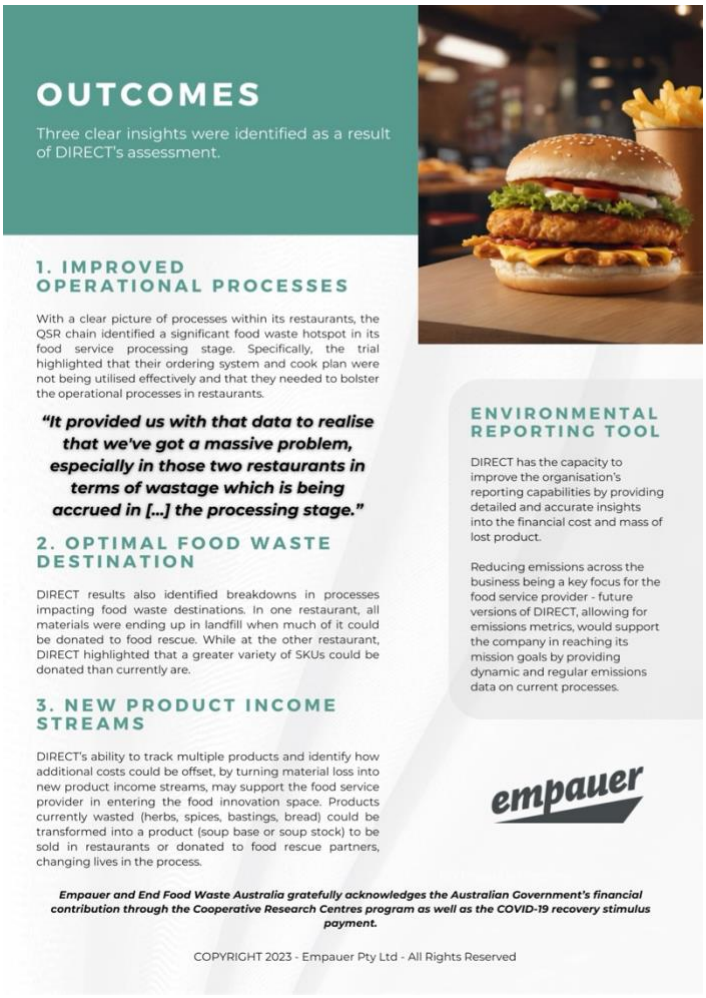

OUTCOMES

Three clear insights were identified as a result of DIRECT's assessment.

1. IMPROVED OPERATIONAL PROCESSES

With a clear picture of processes within its restaurants, the QSR chain identified a significant food waste hotspot in its food service processing stage. Specifically, the trial highlighted that their ordering system and cook plan were not being utilised effectively and that they needed to bolster the operational processes in restaurants.

"It provided us with that data to realise that we've got a massive problem, especially in those two restaurants in terms of wastage which is being accrued in [...] the processing stage."

2. OPTIMAL FOOD WASTE DESTINATION

DIRECT results also identified breakdowns in processes impacting food waste destinations. In one restaurant, all materials were ending up in landfill when much of it could be donated to food rescue. While at the other restaurant, DIRECT highlighted that a greater variety of SKUs could be donated than currently are.

3. NEW PRODUCT INCOME STREAMS

DIRECT's ability to track multiple products and identify how additional costs could be offset, by turning material loss into new product income streams, may support the food service provider in entering the food innovation space. Products currently wasted (herbs, spices, bastings, bread) could be transformed into a product (soup base or soup stock) to be sold in restaurants or donated to food rescue partners, changing lives in the process.

ENVIRONMENTAL REPORTING TOOL

DIRECT has the capacity to improve the organisation's reporting capabilities by providing detailed and accurate insights into the financial cost and mass of lost product.

Reducing emissions across the business being a key focus for the food service provider - future versions of DIRECT, allowing for emissions metrics, would support the company in reaching its mission goals by providing dynamic and regular emissions data on current processes.

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Empauer and End Food Waste Australia gratefully acknowledges the Australian Government's financial contribution through the Cooperative Research Centres program as well as the COVID-19 recovery stimulus payment.

Figure 11 Page from QSR case study

8.3 Case study three: Olam Orchards

Olam Orchards (Australia) is a subsidiary of Olam International, and is Australia's largest almond grower, exporting to over 15 global markets. With over 15,000 hectares of almond orchards across 11 farms in the Sunraysia region in Victoria and New South Wales, the company operates one of the world's largest hulling, shelling, and processing plants with over 120 full-time employees.

The fleshy hulls that protect an almond and its shell create a significant amount of by-product, upwards of 70% of product harvested. To offset some of this material loss, almond hulls are repurposed as animal feed. Being a by-product with some demand, the hulls generated income for Olam Orchards. However, the 'true cost' associated with this by-product stream became clear when utilising DIRECT to examine the waste streams and costs associated with processing almonds in their shells and hulls that had occurred in a recent crop year.

Almond hulls destined for animal feed generated close to 2-percent of the total plant income. However, even with this income offset the material costs and proportional business expenses incurred a substantial 'true cost of waste' when only directing hulls to the animal feed destination, suggesting that higher income valorisation opportunities may be worth investigating.

The value of using DIRECT to compare various capital expenditure and review return on investment was readily evident to the Olam Orchards pilot participant, who said “If you’re looking at additional capital expenditure opportunities in terms of the processing plant sorters or stick removers, you can run different assessments and see what the actual outcome is”.

Not only can capital investment be projected, the benefit of pivoting to new, co-product destinations for almond hulls was clearly something of value to Olam Orchards. Such business opportunities could include compostable dinnerware or sugar alternatives for beers and other beverages. DIRECT could also assist in projecting returns from efforts aimed at improving primary production life cycle stage harvest efficiency, itself before the almonds are brought in for dehulling, as well as measuring the actual impact of efforts once they are implemented (Empauer 2021a).

8.4 Case study four: South Australian Potato Company

Based in Mount Barker, Australia, the South Australian Potato Company processes more than 60,000 tons of fresh potatoes each year. The company employs roughly 100 staff.

Harvesting potatoes brings a substantial amount of sedimentary byproduct with it, including soil, rocks, and weeds. This waste represents a significant amount of wasted energy and effort, both in the transport and processing of the potato product. The company had limited tracking of the product’s use and wastage once it left their grounds, which meant that they were without a comprehensive understanding of the whole food supply chain, including mapping material flows, destinations, and costs – such as rejects from the supermarket. Also, with several areas and departments generating data on different systems, no standardized or centralized process existed. This barrier to communication made it difficult for the South Australian Potato Company to share intelligence or perform analysis on product lifecycle.

Through participation in our pilot study, the South Australian Potato Company could leverage DIRECT to model and compare the process of packing potatoes into different sized bags, across multiple production runs. Due to the system’s ease of use, the company was able to highlight significant business expenditures going towards waste.

With a deeper understanding of their processes, including in-depth understanding of material waste destinations and the associated true cost of waste, the South Australia Potato Company identified reducible costs associated with processing weeds, rocks, and soil entering the processing stage. Additionally, DIRECT was able to capture critical data on packaging lost during processing.

Previously, gathering data across the South Australia Potato Company took longer than needed due to disparate systems. DIRECT helped to break down some of the silos, aiding communication across divisions. Contrasting processes meant the company could determine which product or combination of end products resulted in the most efficient process with the highest value. The easy-to-read analysis from DIRECT gave the company a tool for making these business decisions (Empauer 2021b).

8.5 Cases study five: Meat supply chain waste mapping and interventions

The "Whole of meat supply chain waste mapping and interventions – Phase 1" EFW CRC Project 1.1.4 was conducted by the Queensland University of Technology (QUT) with funding from Meat and Livestock Australia (MLA), focused on mapping beef meat losses and waste in Australia. Running from mid-2021 to early 2023, the project targeted the upstream production stages, from meat processing to retail distribution.

The project involved case studies of two companies: one handling primary and secondary processing, and another handling tertiary processing. By combining case study data with industry processing costs, the project aimed to approximate the total costs of each processing stage. Using the DIRECT tool, the team mapped material flows and calculated the 'true cost' of meat losses, highlighting potential cost savings from reducing waste.

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In primary and secondary processing, the DIRECT analysis excluded inedible parts of the carcass, focusing on components destined for human consumption. The findings from DIRECT showed that the 'true cost of waste' was about 3% of product income for primary/secondary processing, equating to $33 million per year, and 0.4% for tertiary processing. The major costs included purchased materials, wages, freight, facilities, and electricity.

By extrapolating the cost of losses in processing across the sector, the project team suggested that a targeted reduction in beef meat losses of 15-25% across processing stages could result in savings in the order of $18-31 million per year for the Australian beef industry. As the data collected for the case studies was limited, the project recommended that organisations across the industry use DIRECT to help create a more accurate picture of the cost of meat loss and waste within each organisation and across the industry (Renouf et al. 2023).

For more information on Project 1.1.4, see https://endfoodwaste.com.au/projects/whole-of-meat-supply-chain-waste-mapping-and-interventions-phase-1/

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*The two 2024 Somlai publications have not been referenced in the document, so doing so here (Somlai 2024a, 2024b).

10. Reflections and Recommendations

The development of the DIRECT tool during Project 1.1.1 was always limited by the scope of the project and from the outset it was identified that measures other than by providing detailed and accurate insights into the financial cost and mass of lost product could be considered in quantifying FLW. Some of these metrics are meaningful for studies with different foci, such as food security or environmental impact.

Having various output options helps to prioritise areas for reduction of FLW according to specific goals. The greatest mass may not map the greatest greenhouse gas production, or the greatest loss in nutritional content. Linking DIRECT to databases able to represent losses in other terms will allow the tool greater relevance to studies with more diverse aims, by linking materials and destinations to inventories, and presenting these other impact measures as figures and ratios in DIRECT's output. Along with the current cost and mass outputs, this may serve to enhance the relevance of the tool to different stakeholders.

A number of those who participated in the pilot and others who have enquired into using DIRECT since have said that reducing emissions is a key focus of their organisation, so future versions of DIRECT allowing for emissions metrics would support their company by providing dynamic and regular emissions data. Nutrition metrics and more targeted water tracking are also priority metrics users would like to see in future iterations of DIRECT.

Other suggestions/ possibilities were captured from stakeholders/ peer reviewers and remain commercial in confidence.

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11. Impact and Ongoing Monitoring

Since 2019, ongoing industry co-design of a digital tool DIRECT has delivered, through funding and a PhD scholarship, EFW CRC Project 1.1.1. This led Empauer integrating DIRECT into their multinational software platform. Translational impact from DIRECT involves measuring food systems and informing FLW reduction, like measures for regenerative, net positive outcomes from farm to retail. In this context, since being launched at the end of 2021 DIRECT has; helped map the Australian meat supply chain for MLA to consider industry innovations (Renouf et al. 2023); been licensed to Food and Fibre Gippsland to help their local businesses understand their true cost of their waste and deploy change; and been proposed to large Australian companies participating in the voluntary Food Pact to reduce FLW nationally (with projects being developed). As such DIRECT has informed practical outcomes for industry and led to commercial returns for Empauer. Discussions with ReFED, WRI, and companies in the US continue, with financial impact expected through a royalty agreement guaranteeing EFW CRC and RMIT a proportion of global sales of DIRECT. As noted, a key example of translational public impact is the BBC's global amplification of DIRECT by way of the 'Better Lives Through Better Business' film series (BBC Story Works 2021). This represents massive industry and public impact for the EFW CRC. Moreover, these types of public research translations establish the CRC as a global leader.

Specifically in terms of the key impact areas and projected impacts under the CRC's impact model, it is expected that full impact will be felt by the 2031/2 financial year (10 years since the launch at the end of 2021), with an ongoing expected likelihood of adoption being 75%, with a 10% market penetration. The efficiencies gained are calculated against the 5.2 MT pre-consumer 2021 Australian FLW baseline (FIAL 2021) - 433,800 per year (10% minus 10 percentage points of that going to food rescue) - with the CRC impact model calculating the impact (with DIRECT addressing 10% of the waste) by 2033 as 170,809 tonnes. The same model predicting that 205,233 tonnes would be redirected to food rescue. We have also predicted that DIRECT will hit an annual turnover of $3 million for Empauer and up to $50,000,000 in cost savings across the supply chain for the industry using the tool. This has an estimated impact of $120,280,779 by 2033 according to the CRC impact model. We estimate further that the maximum total jobs created by Empauer to deliver the tool, will total 15 and some 240 people a year will be trained to use the tool when being integrated into industry - this equated to 4 circular economy jobs created and 1800 industry people trained by 2033, according to the CRC impact model. We have already seen the 1 future leader graduate, with Roland Somlai being granted his PhD (with minor amendments) in 2024. Finally, the CRC impact model estimates that there will be 809,778 (t C02-eq) of greenhouse gas emission savings attributable to DIRECT's implementation by 2033.

RMIT and the CRC will liaise with Empauer into the future as the actual success and implementation of the tool into the future, with the royalty agreements ensuring that these discussions will occur as par for course.

12. Acknowledgements

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APPENDIX A – Project Summary

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Project Summary
DIRECT Commercialisation Project (1.1.1)

KEY POINTS

- The world is increasingly concerned with and is attempting to measure and compare food loss and waste (FLW) in order to reduce it.
- Software-enabled decision support tools (DST) are prevalent, but their impact has been limited when it comes to FLW.
- DIRECT has been developed as a cloud-based DST that facilitates the standardisation of FLW material flow quantification while accounting for the 'true cost' of that waste.

Figure 1. DIRECT launch brochure

THE CHALLENGE

In order to make effective decisions in their efforts to reduce FLW, accurate, comparable, and easily understandable data must be available to key decision makers. As FLW quantification accelerates, a triple bottom line solution that properly accounts for the ‘true cost of waste’ can make FLW reporting more urgent and impactful for business.

THE OPPORTUNITY

A DST that accurately tracks FLW through a rigorously researched back end that provides data visualisation in a number of different ways in order to standardise reporting outputs and communicate the efficacy of FLW interventions, by reducing both environmental and financial costs.

OUR RESEARCH

• Initial desktop research into FLW quantitative measurement definitions, metrics and methods, and the global move towards measurement reporting and standardisation.

• Subsequent research into the role that technologies and DSTs can have in highlighting efficiencies and drivers of food waste, including new opportunities to act. These can be via software and/or utilising the principles of Material Flow Cost Accounting (MFCA) - better informing strategic decisions and actions towards reducing waste via data metrics and transparency.

• Expert 'user needs' interviews that covered analysis of the existing DIRECT spreadsheet tool, in order to identify areas for optimisation, as well as best practice and trends for FLW quantification.

• Iterative design workshops that created models for user interface.

• Creation of training modules and manuals for use.

• Building, piloting and refining DIRECT online.

• Launch of cloud-based version of DIRECT in 2021.

OUTCOMES

• launch and promotion of Empauer’s DIRECT an industry-ready cloud-based DST, and supporting materials, backed by over a decade of research

• Multiple case studies with primary producers, quick-service restaurant and meat waste mapping research project.

• a suite of academic articles and reports that synopsise the methods and metrics of FLW quantification and benefits of accounting for the 'true cost of waste'.

• a model for co-designing software with industry partners.

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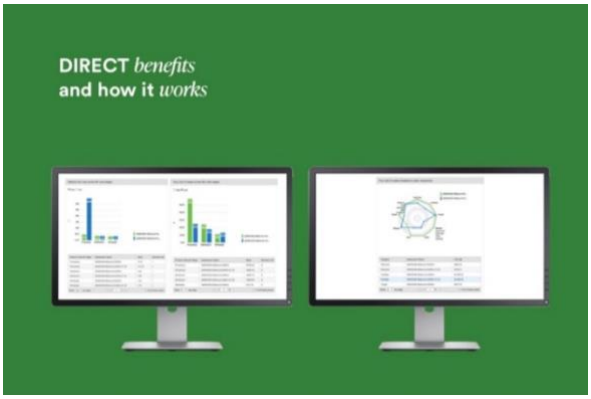

Figure 2. DIRECT launch brochure

IMPACT

Since 2019, ongoing industry co-design of a digital tool DIRECT has delivered, through funding and a PhD scholarship, EFW CRC Project 1.1.1. This led Empauer and their technology partner to integrate DIRECT into their multinational software platform. Translational impact from DIRECT involves measuring food systems and informing FLW reduction, like measures for regenerative, net positive outcomes from farm to retail. In this context, since being launched at the end of 2021 DIRECT has; helped map the Australian meat supply chain for MLA to consider industry innovations (Renouf et al. 2023), been licensed to Food and Fibre Gippsland to help their local businesses understand the true cost of their waste and deploy change; and been proposed to large Australian companies participating in the voluntary Food Pact to reduce FLW nationally (with projects being developed). As such DIRECT has informed practical outcomes for industry and led to commercial returns for Empauer.

Predicted impacts (up to 2033):

Food Waste reduced (t)	**170,809**
Industry profitability ($)	**120,280,779**
Rescued food (t)	**205,233**
Circular economy jobs	**4**
Greenhouse gas emission savings (t CO2-eq)	**809,778**
Industry people trained	**1,800**

NEXT STEPS

Ongoing promotion, utilisation and development of the tool by Empauer (and industry using the tool in their organisations).

Specifically, linking DIRECT to databases able to represent losses in other terms will allow the tool greater relevance to studies with more diverse aims, by linking materials and destinations to inventories, and presenting these other impact measures as figures and ratios in DIRECT's output - such metrics included emissions, nutrition and water use.

The introduction of Ai and Machine Learning for valorisation and supply chain mapping

PROJECT TEAM

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PROJECT WEBPAGE

https://endfoodwaste.com.au/projects/direct-commercialisation/

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APPENDIX B – Supporting Material(s)

14. Qualitative Participant Prep and Plan Documents

14.1 User Needs Interviews: Interview questions

Can you detail what you think the progress is of Food Loss and Waste (FLW) initiatives at the moment?

How do you define Food Loss and Waste? What definition do you follow and why?

What about FLW data collection? How has that progressed? Anything stand out particularly?

What specific industry and/ or governmental Food Loss and Waste data collection methods are you aware of?

What are the positives and or negatives of those/that method/s?

What can be improved?

Are you aware of the challenges that organisations face, with regard to data collection? What are the barriers? What, if anything, is holding them back from doing this more often/implementing more rigorous data collation within their business practices?

What would you like to see out there that hasn't been done? Or/alternatively what method would you like to see promoted and used more widely?

How willing are companies/organisations (including yours/if relevant) to invest resources (time, financial) into waste data collection?

How likely do you think it would be for different operators along the supply chain to cooperate with each other and/or share data? What do you see as being the barriers to this? Is there anything apparent that would make this easier?

What do you know about the FLW standard and protocols that have been developed?

What are some of the specific local and global standards/ protocols govern Food Loss and Waste that you are aware of?

Key features of standard(s)? What works? What doesn't work so well? How extensive has its adoption been?

What about the REFRESH (Resource Efficient Food and Drink for the Entire Supply Chain) reviews of different standard and protocols are you aware of those reviews/reports and do you have feedback on them?

Are there more Food Loss and Waste standards/ protocols on the horizon? If so/what are your impression of them? Do you think more are required or should they refine the existing ones and how?

How is Food Loss and Waste reported?

How is such reporting managed by industry and/ or government?

What reports of note can you think of?

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What reports are doing things well? What not so well? Why is that?

Which countries/sectors are covered well? What's underrepresented?

What specific metrics do you want reported on, in an ideal scenario?

Would you (and/or others in the sectors you work with) be willing to make results/reporting public? Or allow de-identified results to be added to a database to allow comparison in future?

Do you think companies/organisations (including yours/if relevant) would be interested in seeing their results in a comparative context (across regions, industry type etc)? Would this be necessary for a data collection and reporting tool to be relevant to their/your needs?

What kinds of waste drivers/causes would you be interested in identifying via reporting?

What would be useful to include in a tool aimed at assisting Food Loss and Waste data collection, reporting and governance in line with standards/ protocols?

As mentioned at the start, you were sent a copy of the DIRECT article and a presentation deck. Did you manage to look into those in detail?

Is there anything that you have seen in those documents (what was just discussed) that stand out to you?

What looks like it would be useful, from your perspective? What not so useful? Anything you would advise for us to change specifically?

For what purpose would you look at using a tool like DIRECT? Would this focus be reduction of waste from an environmental perspective, as a cost cutting tool, to check progress against international/local targets or to demonstrate compliance with targets? Could you see DIRECT being used for other purposes?

IF NOT FORTHCOMING WITH RECOMMENDATIONS:

What would you like to see in a Food Loss and Waste tool for industry benchmarking and strategy?

What would you like to see in a tool for governments and peak bodies to generate national Food Loss and Waste benchmarks?

How flexible does the tool need to be? Would you need to define the system boundaries in terms of supply chain stages so that they are specific to the subject of the study? Or would a standard supply chain structure, where each step is pre-defined suffice?

Would it be useful to include supply chain stages upstream/downstream from a particular businesses' activity when looking at wastes? Would it be useful to include supply chain stages upstream/downstream?

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