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Waste-tracking tools: A business case for more sustainable and resource efficient food services

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ABSTRACT

Waste-tracking devices are powerful tools to optimise kitchen processes and reduce food waste in food services. The present study investigates how using such tools affect the sustainability of a business in terms of environmental, economic and social benefits.

By tracking leftovers from self-service breakfast buffets, the hotels in our case study were able to reduce leftovers by approx. 1,800 kg/year per kitchen, corresponding to a nutritional value of approx. 3.6 gigacalories/year. The kitchens further achieved net annual environmental impact savings of 6.8 tonnes CO_2 equivalents and 841 PEF mPt per kitchen. In the absence of equipment costs, each kitchen obtained net annual economic savings of 8,317 EUR, meaning they could spend up until about 8,000 EUR/year on waste-tracking equipment and still be profitable. Thus, our business case provides important insights into how food services can become more sustainable and resource efficient through food waste reduction.

1. Introduction

In 2011, food loss and waste were estimated at 1.3 billion tonnes of food waste per year, with about one third of all edible food intended for human consumption being lost or wasted throughout the food chain (FAO, 2011). A more recent study indicates this might actually have been an underestimation as consumer food waste – which includes both waste at household and food service level - was estimated to be almost twice as high in 2019 (UNEP, 2021). To reduce food waste, the United Nations' Sustainable Development Goal 12.3 (SDG 12.3) calls for halving global food waste at retail and consumer level and reducing food losses along production and supply chains, including post-harvest losses (UN, 2015). An EU-wide target has been adopted to meet SDG 12.3 by 2030, and to achieve a midterm goal of 30% food waste reduction by 2025.

Food waste in Europe was estimated to be at 88 million tonnes in 2012, of which about two thirds are generated at consumer level (Stenmarck et al., 2016). Accordingly, Beretta et al. (2017) emphasized it is particularly important to develop policies and strategies that address food waste in households and food services (Beretta et al., 2017).

Based on 2012 data, food services in Europe generate approximately 10.5 million tonnes food waste per year, corresponding to approximately 21 kg per person and year (Stenmarck et al., 2016). According to Silvennoinen et al. (2015), every fifth dish prepared in Finnish food services is wasted. In Germany, this sector is responsible for 14% (or 1.69 million tonnes) of the food waste generated in 2015 (Schmidt et al., 2019b). On a per meal basis, food services waste between roughly 50 and 150 g per meal (Beretta and Hellweg, 2019; Kuntscher et al., 2020; Meier et al., 2021; UAW, 2020).

Most parts of the food waste in food services occur as leftovers from buffets or plates, which is related with resource-intensive preparation processes such as cooling, heating, and cooking (Okumus, 2020; Papargyropoulou et al., 2016). In households, the majority of the food that is wasted consists of unprepared food such as fruits and vegetables (Jepsen et al., 2016; Schmidt et al., 2019a). Therefore, reductions of food waste in the food service sector can lead to relatively higher ecological impact savings than the equivalent in households. Read et al. (2020) in particular, highlight the need for targeting food services when reducing food loss and waste as this sector has the highest potential for reducing food waste related environmental impacts.

To investigate environmental impacts of food waste, the carbon footprint is often used as a key indicator. The impact of one kilogram of food waste ranges between 2.1 or 3.4 kg CO_2 equivalents for different

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subsectors of the German food service sector (Jepsen et al., 2016; Meier et al., 2021; UAW, 2020). In the US, the carbon footprint estimate for food wasted at food service level is even higher, at 4.6 kg CO_2 equivalents per kilogram (ReFED, 2021).

1.1. Benefits and costs of food waste reduction measures

Food waste has been an issue of growing public concern, which resulted in a steadily increasing scientific interest and in a steadily increasing number of food waste reduction measures being proposed. Several studies indicate that the reduction targets formulated by the UN in terms of halving food waste in the food service sector are realistic and can be exceeded in the long term (Beretta and Hellweg, 2019; Clowes et al., 2018b; Clowes et al., 2019; Leverenz et al., 2019; Leverenz et al., 2020a). Based on business data from 42 hotel sites and 114 restaurants in respectively 15 and 12 countries, Clowes et al. (2018b, 2019) found that these companies were able to reduce their food waste by 21% and 26% respectively after only one year. After three years, the restaurants were able to further reduce food waste by 58% on average. Key strategies to reduce food waste were the use of waste-tracking systems and the implementation of measures such as staff training, redesigning buffets, minimizing overproduction, rethink inventory and purchasing practices, and donating surplus food (Clowes et al., 2018b, 2019).

Due to the relatively high diversity in the food service sector, individual reduction strategies and measures are necessary (Eriksson et al., 2017, 2018). These strategies come at a certain cost in terms of both money and time investments. For businesses, it is therefore particularly important that benefits from implementing measures exceed associated costs (WRAP, 2015).

1.2. Waste-tracking as a food waste reduction measure

Measuring food waste is key to encouraging food services to act against food waste (Vizzoto et al., 2020). In fact, it is the second most proposed strategy in literature to reduce food waste in food services (Vizzoto et al., 2021). Measuring food waste can be done in various ways (Eriksson et al., 2019). Firstly, food services could use manual tools (such as paper sheets or spreadsheets) or semi-automatic tools (such as websites or apps). In both cases, observations are to be recorded manually. Secondly, food services could use automatic tools or waste tracking devices. These generally consist of a scale to quantify the food waste, connected to a computer or tablet with a touchscreen. In this way, staff can enter the corresponding food (category) the food waste belongs to. The biggest advantage of (semi-)automatic tools, as compared to the manual tools, is that they allow for automatic compilation and real-time analysis of data. As such, they can provide direct feedback to staff on the amounts of waste being generated on a daily or monthly basis. Moreover, if measurements take place at product(group) level, staff can be informed on which product(group)s are most frequently being wasted.

Eriksson et al. (2019) investigated food waste quantities from 735 hotels, restaurants, and canteens. They found that 61% of the catering units that tracked their food waste were able to reduce the quantities over time. Leverenz et al. (2020a) asked kitchen staff to track breakfast buffet returns in four hotels. After five months, buffet leftovers decreased by 64%. In these studies, waste-tracking increased staff awareness, resulting in behavioural changes and the implementation of other food waste reduction activities by kitchen and service staff. An in-depth assessment of the associated environmental impact savings or cost-effectiveness of these self-reporting interventions is however missing.

For many businesses, it is not clear whether the benefits of using a waste-tracking device will compensate for the associated costs. Moreover, commercial providers of waste-tracking tools are not always transparent about the costs for leasing such tools and prices are not publicly available online. Read and Muth (2021) and ReFED (2021) evaluated the projected environmental impact savings and cost-effectiveness of food waste-tracking in US food services. Both studies hereby base themselves on an expected waste reduction potential of 35–36%. Read and Muth (2021) found that for one dollar spent, the food services could save 2 USD and about 7 to 8 kg CO_2 equivalents. They hereby considered both foreseen investments and recurring costs for waste-tracking, as well as expected savings from no longer having to purchase the food that used to be wasted. Along the same lines, ReFED (2021) calculated that each dollar spent, would allow food services to save 3.5 USD and reduce impacts by 4 kg CO_2 equivalents. The optimisation model from Cristóbal et al. (2018) further prioritises using waste-tracking devices for reducing food waste as it allows for “quick wins”, meaning that large environmental impact savings can be obtained at a low cost. Similar to the study from Read and Muth (2021), these calculations build on the assumptions and data from REFED (2016).

1.3. The research and knowledge gap on the efficiency of food waste reduction measures

Several literature reviews show there is lack of evidence regarding the effectiveness of food waste reduction measures (Goossens et al., 2019; Muth et al., 2019; Reynolds et al., 2019; Stöckli et al., 2018). Furthermore, an assessment of the economic, environmental and social effects associated with food waste measures is often missing (Caldeira et al., 2019; Goossens et al., 2019). This causes a certain complexity for practitioners and decision-makers when distinguishing measures according to their efficiency and prioritizing them for future implementations (Goossens et al., 2019). The FOOD 2030 report from the European Commission confirms this literature gap. Furthermore, it considers the assessment of the effectiveness of food waste prevention interventions, including the environmental impacts and a cost-benefit analysis, as critical for creating new strategies and policy decisions (EC, 2020). In this context, the EU Joint Research Centre (JRC) developed, in collaboration with the EU platform on Food Losses and Food Waste, an assessment framework for evaluating food waste prevention measures to identify best practices amongst existing food waste prevention actions (Caldeira et al., 2019, de Laurentiis et al., 2020).

1.4. Objectives

The main objective of this paper is to present an all-encompassing sustainability assessment of a food waste reduction measure, namely the use of waste-tracking devices in the food service sector. This will be done through a case study on breakfast buffet leftovers. The present study builds on the abovementioned study of Leverenz et al. (2020a) who investigated the food waste reduction potential of using waste-tracking devices. By looking at the sustainability and resource-efficiency of this self-reporting intervention, we will develop an extensive business case. We hereby go beyond *expected* food waste reduction potentials of using such devices and look at proven changes achieved by this intervention. As such, the study will provide additional evidence independent of the expected saving potentials reported by ReFED (2016, 2021).

This paper targets multiple audiences, resulting in a wide range of sub-objectives as visualised in Fig. 1. To start with, the business case developed for this case study will illustrate the monetary saving potentials associated with using waste-tracking devices in a commercial kitchen, allowing food services to have an idea of how much they could spend on waste-tracking devices whilst still being profitable. The business case further assesses environmental and social aspects related to self-reporting. Along the same lines, the paper will give commercial providers of waste-tracking devices scientific evidence of what is feasible and how much a food service business might thus be willing to spend. Next, the paper will contribute to filling existing research and knowledge gaps, relevant to a wide range of stakeholders. The paper further provides policy makers with evidence of a best practice measure

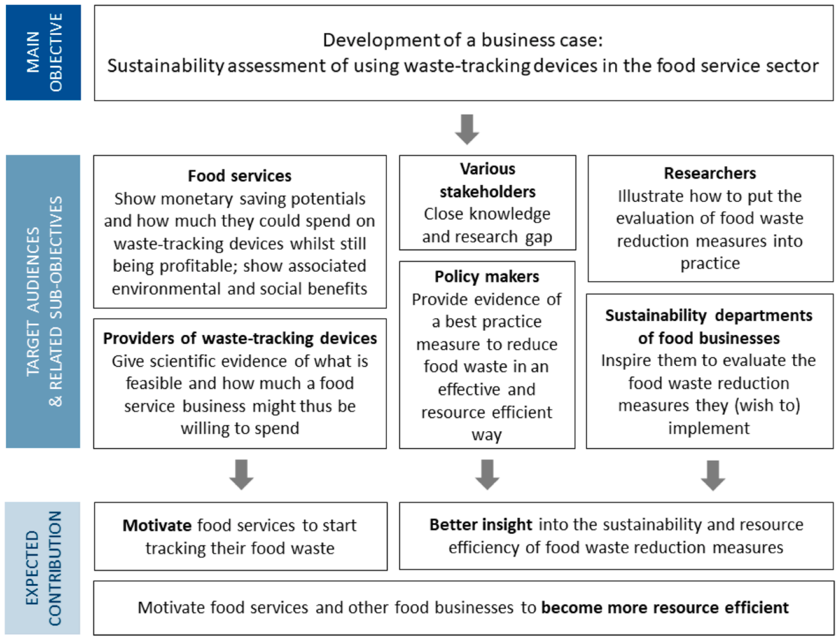

Fig. 1. Visualisation of the (sub-)objectives of this paper, its targeted audiences and its expected contribution to a more resource efficient food system.

to reduce food waste in an effective and resource efficient way. Lastly, this paper addresses the research community as it illustrates how to put the evaluation of food waste reduction measures into practice. Moreover, we hope this paper will also inspire sustainability departments of a wide range of food businesses to evaluate the food waste reduction measures they implement, or wish to implement.

We assume the resulting extensive business case will provide the necessary information to motivate food services to start tracking their food waste and make their business more sustainable and resource efficient. Additionally, we believe our evaluation framework will contribute to providing a better insight into the sustainability and resource efficiency of food waste reduction measures in general, which can help other food businesses to become more resource efficient as well. We therefore expect the paper to contribute to moving towards a more resource efficient food system.

2. Material and methods

This section starts with a description of our case study and the data collection (Section 2.1). Next, the overarching framework for evaluating food waste reduction measures is introduced (Section 2.2) Finally, we provide more details on its underlying methodology and on how this is applied to our case study (Sections 2.3 to 2.5).

2.1. Case study description and data collection

The present study builds on the study of Leverenz et al. (2020a). Leverenz et al. (2020a) monitored breakfast buffet leftovers in four hotels in Germany from the hotel group Maritim Hotelgesellschaft mbH. This Hotel Group was one of the practice partners within the German research project "ELoFoS" ("**E**fficient **Lo**wering **o**f **F**ood Waste in the **O**ut-of-Home **S**ector"). In total, the hotel group has 32 hotels in Germany, of which four hotels were randomly selected to conduct the measurements. The guest clientele consists of both business customers and tourists.

The data used for this paper is the same as the data used by Leverenz et al. (2020a). The data collection lasted for 12 months. The measurements took place in the course of 2014–2016, depending on the hotel in question. The average number of guests at the breakfast buffet in each hotel varied between 277 and 356 per day. An automatic waste-tracking device was used to get insight in the amounts of leftovers returning from breakfast buffets. The gathered data thus excludes waste resulting from other stages of the food service process such as storage losses, preparation losses and plate leftovers.

At the end of the breakfast buffet service, service staff returned the buffet leftovers to the hotel kitchen. Next, they weighted the leftovers using an automatic waste-tracking device ("ResourceManager-Food"), consisting of a digital scale and a computer or tablet. At the start of the measurement period, kitchen staff was instructed on how to use the device. The tracking system is equipped with a touch screen, allowing users to select the product (organised within product groups). The device provides direct feedback to its users on the daily amounts that are measured, and shows how this evolves over time.

During the 12 months of monitoring, the kitchens performed on average 2774 measurements. For all four hotels, the daily number of measurements was at its highest at the beginning of the measurement period. After five months, it was more than halved. More details on the monitoring approach and on which kind of data was collected, can be found in Appendix A (Section 1.1) and in Leverenz et al. (2020a).

As a result of the tracking, staff became more aware of the magnitude of the buffet returns and started to implement strategies to reduce the buffet leftovers. These strategies refer mainly to simple operational changes during breakfast serving time such as the use of smaller serving dishes, which led to a higher flexibility for the just-in-time production towards the end of service. The improvements also affected the menu planning, meaning that recipes and production quantities were more closely aligned with actual demand and less focused on presumed guest expectations, such as an abundant food selection over the entire buffet period. After about five months into the waste-tracking exercise, the buffet leftovers stabilised at an almost constantly low level. The achieved reductions are hereby related to the individually developed reduction measures of each of the four kitchens. On average, the kitchens achieved reductions of more than 50% (Leverenz et al., 2020a).

2.2. Evaluation of food waste reduction measures: evaluation framework

To evaluate our food waste reduction measure, we based ourselves on the framework of the EU JRC (Caldeira et al., 2019, de Laurentiis et al., 2020). This framework contains both qualitative and quantitative criteria. For the purpose of this paper, we regrouped certain elements and complemented the framework with elements from relevant literature sources (Eriksson et al., 2019; Goossens et al., 2019; ReFED, 2018; Sanchez et al., 2020).

Our resulting framework for evaluating food waste reduction measures consists of in total seven components: description of the measure; food waste reduction potential; descriptive evaluation; quantitative sustainability assessment; qualitative sustainability assessment; viability; and quality of the data provided. The present article focusses on the following three main components: quantitative sustainability assessment, qualitative sustainability assessment and viability of our measure.

The next sections describe these three main components in detail, and how they are applied to our case study. A summarising overview can be found in Table 1. The assessment results in a business case, capturing both quantifiable and non-quantifiable characteristics of our food waste reduction measure. Interested readers can find a description of all seven components of the evaluation framework in Appendix A (Section 1.2).

2.3. Quantitative sustainability assessment

The quantitative sustainability assessment follows a four-step approach (Fig. 2). First, the effectiveness or actual amounts of food waste prevented by the measure is calculated. Secondly, the resource efficiency of the measure across all three sustainability dimensions (economic, environmental and social) is assessed, as also outlined in Goossens et al. (2019). In fact, this resembles a classical cost-benefit-analysis whereby resource inputs across all three sustainability dimensions are balanced against resource outputs. For the environmental and economic dimension, we consider avoided product impacts or costs related to the food that is no longer wasted complemented with avoided impacts and costs associated with the waste disposal stage that no longer takes place. Additionally, for all three dimensions, all used resources and resulting benefits inherent to implementation of the measure itself are considered. Then, to calculate overall net benefits and savings, all outputs are balanced against the inputs. Thirdly, thereby complementing the EU framework, the buffet leftover savings are translated into nutritional savings. In a fourth step, benefit-to-cost ratios are calculated, representing the efficiency KPIs (Key Performance Indicators).

The next sections describe how each step is applied to our case study; for full details and formulae applied, please refer to Appendix A (Section 1.3).

Table 1
Criteria included in the evaluation framework of the measure, and how these were applied to the present case study.

Component	Criterion	Case study on using waste-tracking devices
Quantitative sustainability assessment	Effectiveness: Food waste savings (mass)	Buffet leftover mass (kg)
	Resource efficiency: Net environmental impacts	Carbon footprint (kg CO_2 equivalents) Product Environmental Footprint (PEF)
	Resource efficiency: Net economic costs/savings	Cost and savings (EUR)
	Resoucre efficiency: Net social effects	Jobs created/lost, donations made
	Nutritional savings (kcal)	Nutritional value of leftover savings (kcal)
	Efficiency KPIs (Key Performance Indicators)	Benefit-to-cost ratios
Qualitative sustainability assessment	Outreach and behavioural change	Kitchen staff and management
	Effect on working environment	Motivation, team spirit
	Implementation effort and willingness to implement the measure	Efforts, workload, willingness
	Image of the business	Image, website, marketing
Viability - Taking the measure into the future	Long-term character, continuity and durability over time	Long-term waste-tracking; costs of system
	Key success factors and barriers	Kitchen staff and management

2.3.1. *Step 1 - Effectiveness: breakfast buffet leftover reductions*

The daily average amount of leftovers during the first month (M1) is set as a reference. As the buffet leftovers stabilised after about five months, the daily average amount of leftovers during months 5–12 (M5–12) is compared with the reference value in M1. Assuming the leftover amounts achieved after 5 months will be maintained in the future, annual leftover savings were calculated.

2.3.2. *Step 2 - Resource efficiency*

Following the buffet leftover reductions achieved, the product and disposal related savings are calculated (Sections 2.3.2.1 and 2.3.2.2). Next, the implementation related inputs and outputs associated with the measure itself are considered (Section 2.3.2.3). Table 2 summarises the various impact and cost elements taken up in the environmental and economic analysis. Finally, net resource benefits can be calculated (Section 2.3.2.4) and a scenario analysis was performed to model the influence of equipment costs (Section 2.3.2.5).

2.3.2.1. Avoided product impacts and product costs. To calculate the product-impacts and the embedded environmental impacts associated with the daily amounts of buffet leftovers, a Life Cycle Assessment (LCA) approach was applied. The LCA in our case study considers the impacts associated with the production, processing, distribution, storage and preparation of the different food products served at the breakfast buffet. Furthermore, upstream losses throughout the chain and mass changes linked to cooking were considered as well. For this purpose, the environmental impacts available from the French Agribalyse 3.0 database (ADEME-INRAE, 2020a; Asselin-Balençon et al., 2020) were used whereby the functional unit was set at 1 kg of food available at the buffet. The resulting daily and monthly product-impacts are then calculated by multiplying the per kg impacts of each product with the associated amounts of leftovers for each product. To provide tangible results for businesses, we focused on the climate change impact or carbon footprint of each product (expressed as kg CO_2 equivalents). Furthermore, the “PEF” (Product Environmental Footprint) was used as an aggregated indicator. The PEF indicator is based on the impacts across 13 environmental midpoint indicators such as climate change, acidification and water use (ADEME-INRAE, 2020b; European Commission, 2013; European Commission, 2016). The PEF value is obtained after normalising and weighting the various midpoint impacts, using predefined normalisation and weighting factors, as explained in Appendix A (Section 1.3). The resulting aggregated indicator value is expressed in millipoints (mPt). A high PEF score indicates a high environmental load. Its standardised methodology allows for comparing products amongst each other and for informing consumers on the environmental performance of products, whilst ensuring great credibility.

For the monetary assessment, the food purchasing prices take up the majority of the product costs. Additional costs arise in the kitchen for storing and preparing food. As such, electricity costs resulting from the use of a fridge or freezer, and from baking food in the oven or in a pan, are considered. When it comes to labour costs for preparing food, only time spent baking food in a pan (if applicable) was considered, using a default value of 20 EUR/h as suggested by the pilot kitchens. As no detailed data could be gathered for time spent chopping food, ensuring a good mis-en-place, setting the buffet and cleaning up after service-end, these cost elements could not be determined.

The avoided product impacts and costs are calculated by comparing

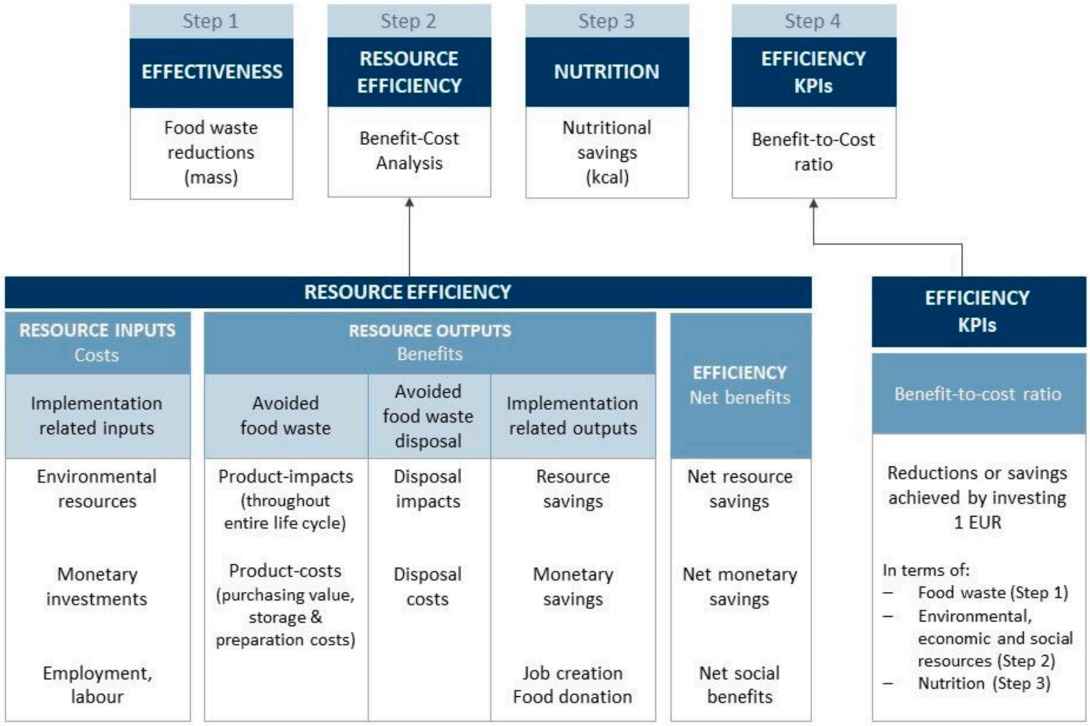

Fig. 2. Quantitative sustainability evaluation of food waste reduction measures: a four-step approach.

the product impacts and costs of leftovers in the first month, with those after five months. From there, annual product impact and cost savings were estimated/extrapolated. Based on the total buffet leftovers cumulatively returned to the kitchen in each hotel, and the total associated product-impacts and product-costs, the average per kilogram impacts and costs of buffet leftovers were calculated. These values are thus weighted based on the mass contribution each product had to the total amounts of leftovers.

2.3.2.2. Avoided disposal impacts and disposal costs. The kitchen disposes its buffet leftovers in a dedicated organic waste bin, which is afterwards collected by a specialised waste treatment company to be treated by anaerobic digestion. The impacts associated with disposing 1 kg of food waste are taken from the values listed in the supplementary file of de Laurentiis et al., 2020. Based on personal communications with the kitchens, specific food waste disposal costs are set at 0.05 euro per kg Maritim, 2020. For the purpose of this paper, all buffet leftovers are assumed to be thrown; some reflections on this and on the possibilities for reusing leftovers are given in the discussion section.

The avoided disposal impacts and costs are calculated by comparing the disposal impacts and costs of the leftovers in the first month, with those after five months. From there, annual disposal impact and cost savings were calculated.

2.3.2.3. Implementation inputs and outputs. Resource inputs and outputs associated with implementing the measure are assessed for each sustainability dimension, and are rescaled on a per year basis.

The environmental resource inputs relate to impacts associated with the production and maintenance of the digital scale and of the computer or tablet, complemented with impacts resulting from daily use of this waste-tracking device. Unfortunately, no reliable data was found to determine impacts associated with the digital scale. However, its impacts are expected to be lower than those of the computer/tablet and can therefore be considered negligible (see Appendix A, Table A.4). The implementation of our measure was not associated with any environmental resource outputs or savings.

For the economic dimension, there are both fixed and daily costs and/or savings to consider. Firstly, there is the cost of using the waste-tracking device. As the equipment was provided to the hotel at no cost as part of an ongoing research project, the costs equal zero. Outside of this research project, food service businesses would need to lease or buy the equipment from a commercial provider. How much this would cost, is not clear as providers tend to not publish their prices and rather ask food services to request a custom pricing estimate based on location, business size and food turnover. It was therefore decided to not consider this cost element here and see, based on the final outcome of the calculations, which cost would be acceptable (and profitable) for a food service business. Furthermore, a scenario analysis is performed to model the influence of the cost for using waste-tracking devices (see further). A cost element that is assumed to be similar for the various waste-tracking devices, independent of the waste-tracking provider, and that thus could be considered, is the daily electricity cost for using the device. In addition, there are labour costs associated with the time spent weighting buffet leftovers as part of the self-reporting exercise. Other costs borne by the hotel as a consequence of the intervention, are labour costs associated with interpretation of the direct feedback received on the screen of the device, and with subsequent identification and implementation of strategies to reduce leftovers (as a result of the increased awareness raising, as explained in Leverenz et al. (2020a)). Finally, costs for training staff to use the equipment and interpret measurement data need to be considered. In our case study, the kitchen manager was shortly instructed on how to use the device, after which he/she instructed other kitchen staff. At the time of the monitoring, no data was gathered on the time spent for learning how to operate the device, for data interpretation or for identifying and implementing strategies to reduce leftovers. Nor was any information collected on whether or not the implementation of these new strategies implied additional costs for the kitchen. As such, no implementation costs could be assigned to these cost elements. When it comes to implementation related outputs, there were no economic savings.

For the social resource inputs, the number of volunteers deployed to implement the measure was considered, whereas social outputs referred to the number of meals donated or the number of jobs created (or lost).

Table 2
Overview of the impact and cost elements included in the environmental and economic analysis (for full details: see Tables A4-A5).

Elements	Environmental dimension	Economic dimension
Resource inputs		
Implementation inputs	Production and usage of digital scale* Production and usage of computer/tablet Inputs related to the waste reduction strategies developed by staff *	Procurement of digital scale and computer/tablet ** Electricity use: digital scale and computer/tablet Training of staff, associated labour costs *** Labour costs: time spent monitoring Labour costs: time spent interpreting data; identifying and implementing leftover reducing strategies * Inputs related to the waste reduction strategies developed by staff *
Resource outputs		
Avoided product impacts/costs	Life-cycle impact of purchased food products (agricultural production, processing, storage, packaging, transport, distribution) Electricity use in the food service kitchen: Refrigeration + preparation (baking in pan/oven) Upstream losses and mass changes linked to cooking	Purchase of food (net purchasing price) by food service Electricity use in the food service kitchen: Refrigeration + preparation (baking in pan/oven) Labour costs for preparation: baking in pan Labour costs for preparation: chopping of food, mis-en-place, setting up buffet, cleaning up the buffet after service *
Avoided disposal impacts/costs	Disposal of food waste	Disposal of food waste
Implementation outputs	No effects	No effects

* Could not be quantified.
** Not included in the initial calculations; will be considered in the scenario analysis.
*** Not applicable in present case study; set to zero.

Any qualitative social effects of the measure were investigated in the qualitative sustainability assessment.

2.3.2.4. Efficiency: net benefits and savings. The overall net benefits and savings for each sustainability dimension were calculated by balancing all resource outputs against the resource inputs. For each sustainability dimension, positive net values refer to overall benefits or savings, whereas negative values refer to additional impacts or costs. For the economic dimension, the net benefits are usually referred to as the "net present value (NPV)".

2.3.2.5. Scenario analysis. Following the objectives of the paper, the cost for using a waste-tracking device is not included in the initial calculations. To illustrate how much a food service business could spend on a waste-tracking device, whilst still being profitable (and thus have a positive NPV), a scenario analysis was performed to model the influence of equipment costs on net economic savings. The investigated costs for leasing such a device hereby range between 1000 and 12,000 EUR per year per kitchen.

2.3.3. Step 3: Nutritional savings

To analyse the nutritional composition of the buffet leftovers, the ANSES-CIQUAL French food composition table is used (ANSES-CIQUAL, 2020). As nutritional indicator, the energy content of each food item, expressed as kilocalories (kcal) per 100 g edible part of the food was considered. The nutritional savings are calculated by comparing the energy density of the leftovers collected in the first month, with those after five months. From there, annual nutritional savings were calculated.

2.3.4. Step 4: Efficiency KPIs or benefit-to-cost ratio of the self-reporting measure

The benefit-to-cost ratio (BCR) of a measure expresses which savings can be achieved by investing 1 EUR. This is applied for all indicators under study, namely buffet leftover savings, net ecological savings, economic savings, net social savings, and nutritional savings. The resulting BCRs are then expressed as kg leftovers, kg CO_2 eq., mPt PEF, EUR and kilocalories saved per EUR invested.

Similar to the approach taken for calculating the net economic savings, a scenario analysis is performed to model the influence of equipment costs on the BCRs for each indicator under study.

2.4. Qualitative sustainability assessment

The qualitative sustainability assessment considers the number of people reached by the measure and the behavioural change brought about by the action. This includes effects both within the business where the measure is implemented as well as the consumers or end-users. Hereby complementing the EU JRC framework, our assessment also indicates how the measure has affected the working environment within the business. We also assess the feasibility of implementing the measure by looking at implementation effort (extent of procedural updates, staff training and systems needed (ReFed, 2018)) and the willingness to implement the measure. Furthermore, we document and list possible effects of the measure on the image of the business.

2.5. Viability of our measure: taking the measure into the future

To assess the viability of our measure, we assess its durability over time, which means looking at what is needed for the measure and/or its beneficial effects to remain. Furthermore, we list the key success factors and barriers for implementing the measure.

3. Results

This paper focusses on the three main components of the evaluation framework. Results are given as an average value across the four hotels. Hotel-specific results are given in Appendix A (Section 2). A complete overview of the assessment, following all seven components of the evaluation framework as explained in Section 2.2, is given in the Factsheet in Appendix B.

3.1. Quantitative sustainability assessment

3.1.1. Achieved leftover reductions, nutritional savings, and avoided impacts and costs

Leverenz et al. (2020a) analysed the buffet leftover reductions achieved throughout the measuring period: after five months, the buffet leftovers were 64% lower as compared to the first month of the measuring period (Fig. A1; Table A6). We translated these mass reductions into nutritional savings, and found that 61% less kilocalories returned from the buffet. At the same time, daily costs associated with the buffet leftovers decreased by 61%. From an environmental viewpoint, the reductions in buffet leftovers resulted in PEF impact savings of 56% and carbon footprint savings of 55%.

In absolute values, the hotels have reduced their leftovers by 4.8 kg per day and per hotel. This coincides with nutritional savings of almost 10,000 kcal per day per hotel. The costs hereby decreased from 41 EUR/d during the first measuring month to 16 EUR/d after five months. The avoided product and disposal costs thus mount to 24 EUR/d per hotel. The buffet leftover reductions can further be translated into average avoided product and disposal impacts of 2 PEF mPt and 19 kg CO_2

equivalents per day.

Based on the total leftovers returning to the hotel kitchens, the average product cost is 5.95 EUR/kg, whereas the product impacts are at 0.67 PEF mPt and 5.39 kg CO_2 equivalents per kg leftovers (Table A7). Disposing the leftovers as food waste costs the hotel kitchens 0.05 EUR per kilogram. The carbon footprint for disposing 1 kg leftovers lies at 0.46 kg CO_2 eq., whereas the PEF impact is $1.3 * 10^{-9}$ mPt.

Assuming that the daily reductions achieved during M5–12 will be maintained in the future, this translates into a reduction of 1.8 tonnes of leftovers per year per hotel, with an energy density of about 3.6 Gigacalories (Fig. 3; Fig. A3). This further translates into avoided product and disposal impacts of in total over 6.8 tonnes CO_2 eq per year and 841 PEF mPt per year (Fig. 3). About 12% of the climate change savings are related with the avoided disposal, whereas 88% of the savings comes from no longer having to produce, prepare and store the food (avoided product impacts). When it comes to the PEF impact savings, almost all savings are attributable to avoided product impacts (99.99%). Furthermore, the avoided product and disposal costs together result in savings of about 8,900 EUR per year per hotel (Fig. 3). The majority of these savings (99%) stems from avoided product costs.

3.1.2. Implementation-related inputs and outputs

Resource inputs or costs - The environmental impacts associated with resource inputs for producing and using the waste-tracking device mount to 17.9 kg CO_2 eq. and 3.93 * 10–5 PEF mPt per year per hotel (Fig. 3; Table A8). Only small differences are observed between the hotels, following small differences in total days of measurements within the monitoring period. Financially, the implementation of a waste-tracking device – while excluding the leasing costs for using the device - costed the kitchens 778 EUR per year. This cost mainly resulted from having to weigh the buffet leftover returns, in terms of its associated labour costs. The hotels spent 2.13 EUR per day per hotel on measuring buffet leftovers. Regarding the social dimension, no volunteers were deployed, thus the quantitative social resource inputs equal zero.

Resource outputs or benefits - As the implementation of the self-reporting measure was not associated with any environmental or economic resource outputs or savings, the implementation outputs equal zero. This was also the case for the social resource outputs, as no meals were donated and there were no effects on jobs within the food service business.

3.1.3. Net benefits and savings of the waste-tracking measure

From the environmental perspective, the net impact savings mount to over 6.8 tonnes of CO_2 eq. and 840 PEF mPt per year per hotel (Fig. 3; Table A9, Figure A3). The self-reporting further led to net cost savings of over 8,100 EUR per year per hotel. The greatest contributors to these net savings are the avoided product impacts and costs. On a social level, there are no quantifiable net benefits (since the benefits or costs equalled zero).

3.1.4. Benefit-to-cost ratio (BCR) as a KPI

After one year, the hotels achieved a mass BCR of 2.3 and a nutrition BCR of 4600 which means that the input of 1 EUR resulted in an average reduction of 2.3 kg leftovers and 4600 kilocalories (Fig. 3; Fig. A4). From an environmental perspective, 1 EUR spent, allowed average net savings of 8.8 kg CO_2 eq and 1.1 PEF mPt. The economic BCR lies at 11.5 which means that 1 EUR inputs allows each hotel to save over 11 EUR, which is a return of over 10 EUR.

3.1.5. Scenario analysis to model the influence of equipment costs

In the absence of equipment costs, the kitchens achieved net savings of on average 8,317 EUR/yr. Fig. 4 visualises how the economic benefit-to-cost ratio (BCR) after one year of implementing the waste-tracking device is influenced by the equipment costs. The economic BCR would be at 5 at an annual cost of 1,000 EUR, showing an exponentially decreasing trend for increasing equipment costs. The break-even point, where the economic BCR equals 1, is reached for equipment costs of

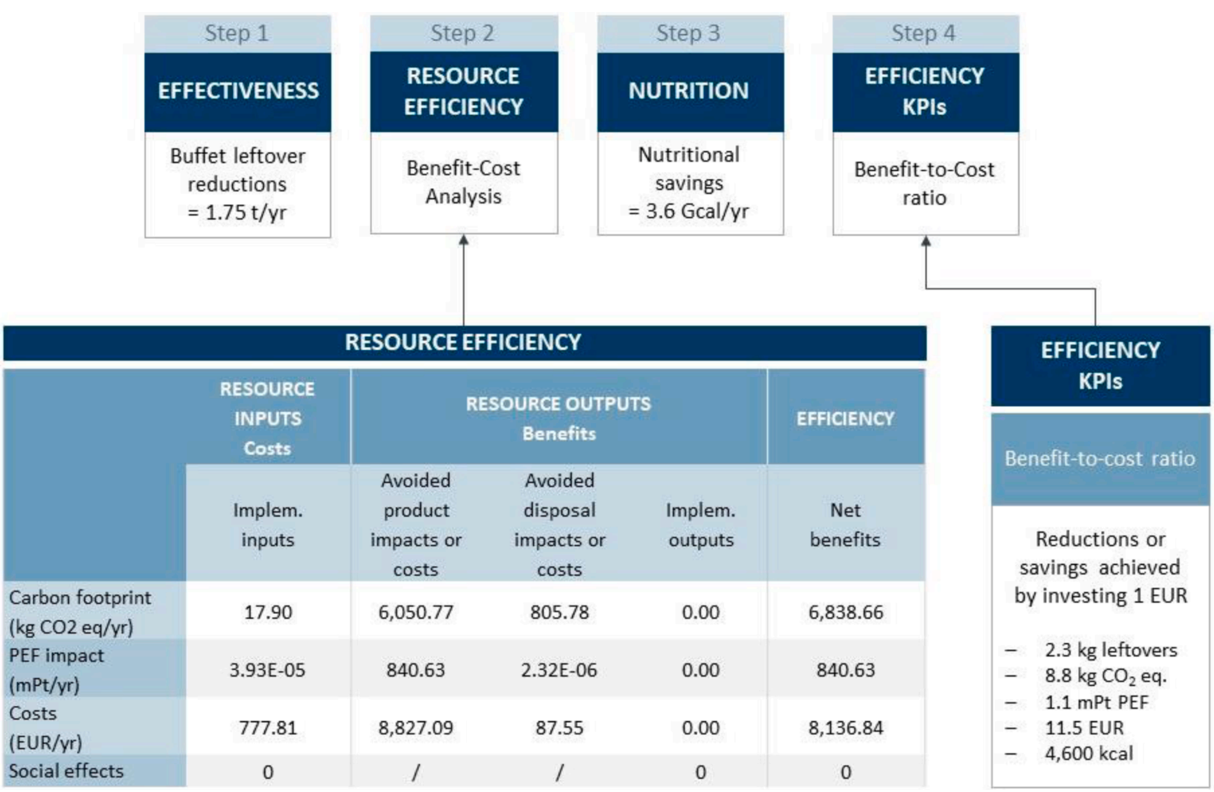

Fig. 3. Quantitative sustainability assessment of the self-reporting exercise. The savings achieved refer to savings at breakfast buffets, as an average across four hotel kitchens in the absence of equipment costs (For details on each hotel: see supplementary Table A9).

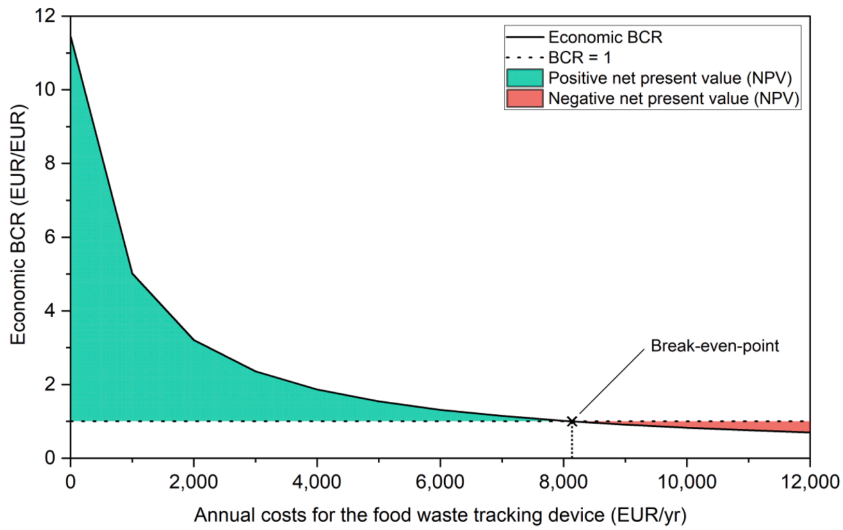

Fig. 4. Scenario analysis to model the influence of the annual cost for using a waste-tracking device: Economic benefit-to-cost ratio (BCR) associated with a device cost ranging between 0 and 12,000 EUR per year, per kitchen. Calculations are based on the saving potential of using the device over the course of one year for monitoring breakfast buffet leftovers.

8,137 EUR/yr. Consequently, businesses could invest up to about 8,000 EUR/year for equipment to monitor breakfast buffet leftovers in order to stay within the range of a positive NPV.

The other BCRs show a similar trend of exponentially decreasing BCR values for increasing equipment costs (Figure A5). At an annual equipment cost of for example 4,500 EUR, one EUR spent would allow each kitchen to save 0.33 kg leftovers, 1.30 kg CO_2 eq, 0.16 mPt PEF, 1.69 EUR and 680 kcal.

3.2. Qualitative aspects

Outreach and behavioural change. The self-reporting measure reached all personnel involved in the breakfast buffet, from those active in the kitchen to those involved in setting the breakfast buffet. The measure helped to raise awareness amongst kitchen and food service personnel. Furthermore, it helped to identify optimisation potentials and encouraged staff to realise improvements. Consequently, the kitchen staff developed its own strategies for reducing leftovers such as using smaller serving dishes, especially towards the end of service. This however did not affect the range of products available, as the buffet was still being refilled until service-end. As such, consumers or hotel guests were not negatively affected by the measure.

Working environment, implementation effort and willingness to implement the measure. Weighing buffet returns requires the introduction of an additional process into the daily workflow, which may be perceived as an additional workload by kitchen staff. When food waste-tracking was introduced, several staff members expressed concerns regarding the work overload it might cause. However, within short time, they integrated the measurements into the daily kitchen routine. The associated effort did not lead to an additional workload, since other work processes could be improved, such as replenishing the buffet with smaller quantities. Hence, staff members experienced a raised awareness and consequently recognized the added value of measuring food waste. This led to a higher acceptance of the food waste tracking. The behavioural changes reported above show that staff felt empowered to make changes, which formed the basis for a more motivating working environment, for a common goal to work towards, and for an increased team spirit. Moreover, it was reported that the time spent for weighing the buffet leftovers was compensated by the fact that – after a few months of monitoring - they had less leftovers to return to the kitchen, thus reducing the time spent cleaning the buffet.

Image. The food service business used various marketing channels to highlight their achievements. The use of the waste-tracking device was thus perceived as a contribution to a more positive and green business image.

3.3. Viability: taking the measure into the future

Long-term character, continuity and durability over time. The use of the waste-tracking device has led to a decrease in buffet leftovers. After about five months, the buffet leftovers stabilized at an almost constantly low level. Continued use of the scale will thus most probably not lead to major further reductions, but the initial reductions as compared to the first measurement month are expected to remain. If the use of the scale would however be discontinued in the future, personnel are no longer reminded on a daily basis of the magnitude of the buffet leftovers. Preventing food waste and leftovers may then no longer be part of the kitchen culture. As also stressed by one of the kitchen chefs, this could lead to staff reverting back to old habits, possibly leading to increased buffet returns.

In the present case study, the waste-tracking device was provided at no cost. Costs for continued use of the scale outside of the research project will highly affect the willingness to further use the scale, and will thus affect the potential for taking the measure into the future. On the other hand, new developments around the monitoring software (in preparation) could make it possible to connect this software with a readily available digital scale in the kitchen, thus lowering overall investment costs. Another advancement of the software is a free smartphone app, which is already available for Android devices (Google Play Store, 2021) without the need to purchase additional hardware or software licenses (and support).

Key success factors and barriers. A key success factor is the participation and motivation of the kitchen manager and staff to track their leftovers and reduce it. One of the main barriers for implementation might be initial concerns of kitchen staff towards the measurements. After realising the potential for reducing buffet returns, staff felt more engaged to do better and their willingness to measure increased considerably. Additionally, they realised they returned fewer full plates and containers from the buffet, which saved them effort and time in cleaning the buffet at the end of service. More training of staff at the start of the monitoring could clarify these benefits to staff and thus remove this barrier. Additionally, management may need to think about creating incentives for staff in order to compensate for the additional time spent at measuring buffet returns on top of the already existing time pressure within the food service sector.

4. Discussion

4.1. The applied sustainability assessment framework

The quantitative sustainability assessment framework applied in this study to develop a business case is largely based on that of the JRC. The online performance calculator provided by the JRC in that context uses a set of 32 commodities from literature to model product impacts de Laurentiis et al., 2020. Our dataset, however, has a higher depth of detail and contains 133 different products for which the product impact was modelled using 96 Agribalyse data records, coinciding with the level of preparation of each food product. It has to be noted, however, that all records within this database are representative for France. As such, all underlying electricity use is based on the French electricity mix, with a high percentage of nuclear power, which differs from the German or European mix. Along the same lines, other assumptions taken in the database, such as production processes, may not be 100% representative for the products available on the German market (Asselin-Balençon et al., 2020). Nevertheless, the database was found to be a very practicable tool to obtain detailed and credible product impacts for a wider range of products (and levels of preparation) than the 32 commodities used by JRC.

For the product prices, the JRC calculator uses market prices, e.g. from statistical datasets de Laurentiis et al., 2020. In our study, business specific data on purchasing prices was gathered and complemented with costs for electricity use and labour costs for preparing warm foods. The disposal costs included in the JRC calculator are based on literature data (Laurentiis et al., 2020), whereas we obtained the costs directly from the hotel kitchens. When it comes to disposal impacts on the other hand, JRC data was used.

For the implementation related costs and benefits, we considered and prioritized the business perspective. This means that only the costs and benefits (across all three sustainability dimensions) for the business implementing the intervention are considered, which allows us to highlight the pros and cons for food services for using waste-tracking devices to reduce food waste. This approach was also used by the Champions 12.3 Group (Clowes et al., 2018a; Clowes et al., 2018b; Clowes et al., 2019; Hanson and Mitchell, 2017). The economic implementation resources could, however, also be assessed using a societal approach, whereby the costs and benefits for all stakeholders along the food chain would be considered, as is done by for example Bergström et al. (2020) and ReFED (2021). In that case, the implementation resources would need to also consider costs and benefits from those providing the necessary tools for the measure, such as the soft- and hardware developers behind the waste-tracking device. Along the same lines, the environmental assessment could be extended to also include impacts for transportation of researchers (or waste-tracking providers) when implementing or demonstrating the use of the waste-tracking device on site. Additionally, on a social level, there may have been jobs created for software development and research, whereas lower food waste levels may in the long term affect jobs in the food waste management sector. In the supplementing factsheets of the JRC report from Caldeira et al. (2019), one intervention refers to the use of waste-tracking devices in food services ("intervention S4"). However, no implementation costs or social effects are reported by JRC, so it is not clear if the costs and benefits for other stakeholders besides the food service industry are included in the assessment.

4.2. Closing the research gap

The present case study looks into the costs and impacts associated with self-reporting of buffet leftovers based on the results of Leverenz et al. (2020a), who provided evidence about the positive effects of food waste-tracking. Consequently, food waste-tracking is considered as a food waste reduction measure itself. Following the self-reporting intervention, greater awareness was achieved in the kitchen and staff started implementing strategies to reduce food waste. As such, the present assessment is actually an assessment of the effects of a wider range of food waste reduction measures. In fact, as also stated by Goossens et al. (2019) and Stöckli et al. (2018), it is often hard to single out the effects from one specific measure. Our study, however, is one of the few providing a thorough sustainability assessment and business case of a food waste reduction measure. The use of a waste-tracking device to measure buffet leftovers has proven to successfully reduce buffet leftovers, whilst at the same time resulted in substantial environmental and economic savings. These findings could motivate food services to act and take part in such a long-term intervention.

The findings of our study are in line with technical reports from Hanson and Mitchell (2017), who analysed the return on investment in food waste reduction measures for a wide range of companies. For food services in particular, Clowes et al. (2018b, 2019) looked into the business case for reducing food loss and waste in hotels and restaurants. In both cases, the average benefit-to-cost ratio (BCR) for food waste reduction was nearly 7:1 over a three-year time frame. This means that, for every dollar or euro invested in food waste reduction, a net benefit of 6 dollars or euros is realised. Furthermore, for more than 70% of the businesses, investments were recouped within the first year of implementing the food waste reduction measures.

4.3. Possibilities for reusing buffet leftovers

In general, hygiene guidelines recommend not reusing unwrapped food and perishable food products that have been put out in display (Ferco, 2009; Fink et al., 2016; Lebensmittel-info, 2016). In practice however, a part of the buffet returns may be served to staff whereas another part may be reused for a later meal (Hofer, 2019). As such, not all leftovers necessarily end up as food waste. Nevertheless, Hofer (2019) found that about 50% of what is served to staff, eventually does end up in the bin. Furthermore, even when leftovers can be reused, overproduction in the kitchen and overserving of the buffet can be seen as an inefficient use of resources within a food service business. For the four kitchens in which the self-reporting exercise was implemented, it was not clear to what extent the measurements also included leftovers that were later on given to staff or that were reused. Some products that are typically being reused and are present on each breakfast buffet, such as marmalade or bananas, are underrepresented or missing in the data records. Other products that we know are often given to staff, such as croissants, are included in the reporting. Following the many uncertainties surrounding this issue and the differences in handling leftovers between the various kitchens, the effect of repurposing buffet leftovers or giving them to staff could not be analysed. It should further be noted that it was out of scope of this paper to investigate if such practices comply with the health and food safety regulations in place. The present study therefore focusses on how self-reporting affects the amounts of leftovers returning from the buffet, while assuming all leftovers to be treated as food waste.

4.4. Assessment of the self-reporting intervention and limitations to the study

As indicated in Leverenz et al. (2020), the self-reporting effect may incorporate other influences that we did not control such as the social desirability aspect or bias. At the start of the self-reporting intervention, the kitchen manager was shortly instructed on how to use the equipment. Afterwards, it was up to the kitchen managers to instruct staff on how to measure buffet leftovers. The time spent on learning how to use the waste-tracking device is assumed to be incorporated in the 47 s per measurement. According to Clowes et al. (2019), lack of motivation and fear of judgement can negatively affect the accuracy and consistency of waste-tracking. In our case study, qualitative interviews with the kitchen managers showed that staff was highly motivated to take part in the waste tracking. This was particularly the case after a few days, once the waste-tracking became part of the daily routine. Additional staff training to inform staff on the whys and hows of reducing food waste could further boost and speed up the food waste reduction process. In future studies, it would be interesting to analyse if additional staff training could reduce the time needed to achieve significant food waste reductions within the self-reporting effect.

Data collection took place in four hotels between 2014 and 2016. At that time, the occupancy rate of the hotels was relatively high as compared to how it has been the last two years following the COVID-19 pandemic. Moreover, for a considerable period, hotels were closed and/or buffets were not taking place. Instead, breakfast was served in the room or at the table. At the moment of writing however, hotels have reopened, breakfast buffets have been reinstated and the hospitality sector is going back to normality. We therefore believe the findings of the paper are still valid in this (post-)pandemic world.

The current self-reporting intervention involves using a waste-tracking device “ResourceManager Food” (RMF) which consists of a digital scale connected to a computer/tablet and which was provided to the kitchens as part of a research project. The license cost for the RMF software used in the present exercise is not set yet. The RMF is currently under development and will in the future be offered as a software application, to be installed on a computer, tablet, or smartphone of choice which is connected, through Bluetooth, with a digital scale of choice. In fact, it has been made available as a free Android smartphone app (Google Play Store, 2021). As such, in the future, kitchens may be able to use their own equipment, readily available in the kitchen which would positively affect the equipment costs. Read and Muth (2021) assumed annual fees of 4482 USD per kitchen for using waste-tracking devices, including licensing fees, support and equipment. Considering annual fees of 4,500 EUR, the net economic savings achieved in our case study would still be over 3,500 EUR/yr. Moreover, if the device would also be used for lunch and dinner, additional economic savings could be achieved. Hence, the resulting overall net economic savings would likely be higher and the profitability of using the device would increase.

The waste-tracking device that is used for the purpose of this study belongs to the category of “automatic systems” for quantifying food waste (Eriksson et al., 2019). This means that the users receive direct feedback on the amounts of waste that is measured on a daily or monthly basis. Human intervention is needed to put the food on the scale, and select which food category the food belongs to. The last few years have led to new developments in the field of automatic waste-tracking devices, such as the use of artificial intelligence and machine learning. These smart devices are able to discriminate between types of food waste, making it unnecessary for staff to select the food category on the touchscreen. Whereas such devices may come at a higher cost than the device this study is based on, they might also reduce the time required for staff to perform the food waste measurements. It would thus be interesting to consider in future research the changes brought about by more advanced waste-tracking systems.

The current labour costs for weighting the buffet leftovers (778 EUR/yr) coincide with about 6 min of measuring per day and a daily operational cost of, on average, 2.13 EUR per hotel. This was calculated based on the labour costs generated during the first year of monitoring, thus including the first few months where a relatively high number of measurements took place. If the buffet leftover returns remain constant at the level that was achieved after five months, the average number of measurements during subsequent months would be lower. As a result, the daily operational costs would go down to 1.81 EUR per day per hotel kitchen (5 min of measuring per day). Moreover, as staff is more familiar with the measurements, the time needed to perform one measurement may go down as well. Whereas the time stamps of our measurements indicate an average of 47 s per measurement, Read and Muth (2021) based their calculations on only 12 s per measurement. It is not clear if these measurements were also done at detailed product-level, or rather at category level, which could explain differences in time spent measuring.

To further reduce the time spent in the self-reporting process, and thus save on labour costs and motivate more businesses to participate, food services could decrease the level of detail in which the self-reporting takes place. For instance, Leverenz et al. (2020b) showed in a case study on buffet leftovers from event catering, that only three product groups caused 54% of buffet leftovers and 65% of monetary equivalents. Thus, a large effect can already be achieved by focusing on these product groups that are most frequently discarded. Consequently, rather than measuring at product-level, the category level could be applied. The associated product impacts and costs for the assessment would then be based on an average representative value. The buffet leftovers in our study showed an average weighted cost of 5.95 EUR/kg, which is lower than the average value of 8 EUR/kg for breakfasts in the German hospitality sector (UAW (2020). When it comes to the carbon footprint of the buffet leftovers, our study found 5.39 kg CO_2 equivalents per kg leftovers, which is above the 3.4 kg CO_2 equivalents found for breakfasts and lunches in the German hospitality sector (Meier et al., 2021). These differences could be explained by methodical differences or by differences in the leftover composition. Nevertheless, the authors of this paper would recommend food services to track their buffet leftovers at product-level. Only then, the real hotspots can be identified and product-specific strategies to reduce buffet leftovers can be developed.

At the time of the self-reporting intervention, the assessment framework as set out in this paper was not available yet. Neither was there much knowledge on the environmental and economic performance of food waste reduction measures, as also confirmed in literature (Goossens et al., 2019; Muth et al., 2019; Reynolds et al., 2019; Stöckli et al., 2018). As such, during the self-reporting intervention, data collection focussed on measuring buffet leftover returns and some critical data for evaluating the resource-efficiency of the measure was not collected at the moment of implementation. This refers to, amongst others, the time staff spent interpreting the direct feedback received by the waste-tracking device or the time spent identifying and implementing strategies to reduce leftovers. Read and Muth (2021), for example, assume a kitchen chef needs 1 h per week for reviewing the records and 2 h for communicating and implementing changes, resulting in 156 employee hours per year. Our case study might thus possibly underestimate the input costs, depending on how much time staff exactly needed (as discussed further below). Qualitative interviews with the kitchen managers, however, revealed that no additional staff had to be hired to take up these additional employee hours and that the additional hours reported in literature would be an overestimation. Furthermore, the kitchen managers felt that any additional time spent in measuring the leftovers was compensated by time savings from having less buffet leftovers to return to the kitchen at service end, and from time savings in no longer having to prepare so much food in the first place. According to WRAP (2013), about 38% of the total value of the food that is wasted in food services comes from the labour costs for preparing and cooking this food. Unfortunately, we were unable to quantify how much time is spent on preparing the breakfast buffet items, with the exception of warm items for which a default time for baking in the pan was assigned. We however expect the contribution of the labour costs for preparing the breakfast items to be lower than 38% as they are less time-intensive to prepare than lunch or dinner. Nevertheless, by not including all labour costs, our study might be underestimating the associated financial savings. Rather than assigning a random value to these cost elements, we decided to not assign any cost to these aspects at all. It would however be interesting to duly consider and quantify these cost elements in future case studies on the use of waste-tracking devices in food services.

Our calculations show a Benefit-to-Cost Ratio (BCR) of 11:1 whereas the findings from Read and Muth (2021) indicate a BCR of 2:1. Their calculations however go beyond breakfast buffets and focus on the entire food service sector and all possible meals served. Additionally, they assume a food waste reduction potential of 35% whereas our measurements found that the buffet leftovers were reduced by on average 64%. As such, the averted food purchase costs are a lot higher in our study. Furthermore, our economic implementation inputs mainly stem from labour costs from measuring leftovers (at detailed product-level). In the US study however, the expected labour costs mainly stem from time needed to set up the waste-tracking system (1 h/day) and to review records and communicate and implement changes (3 h/week); two elements that were not considered in our case. On top of that, they had annual costs for using the equipment and getting support, whereas our kitchens were provided the waste-tracking device for free.

Without the equipment costs, our implementation costs were less than 10% of the economic savings achieved by the self-reporting. Even when including the estimated annual costs of 4482 USD from Read and Muth (2021) for using a waste-tracking device, there would still be net benefits from using waste-tracking devices to reduce buffet leftovers. Our scenario analysis showed that the use of a waste-tracking device would be profitable up to an annual cost of 8,137 EUR per kitchen. In addition, the device could in fact also be used for other meals besides breakfast buffets, which would likely result in further savings while equipment costs would remain the same. From our experience, there would not be any substantial costs related to setting up the system in our kitchens. There would however be additional costs for time spent reviewing the records, but it is hard to estimate how much this would be. When it comes to time spent by kitchen chefs for communicating and implementing changes, this might already be part of the daily routines and may not pose an additional cost as communication with staff and optimisation of kitchen processes is not new. The only change being, is that these activities are now better targeted to the issues at stake, and are thus more effective. As such, the estimated 3 h per week from literature may overestimate the contribution of the self-reporting to time spent in optimising kitchen processes. Lastly, the optimisation of the kitchen processes will lead to time savings in terms of mise-en-place, food preparation (less food to chop and cook) and setting up and cleaning the buffet. These aspects were not considered in the US study. In our study, these are part of the "avoided product costs" as they are directly linked to the food that is served; unfortunately, they could not be quantified due to lack of data as discussed above.

Lastly, the feedback generated by the waste-tracking device led to the implementation of other strategies to reduce leftovers. As such, as mentioned above, the assessment performed in this paper, and the leftover reductions achieved, go beyond the effects of waste-tracking. To get a deeper understanding of its full effects, some data gaps on the implementation inputs related to these additional interventions would need to be filled. Our study further highlights the need to know beforehand, before implementing a measure, which data will be needed for the assessment as this will have to be collected at the moment the resource inputs or outputs occur. Only then, a complete sustainability assessment can be made. Despite the few data gaps this study encountered, the authors believe the business case would still stand if all missing cost elements were to be included. The authors further stress the need to also consider qualitative aspects when evaluating measures, for which data will also have to be collected from the start.

4.5. Contribution to a more resource efficient food system

We expect using an automatic waste tracking device to also be profitable to other food services outside of our research project. Nevertheless, the exact food waste savings potential will strongly depend on how the buffet is set up, on kitchen management and on which strategies have already been applied to optimise food serving processes. Furthermore, the environmental and economic saving potentials depend on the kinds of food that are served on the buffet, and subsequently wasted.

The waste-tracking of buffet leftovers empowers food services to make decisions and develop strategies aimed at reducing leftovers. The present paper shows food services the potential of using such tools. Moreover, it gives food services an indication on how much they could spend on a waste-tracking tool while still being profitable. This in turn is of interest to providers of such waste-tracking devices. We therefore believe the business case developed in this paper can help food services become more sustainable and resource efficient.

The findings further provide policy makers with evidence on a best practice measure to reduce food waste in food services. In addition, the application of the framework to evaluate food waste reduction measures provides a practical example for a wide range of stakeholders, including researchers and representatives of food businesses, on how to evaluate measures. As the framework allows us to get better insight into the potential and resource efficiency of food waste reduction measures, it can help other businesses to become more resource efficient as well. Furthermore, reducing food waste throughout the entire food system, contributes to greater food security.

5. Conclusions

The case study confirms that waste-tracking devices are powerful tools to optimise kitchen processes and reduce buffet leftovers, thereby reducing food waste in food services. Based on actual measurements rather than forecasts, the study shows which environmental and economic savings are possible.

The use of the waste-tracking tool, and more specifically the direct feedback given to staff, lead to greater awareness amongst staff on the total amounts of leftovers returning from the buffet on a daily basis. This in turn encouraged staff to act, adapt its behaviour and implement strategies which successfully reduced the buffet returns. By doing so, the pilot kitchens were able to reduce their breakfast buffet leftovers by on average 1.8 tonnes per year (per kitchen), with a total nutritional value of 3.6 gigacalories. In the absence of equipment costs, and considering all other necessary implementation inputs needed to achieve these reductions, each kitchen obtained net savings of over 8,000 EUR per year. This means that the use of waste-tracking tools for the breakfast buffet would be profitable to the kitchen up to annual equipment costs of 8,137 EUR per kitchen. When using the tracking device for other meals as well, net savings are expected to increase, meaning profitability for using the waste-tracking device will increase as well. When it comes to how the tracking of buffet leftovers affected the environment, it was found that each kitchen obtained net savings of on average 6.8 tonnes CO_2 equivalents and 841 PEF mPt per year.

There is a clear business case for using waste-tracking devices to reduce buffet leftovers. In the absence of expenses for using the waste-tracking device, the input of 1 EUR allowed the kitchens to each reduce their leftovers by 2 kg and simultaneously save 11 EUR, thus leading to a benefit-to-cost ratio of 11:1. Each invested EUR further allowed saving 9 kg CO_2 equivalents and 1 PEF mPt. The economic BCR would drop to 5 at an annual equipment cost of 1,000 EUR/year. At an annual equipment cost of for example 4,500 EUR, one EUR spent would allow each kitchen to save 0.33 kg leftovers, 1.30 kg CO_2 eq, 0.16 mPt PEF, 1.69 EUR and 680 kcal.

Applying the SDG 12.3 target of halving food waste to serving waste from self-service buffets is thus realistic and proven profitable to food services. Furthermore, the environmental savings achieved by implementing self-reporting in food services contribute positively to SDG target 3 on tacking action to combat climate change. As such, self-reporting empowers food service businesses to tackle climate change and become more sustainable.

Finally, the application of the framework to evaluate food waste reduction measures provides more insight into the resource efficiency of food waste reduction measures. We believe this will contribute to moving towards more sustainable and resource efficient food systems.

CRediT authorship contribution statement

Yanne Goossens: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Dominik Leverenz:** Conceptualization, Data curation, Investigation, Writing – review & editing. **Manuela Kuntscher:** Conceptualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rcradv.2022.200112.

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