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A rapid assessment tool of environmental and economic impacts of food waste in collective catering: an example from 8 European school canteens

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ABSTRACT

Food waste (FW) in collective catering settings remains a critical barrier to sustainable food systems, due to its magnitude and multidimensional negative impacts. Food waste reduction and prevention measures are often difficult to design and implement due to the lack of specific data on the amount of waste generated, but also on the associated environmental impacts and costs. To tackle this lock-in, this study presents and validates a novel tool for assessing both the environmental and economic impacts of FW in collective catering. Grounded in Life Cycle Thinking (LCT), the tool integrates multiple sustainability assessments to support practitioners in identifying strategies and leverage points for FW reduction. The tool was tested with real-world data from eight school canteens in Austria and Italy. Results unveil cross-country differences in FW amounts, composition and environmental and economic impacts. Findings underline the need for tailored FW prevention strategies to account for different food service contexts and cultural norms. Suggestions were formulated to adapt portion sizes in Italy, and to envision redistribution of unserved food in Austria. Despite national differences, absolute sustainability analyses indicated that several hotspots—including land use, climate change, and ecotoxicity—exceeded planetary boundaries by multiple times in both countries' samples, reflecting school menus' dependence on resource-intensive foods. The study demonstrates how coupling FW monitoring with environmental monetization can strengthen diagnostics, offer benchmark values for school food services, and support reduction efforts to ensure compliance with forthcoming EU FW reduction targets. By embedding the tool in catering management, practitioners can integrate environmental and economic considerations in the prioritization of FW reduction interventions and in menu redesign.

1. Introduction

Food waste (FW) remains a major challenge in the transition to sustainable food systems. The global environmental, social and economic impacts of FW are by now widely recognized (FAO, 2019). In Europe, about 132 kg of food are wasted per capita every year, mostly at the consumption level (EUROSTAT, 2024). Due to the increased awareness on this topic, policymakers have placed FW as a key issue in the Farm to Fork (F2F) strategy (European Commission, 2020), which called for the introduction of legally binding food waste reduction targets for all Member States (MSs). The FW binding targets for 2030 are the main achievement of the F2F policy initiative, as the Commission proposal was recently adopted by the European Parliament (European Commission, 2025). This underlines the urge to place FW reduction as a key priority for national and local governments, together with food supply chain stakeholders. Monitoring FW magnitude, and its associated economic and environmental impacts, becomes therefore an indispensable step in achieving food waste reduction targets (Cattaneo et al., 2021), such as those set at EU level as well as by SDG target 12.3.

Collective catering environments like schools and other education environments have garnered considerable attention in the investigation of FW quantification and prevention (Casonato et al., 2023). Implementing food waste monitoring strategies and reduction initiatives within these food environments is facilitated by their controlled nature, in contrast to households or restaurants (Petruzzelli et al., 2025a). These settings provide actionable and scalable opportunities to encourage sustainable food consumption behaviours (Pastorino et al., 2023).

Robust monitoring methods can help food service providers in measuring waste quantities. Numerous FW quantification standards and protocols exist (IFWC, 2024; WRAP, 2023; Hanson et al., 2016) with large variability in accuracy and data needs. Conversely, there is a lack of reliable tools to provide a quantification of the environmental and economic impact associated with FW. Gauging the environmental and economic impact of FW in school canteens can be instrumental in pinpointing hotspots and guide intervention design towards reduction (Sundin et al., 2024). Extant literature focuses on few impact categories and limits the economic assessment only to market costs (García Herrero et al., 2019). In addition, food service stakeholders lack reliable and open access tools that can support their decision making (Petruzzelli et al., 2025b).

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To fill this gap, this work presents a ready-to-use tool for the assessment of environmental and economic impacts of FW, validated through real world data on school meals' FW. Furthermore, the tool explores the relation of FW environmental impacts to the planetary boundaries (European Commission. Joint Research Centre, 2025; Sala et al., 2020) and provides an economic assessment of the true price of one meal, by accounting for environmental externalities (Amadei et al., 2021). Compared to previous works, the tool provides an estimate of several environmental impacts, following the Product Environmental Footprint (PEF) impact categories (European Commission, 2021). Furthermore, by monetizing the environmental impacts, it offers an economic assessment of the true cost of each meal served, providing food service managers with a clear diagnostic of the environmental and economic trade-offs of FW reduction, to subsequently devise appropriate reduction strategies. The main novelty of this tool is represented by its unique strategy to make robust, data-intensive methods accessible for collective catering practitioners. Complex metrics are computed with few limited and readily available information. While no advanced modelling is required, it is still made possible thanks to the detailed description of the tool's building process, and the open access provision of all the relevant materials.

The tool is validated through its application on a case study drawn from the INTERREG project foodCIRCUS – which brings together research institutes and stakeholders from 5 MSs in Central Europe: Austria, Czech Republic, Hungary, Italy and Poland. FW was monitored for 2 days in 8 schools in Italy (4) and Austria (4): data on waste composition, mass, cooking method and waste management practices was collected through direct measurement to test the tool.

The article is organized as follows. Section 2 presents the goal and scope of the tool, its functioning and the data sources – both primary and secondary – it relies on. Section 3 describes the results obtained from the tool's testing on the Austrian and Italian sample of school canteens. At last, Section 4 discusses results, limitations and future research pathways.

2. Materials & methods

2.1. Goal and scope of the tool

The goal of the assessment tool is to estimate the environmental and economic impacts of FW in collective catering in Europe, with a particular focus on school canteens. The tool provides actionable results for collective catering stakeholders (e.g. caterers, school canteens managers) on FW's environmental impacts, costing impact, and on the breach of planetary boundaries (based on the economic value of 1 meal), that can be communicated and used for strategic planning. The design of the tool and the selection of the modelled food items (see Table 1) followed an analysis of FW in Austrian and Italian school canteens.

2.2. Methodological background

The tool draws on Life Cycle Thinking (LCT) principles in accordance with ISO 14040:2006 (ISO, 2020), estimating environmental impacts and integrating both environmental externalities and the Absolute Environmental Sustainability Assessment (AESA) approach (European Commission. Joint Research Centre, 2025) to allow for easier interpretation of results by practitioners. FW environmental impacts are calculated through Life Cycle Assessment (LCA), while the economic costs are estimated based on ingredients' cost and monetized environmental externalities (Amadei et al., 2021). Moreover, an additional analysis of environmental results is provided by comparing the impact generated by one meal with the share of the planet's carrying capacity estimated through AESA.

To reach this goal, the study adopts the wasted fraction of 1 meal as a functional unit (FU), measured in grams of FW generated per meal. The system boundaries encompass the full life cycle of food products—from raw material extraction and agricultural production, transportation, food preparation and cooking, and final waste management. The tool distinguishes between plate waste (PW) – intended as the food fraction not consumed and hence left on the plate, and serving waste (SW) – including both unserved food and serving leftovers from a buffet restaurant (Petruzzelli et al., 2025a; Scherhaufer et al., 2018).

Table 1
Ingredients modelled in the tool and corresponding food category.

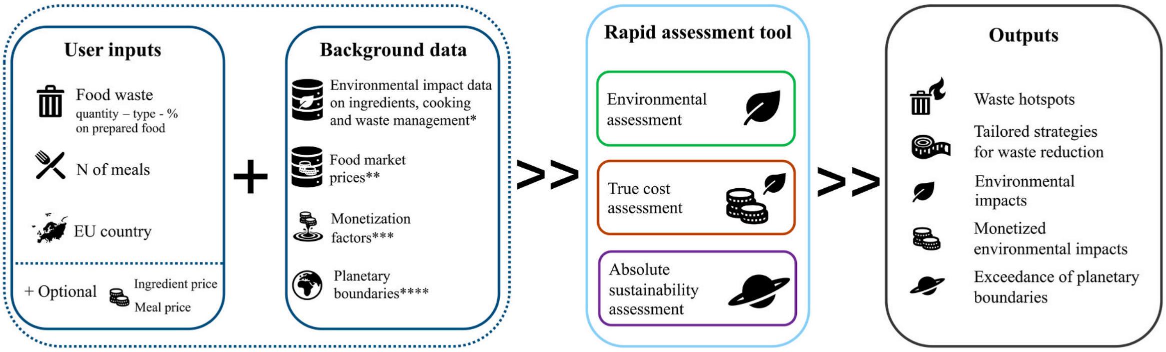
Category	Ingredient
Beef	Beef; Beef sausage; Beef, without bone; Veal, without bone
Dairy products	Butter; Cheese, cheddar; Cheese, edam; Cheese, Emmenthal; Cheese, hard; Cheese, mozzarella; Cheese, unspecified; Heavy cream; Milk; Cheese, parmesan; Yoghurt
Desserts	Dark chocolate 40%.; Dark chocolate 70%; Milk chocolate; Vanilla
Fish	Fish, anchovies; Fish, cod; Fish, salmon; Fish, sardine; Fish, tuna; Mussels
Fruit	Apple juice; Apples; Apricot; Avocado; Cherries; Chestnuts; Fruit juice, unspecified; Fruit puree; Grapefruit; Lemon; Mango puree; Orange juice; Oranges; Peach; Pears; Pineapple; Plums; Pomegranate; Raspberries; Strawberries; Table grapes
Meat (excluding beef)	Chicken, without bone; Cooked ham; Dry sausages; Duck; Duck fat; Lamb, without bone; Mutton, without bone; Pork; Pork fat; Pork sausage
Other	Almonds; Cashew; Coconut; Coconut milk or coconut cream; Eggs; Hazelnuts; Honey; Margarine, vegetable fat; Mayonnaise; Nuts; Oil, blend; Oil, coconut; Oil, olive; Oil, olive blend; Oil, palm; Oil, peanut; Oil, rapeseed; Oil, soybean; Oil, sunflower; Parsley; Peanuts; Vinegar
Plant-based protein	Bean, haricots; Bean, kidney; Chickpeas; Green peas; Lentils; Soybean; Plant-based mince; Seitan; Tofu; Vegetable steak.
Salad	Endive; Red chicory; Salad; Winter endive
Soup	Broth
Starch/satiating food	Bread, burger or hot-dog bun; Bread, white; Bread, whole grain; Brown sugar; Flour; Maize or corn; Oats; Pasta; Potatoes; Quinoa; Rice; Semolina; Sugar; Sweet potatoes
Vegetables	Asparagus; Bell pepper; Broccoli; Carrots; Cauliflower; Celeriac; Celery; Chicory; Chili pepper; Chives or spring onion; Courgettes or zucchini; Cucumber; Eggplants; Fennel; Garlic; Ginger; Green beans; Green cabbage; Green pepper; Leek; Mushrooms; Olives; Onions; Pumpkin; Shallot; Spinach; Sweet chilli; Sweetcorn; Tomato puree; Tomatoes; Turnip; White cabbage

The tool operates through a structured Excel interface that allows users to input primary data and elaborate an environmental and economic assessment based on secondary data. The tool performs automated calculations and generates an environmental and economic assessment useful to support school canteens stakeholders in planning school meals, while taking into consideration potential sustainability trade-offs.

The tools' outputs include the environmental impacts embedded in FW, expressed through the 16 impact categories of the PEF (Zampori and Pant, 2019), as well as the economic cost of food waste. This ensures a multidimensional assessment which can be further used in decision making by food service providers or public authorities who want to balance environmental sustainability with budget-friendly targeted interventions. Moreover, the tool produces an index expressed on a percentual scale, indicating the distance to an environmental impact target, resulting from the average price of a meal in each country (European Commission. Joint Research Centre, 2025). Results are displayed in a summary dashboard, which highlights both aggregated and per-meal indicators and includes graphical representations of the deviation from sustainability thresholds.

The tool's modular structure allows for the modelling of new ingredients by the user. The accompanying database (SM2) presents the data sources used to build the tool, alongside with environmental and economic coefficients elaborated on the retrieved data.

The structure of the tool is described below and presented graphically in Fig. 1.



*adapted from AGRIBALYSE 3.1 & ecoinvent 3.10
**taken from EUROSTAT
***adapted from Amadei et al. (2021)
****adapted from Sala et al. (2020)

Fig. 1. Methodological flowchart of the rapid assessment tool, presenting a schematic illustration of the tool's inputs, methodologies and outputs.

2.3. *Data sources*

The assessment tool relies on a combination of primary user inputs and secondary data drawn from publicly available databases. Primary data refers to the quantities of FW (both PW and SW), the waste composition (to choose from 139 food items, reported in Table 1), the food preparation (raw, electric boiling, gas boiling, baking, frying, boiling - unspecified, cooking - unspecified) and waste management method (anaerobic digestion, industrial composting). Moreover, the user needs to input the number of meals served, the percentage of food waste on the total food prepared, whether as a calculated percentage or as an estimation, and the country in the EU where the assessment takes place to use the most appropriate country-based coefficients. The purchasing price per kilogram of the food items and the price of a meal can be also added as optional data. Secondary data that are used by the tool for automatic calculations are related to the environmental impacts of food items (ingredients), cooking and waste management; food prices; monetization factors; regional carrying capacity estimations.

Environmental impact data – Environmental impact data for ingredients are retrieved from the French AGRIBALYSE ® 3.1 database (AGB) (Asselin-Balençon et al., 2022), which provides life cycle inventories (LCIs) for more than 2000 food products in France. A selection of 139 common ingredients is modelled to simplify the use of the tool (see Table 1). Two criteria are adopted for the selection: a) the ingredients that were common in the menus of the Austrian and Italian sample used in the tool and b) the main ingredients used is the AGB recipes layer. However, the mapping file provided in SM2 allows the user to include in the tool any other ingredient available in the AGB database. Environmental impact data for cooking methods and waste management scenarios are modelled from secondary LCI datasets integrated into the database. Cooking methods are modelled following the Annexes of AGB (Asselin-Balençon et al., 2022), and include electric boiling, frying, gas boiling, baking, raw, and unspecified. Following the approach employed for the European Food Composition Database (Bell et al., 2006), a raw-to-cooked correction factor was applied to all the ingredients that would incur in at least 5% of weight increase or decrease after cooking. The factors were estimated based on the estimations reported in Annex 4 of the white paper by Bell et al. (2006). Cooking times are assumed to be equal in all the countries, as similar ingredients are likely to be processed in a similar way across the EU. To account for variation in the impact of energy consumption for meal preparation, energy data are disaggregated by each European country to reflect differences in electricity mixes and appliance efficiency. Data are sourced from the ecoinvent ® v3.11 (EI) database (Wernet et al., 2016). In accordance with EU legislation, the waste management options provided are industry-standard anaerobic digestion and industrial composting, which are adapted from EI with processes localized in the EU. These two processes are assumed to be representative of organic waste standard treatment in the EU.

Food prices – Food prices are estimated using EUROSTAT data. Two main datasets are integrated: the EUROSTAT database of EU food monthly market prices (EUROSTAT. Agridata, 2025a), and the EUROSTAT database of EU yearly agricultural product prices, at production stage (EUROSTAT. Agridata, 2025b). The prices are production or wholesale prices, not end consumer prices to better tailor the tool to the needs of catering stakeholders. The prices are presented as national averages of the last 5 years, using a data quality logic where: a) national monthly prices for a given product are chosen over national yearly prices; b) if national monthly prices are not available for a given product, national yearly prices are considered; c) if both national monthly and yearly prices are not available, an average of European monthly prices for a given product is considered; d) if no European monthly prices are available, European yearly prices are considered. No price estimations are provided for cooking and waste management, as the variability across and within country is too high to be modelled consistently, and would drive a greater degree of complexity for the user. Prices can however be inputted as optional primary data by the user: in this case, the tool employs automatically the primary data instead of the secondary data estimations.

Monetization – The parameters for the monetization of environmental impacts are adapted from the PEF-compliant ones described by Amadei et al. (2021), which are inflated to 2025 euros (€) following World Bank (2025) indexes. When information about the market cost is not available – whether because of their absence in the EUROSTAT database, or for the lack of primary data, only the total environmental costs are computed.

Carrying capacity – The carrying capacities per each PEF impact category used to perform AESA were retrieved from Sala et al. (2020) following European Commission. Joint Research Centre (2025). Data on the GDP of European countries were sourced from the World Bank.

The complete list of the databases included in the tool is available in SM2.

2.4. *Data elaboration*

To simplify and standardize FW inventory building, an AI-based method for dish ingredient analysis was designed. The process employs a large language model (ChatGPT ®) to infer ingredient compositions from the dish name and description. The algorithm predicts a list of major ingredients, excluding those contributing less than 5% of total weight of the dish (e.g. spices, salt, cooking wine). The full prompt is available for consultation in the SM 3 (Supplementary Information 1). These ingredients are then normalized to total 100%, following a classification system presented in Table 1. The reasoning behind the classification systems is based on the segregation of food items both due to their nutritional feature (potatoes are functionally closer to pasta than vegetables) as well as their environmental impacts. For examples, this is the reason behind the choice of separating beef from meat, and of assigning yoghurt to dairy and not to dessert. The AI-inferred list should be subsequently reviewed and adjusted by the user to ensure it aligns with site-specific meal preparations and recipes. Practitioners are assumed to be the best-informed stakeholders and as such are encouraged to collect the best available information on the recipes and to check thoroughly the accuracy of the AI-based estimations. This method enables a rapid first approximation of ingredient composition, facilitating the analysis of food waste even when exact recipes are unavailable and allowing comparability across collective catering environments and countries.

After inputting the inventory, the tool automatically compiles the environmental assessment. The environmental impacts for the ingredients are taken from AGB as such, while the environmental impacts connected to the cooking methods and waste management are contextualized for each country through energy mix coefficients – presented in the SMs. Then, environmental impacts are monetized through the inflated coefficients by Amadei et al. (2021) described above. The final cost is computed by adding the environmental cost to the market ingredients' cost. All the impacts are presented for the functional unit of the FW associated with 1 meal. At last, the environmental impacts are compared to their allocated share of the total ecosystem carrying capacity, to assess whether they are exceeding the planetary boundaries. This comparison is build following the principles of absolute environmental sustainability assessment (AESA). A combination of the “Equal per capita” and “Economic value” allocations methods described by the recent work on AESA by the JRC (European Commission. Joint Research Centre, 2025) is used to determine the allocated shares of the planetary boundaries of 1 meal. This approach is chosen as it has been recognized as the most straightforward and used in AESA studies (Sala et al., 2020). The EU per capita carrying capacity is taken from the estimations by Sala et al. (2020). To obtain the allocated share for the functional unit of 1 meal, a function relating the total carrying capacity per capita for each impact category ($CAR.CAP_{capita}$) to a ratio expressing the utility attributed to the functional unit is employed. The utility ratio is obtained by relating the average price of a school meal in a given EU country ($P_{meal,\ country}$), to that country's GDP per capita ($GDP_{capita,\ country}$) retrieved from EUROSTAT (2025), as expressed in Eq. (1).

$$\begin{cases} CAR.CAP_{capita} = CAR.CAP_{world} / Pop_{world} \\ CAR.CAP_{meal,country} = \left(P_{meal,country} / GDP_{capita,country} \right) * CAR.CAP_{capita} \end{cases}$$

Equation 1

Then, the environmental impact of a meal ($ENV_{meal,\ country}$) – computed as the sum of the total impact of food ingredients and cooking for 1 meal, and the impact of disposing that meal's food waste fraction– is compared against its allocated share of the carrying capacity for each impact category, to assess the exceedance of the planetary boundaries.

$$EX\ (\%) = ENV_{meal,country} / CAR.CAP_{meal,country}$$

Equation 2

Results are visualised through pivot tables on Excel (see SM1), focusing on i) the total FW mass per meal, with a breakdown on the food categories, per each sampled school, ii) the total FW mass per country, with a breakdown on PW and SW, per each food category, iii) the share of PW, SW and eaten fraction on the total prepared food, per each food category, iv) the share of environmental impact, with a breakdown on the food categories, per PEF impact category, v) the share of ingredients' market cost and environmental cost on the total cost, per food category and vi) the exceedance of PB.

2.5. Sensitivity analysis

Several sensitivity analyses were carried out to test the impact of utilising different environmental inventory databases – ecoinvent ® 3.11 (EI) (Wernet et al., 2016) and the European Environmental Footprint of Food database (EFF) (Merieux NutriSciences & RIVM, 2025), and choosing different environmental impact's monetization factors for the calculation of total environmental costs. Then, two alternative allocation approaches for AESA were tested: Historical Responsibility and Capability to Reduce (European Commission. Joint Research Centre, 2025). Absolute sustainability results were also calculated varying the meal price to test the change in carrying capacities, and consequently on the exceedance of PB. At last, to test the acceptability of more complex recipes' estimations elaborated with the tool, environmental impact results for the recipes in the database were calculated using AGB from cradle to consumer: this allowed to observe the percentage of impacts not captured by the tool.

Different databases – To test the impact of choosing different background environmental databases, the ingredients' layer of the tool was redesigned to run with EI and EFF instead of AGB. To do so, ingredients modelled in AGB were matched with those available in the two other databases. If an exact match could not be established, a similar product was chosen. If no similar product could be identified, the AGB entry was kept instead. The modelling of cooking processes and the waste management was maintained unchanged. A table summarising the database entries used for each ingredient is available in SM3 (Supplementary Information 3.2).

Different monetization factors – Starting from the review by Amadei et al. (2021), only PEF-compliant monetization factors were considered: no other monetization factor different from those available in Trinomics (2020) were retrieved for PM, IR, PO, AC, LU and Eute, therefore for these impact categories a 50% reduction or increase compared to the reference value was tested. The considered factors are reported in the SM3 (Supplementary Information 3.3). Then, 100k simulations were run through a python script to represent the probability of different total environmental costs in the AT-s and IT-s considering the sum of all the monetized environmental impacts.

Different allocation approaches – A sensitivity analysis was performed to test different strategies to allocate AESA carrying capacities. As detailed in the previous section, the tool's absolute sustainability assessment module is based on the “Equal per Capita” approach, which distributes an equal share of the planet's carrying capacities to each person on the planet. The two alternative approaches tested in this work – “Capability to Reduce” and “Historical Responsibility” – use gross domestic product (GDP) and previous national cumulated emissions (NCEs) per capita to compute correction factors for allocating carrying capacities' shares (European Commission. Joint Research Centre, 2025). In particular, the “Capability to Reduce” approach factors in the GDP per capita to inversely relate the resources available to reduce impacts to the allocated carrying capacity, i.e. the higher the GDP per capita, the lesser the allocated share. The “Historical Responsibility” approach builds on the latter by including also historical CO_2 NCEs, to assign a lesser share of the global carrying capacities to the largest historical emitters – i.e. the higher the historical emissions, the lesser the allocated share. Equations and a scheme illustrating the allocation rationale are presented in SM3 (Supplementary Information 3.4).

Different meal prices – To examine how varying meal prices affect the allocation of carrying capacity for AESA, calculations were performed using both the minimum and maximum observed meal prices in Austria and Italy, rather than the average price chosen in the tool. In accordance with the selected allocation method, an increase in meal price would result in a higher assigned carrying capacity and a reduced exceedance of planetary boundaries.

Environmental impacts' estimations of complex recipes – As a consumption-based life cycle inventory, AGB already accounts for impacts associated with the transportation and packaging of raw ingredients, which are modelled as delivered to the final consumer. However, this representation implicitly assumes that dishes are prepared entirely from basic ingredients at the point of consumption. In practice, not all meals are cooked from scratch: some components may undergo intermediate processing off-site, entailing additional packaging and transport burdens (e.g. pre-prepared Bolognese sauce). This analysis explored the potential influence of these additional stages. Recipes in the sample comprising more than four ingredients—considered more likely to include externally processed components—were matched with functionally comparable, ready-made food products available in AGB, based on an acceptable degree of compositional and culinary similarity (e.g. "broccoli cream soup" matched with "pre-packed vegetable soup with cheese, to be reheated"). This approach enabled the estimation of the contribution of additional packaging and transportation to the overall environmental impacts of the most complex dishes. The analysis was performed on a subset of five dish categories - soups, starchy meat-based dishes, starchy vegetarian dishes, meat or fish-based dishes, and desserts, analysed for the most relevant PEF impact categories – CC, PM, LU, EC, EN.

2.6. Case study description & food waste quantification

To show its functionality, the tool was applied on a convenience sample of school canteens in Austria and Italy, 4 per each country, at different education stages – kindergarten, primary school and secondary school. Data was collected directly in the school canteen both in Austria and Italy between March 2025 and June 2025 on prepared food, waste quantity, type and origin (PW or SW, as defined in Section 2.2) were collected for 2 days in each school, leading to a total of 16 observations. The sampled school canteens offered meals to students in a number ranging from 38 to 172, with most of the observations (10 out of 16) ranging in the 63-68 interval. Differences in the catering system were described and accounted for. While Italy adopts a fixed portion system, where each pupils gets the same portion, Austria features a buffet system, where pupils can choose their meal. Food preparation methods vary, with both Cook&Chill and Cook&Serve systems implemented in the two countries. A detailed description of school canteens functioning in Italy can be retrieved from Petruzzelli et al. (2025b), while the Austrian catering system is thoroughly described by Sundin et al. (2024). The quantification method was direct weighing. In Austria, each available fraction was weighted separately, while in Italy plate waste was weighted on a serving-type basis, i.e. first course, second course, side, fruit and bread (as in Petruzzelli et al., 2025a). Serving leftovers and unserved food were considered as only one fraction in Italy, as the caterers served the same amount of food to every pupil. Soup was weighted with its add-ins in both countries. Pasta and rice were weighted with their accompanying sauce in Italy, while in Austria sauce was weighted separately for the prepared food and SW, but jointly for PW. To simplify the dish ingredients' analysis and to ensure homogeneity with the Italian inventory, in the Austrian dataset the weight of pasta (or rice) was summed with its accompanying sauce, both for prepared food, PW and SW.

3. Results

3.1. Application of the tool to the case study

The results presented in the sections below are connected to the two samples described above. The primary data inputted in the tool are reported in a synthetic form in Table 2, while the whole datasets are available for consultation in SM1 (Tab "Dataset_IT and Dataset_AT).

3.2. Food waste analysis

Fig. 2a describes the school sample in terms of average waste per meal, with a breakdown on the contribution of each of the 12 food categories, per each observation in the sample, while Fig. 2b presents a breakdown on consumed fraction, PW and SW on total food prepared aggregated per country, per food category (Fig. 2b). On average, FW per meal (including both PW and FW) in the Austrian sample (AT-s) is 53% higher than that observed in Italian sample (IT-s). The starch or satiating food category (in yellow in Fig. 2a) is predominant across all samples, followed by vegetables (in green). Dairy product waste is more significant in the AT-s, mainly because of yoghurt and milk served as dessert but also because of special Austrian dishes like rice pudding, whereas fruit waste is notable in the IT-s. Additionally, soup waste is relevant in the AT-s but absent in the IT-s. As illustrated in Fig. 2b, most food waste occurs at the plate level in the IT-s, while in the AT-s, PW is minimal when compared to SW. In the sample the consumed share is always higher in percentage terms in the IT-s than in the AT-s, with the exception of fruit. This outcome is associated with differences in the catering systems (IT-s' schools have fixed portions, while AT-s' schools use a buffet system) and with the treatment of data for the AT-s (as unserved food and serving leftovers were combined in one figure). As a general trend, the consumption rate for salad ranks the lowest among the food categories both in the AT-s and the IT-s (20-30% of the prepared amount). In Italy the highest consumption rate is found in meat and dairy, all consumed for more than 2/3 of the total prepared amount. Similarly, in the AT-s beef, starchy food, fruits and desserts figure among the most consumed foods. Looking only at plate waste paints a slightly different picture: fish, fruit and salad are among the most wasted food in the IT-s, while in the AT-s the top scorers are beef, dairy and soup.

Table 2
Inventory data for the Austrian and Italian sample.

Country	Austria	Italy
Schools IDs	AT1_D1, AT2_D1, AT3_D1, AT4_D1, AT1_D2, AT2_D2, AT3_D2, AT4_D2	IT1_D1, IT2_D1, IT3_D1, IT4_D1, IT1_D2, IT2_D2, IT3_D2, IT4_D2
FW Phases	Plate waste; Serving waste	
Total FW weight – PW (kg)	31.61	78.03
Total FW weight – SW (kg)	152.87	20.76
% PW on prepared food (min-max)	0-62	0-91
% SW on prepared food (min-max)	0-84	0-38
Total number of meals served (n)	650	520
Average meal price (€)	3.39	4.25
Food categories	Beef; Dairy products; Desserts; Fish; Fruit; Meat (excluding beef); Other; Plant-based protein; Salad; Soup; Starch/ satiating food; Vegetables	
Cooking methods	Baking, Boiling (unspecified), Cooking (unspecified), Frying, Raw	
Waste management	Industrial composting	

3.3. Environmental impacts of food waste

Fig. 3 presents the environmental results divided per impact category, with a breakdown on the 12 food categories. In the AT-s, animal-based products such as beef and dairy are the main contributors to the environmental impact of the total generated food waste. For instance, beef waste is the principal contributor to climate change (CC), land use (LU), and terrestrial eutrophication (Eute), accounting for up to 50% of the impact in these categories. Dairy waste contributes more than 20% to acidification (AC), particulate matter (PM), and both cancer and non-cancer human toxicity (HTc, HTnc). Soup, a waste fraction present only in the AT-s' schools, increases impacts in fossil resource use (EN), ionising radiation (IR), due to the energy-intensive cooking process, and on cancer human toxicity (HTc), and ecotoxicity (EC), connected mostly with the pesticides use for the agricultural products employed in the preparation.

In contrast, waste composition in the IT-s is characterised by the predominance of starchy foods and fish protein. Starch-rich foods account for 30–40% of the impact in marine and freshwater eutrophication (EUfw, Euma), ionising radiation (IR), HTnc and EN; these impacts are all connected to production and processing, and more specifically to the emission related to the use of fertilizers and pesticides, and to energy

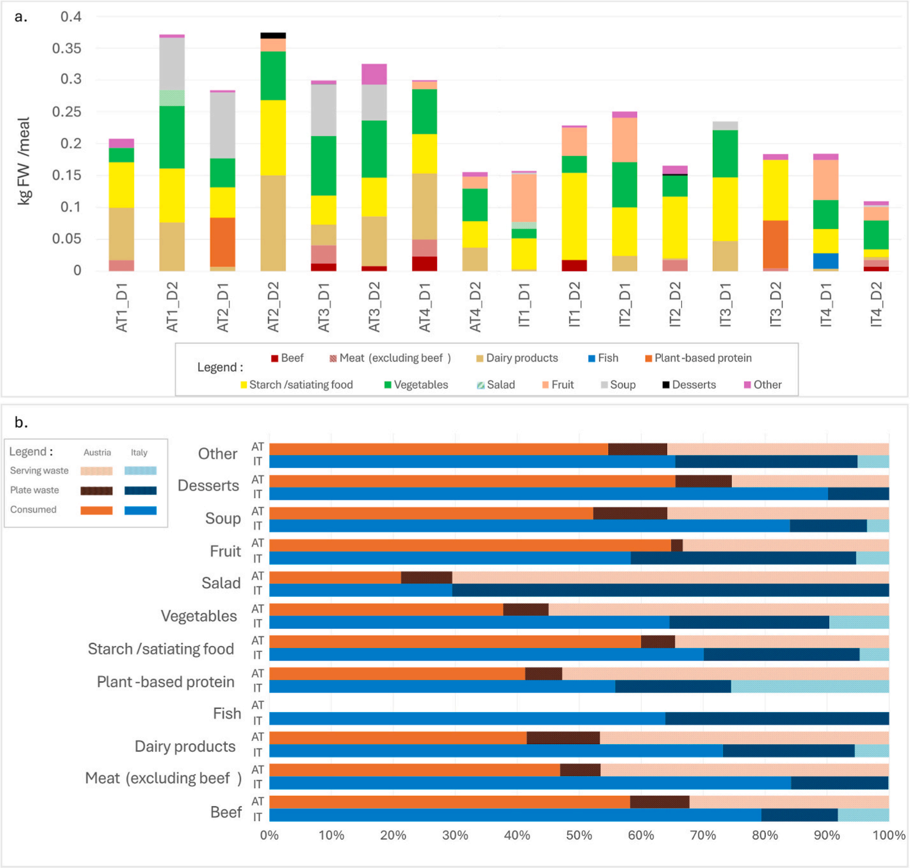


Fig. 2. Food waste per food category (a) and per waste stage (b), for the Austrian and Italian sample. For interpretation of the colour references in this figure legend, the reader is referred to the web version of this article.

intensive processing. Fish waste stands out in the IT-s, especially for its contributions to photochemical ozone formation (PO), IR, and Euma and Eute, with respective shares often between 25 and 35%. Dairy waste remains relevant in the IT-s, but its impact is less pronounced than in the AT-s: it figures among the top contributors to several animal husbandry-relevant impact categories like AC, CC and LU. Fruit and vegetable waste, while negligible in the AT-s, play a larger role in the IT-s, especially regarding EC and water use (WU) – fruits alone account for 30% of WU in IT.

When comparing the overall environmental impact per meal, the AT-s exhibits higher absolute results in 12 out of 16 categories. For example, in the analysed sample the average AT-s school meal generates 35% more greenhouse gas emissions (CC), uses 25% more fossil energy resources (EN) and 27% more non-fossil resources (RU) compared to the IT-s one. In general, for this sample Austrian school meals show impacts that are 25–40% higher than Italian. However, IT-s school meals register over double the water use (WU), and 50% higher cancer-related human toxicity (HTc) compared to the ones in the AT-s. Similarly, photochemical ozone formation (PO) and ozone depletion (OD) are higher in the IT-s by 12% and 16%, respectively. The positive environmental impact on LU in the IT-s is connected with the relatively high presence of plant-based proteins in the sample menu.

A concise comparison of environmental impacts per meal for both countries' samples is available in SM3 (Supplementary Information 3.5), while the full dataset can be consulted in SM1 (Visualisation_Austria and Visualisation_Italy sheets).

3.4. *Economic impacts of food waste*

Due to limited data at the ingredient and recipe level, only food categories for which EUROSTAT market prices were available are reported for the economic evaluation (see Methodology). Fig. 4 shows that for vegetables, salad, and fruit, market price accounts for 75–90% of total costs, whereas for meat, environmental costs make up around 50-60% of the total.

3.5. *Absolute sustainability assessment of food waste*

The absolute sustainability assessment was conducted by comparing environmental outcomes with their respective allocated share of carrying capacity estimated through the average meal price in Austria and Italy (refer to Methodology). Differently from the results stemming from the more standardized approaches adopted for the environmental and economic assessment, the absolute sustainability assessment results are exploratory and highly assumption dependent, and as such should be interpreted with care. As evidenced in Fig. 5, 12 out of 16 impact categories are exceeding their allocated carrying capacities both in AT and IT, with four impact categories – LU, PM, CC and EC – reaching more than 10 times beyond their allocated share. EC surpasses planetary boundaries by a factor of 10 in the AT-s and 11 in the IT-s, highlighting a waste of animal-based products (in the AT-s) and of foods with substantial fertilizer and pesticide inputs (notably starchy foods in the IT-s). CO_2^{eq} (CC) exceeds its allocated share by factors of 40 and 20 in the AT-s and the IT-s respectively, indicating significant waste of energy-intensive foods relying on fossil fuels—both in production, preparation, and disposal—in both countries. Similarly, PM is 40 and 20 times higher in the AT-s and IT-s respectively. At last, the analysis found an impact on land use (LU) 1000 and 600 times greater than its allocated share in the AT-s and the IT-s. This reflects a potential overdependence on foods produced under agricultural land-intensive farming conditions,

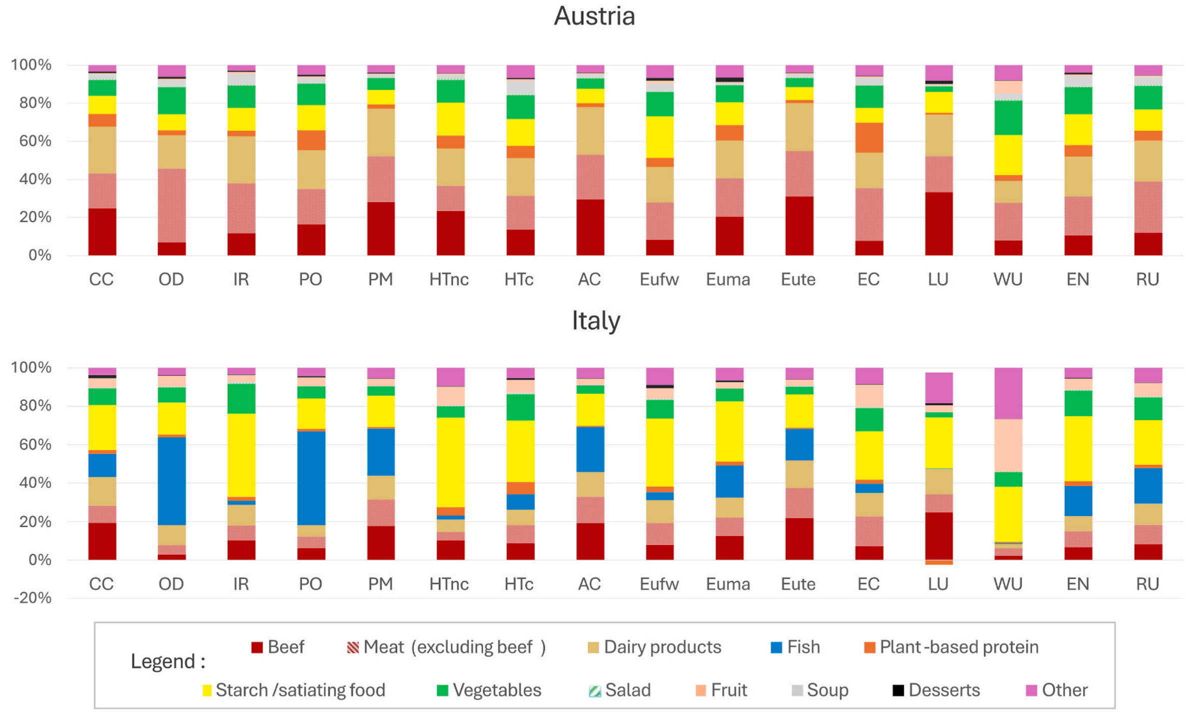


Fig. 3. Environmental impact assessment of total food waste, per impact category, for the Austrian and Italian sample. AC = Acidification; CC = Climate change; EC = Ecotoxicity, freshwater; EN = Resource use, fossils; Eufw = Eutrophication, freshwater; Euma = Eutrophication, marine; Eute = Eutrophication, terrestrial; HTnc = Human toxicity, non-cancer; HTc = Human toxicity, cancer; IR = Ionising radiation, human health; LU = Land use; OD = Ozone depletion; PM = Particulate matter; PO = Photochemical ozone formation, human health; RU = Resource use, mineral and metals; WU = Water use. For interpretation of the colour references in this figure legend, the reader is referred to the web version of this article.

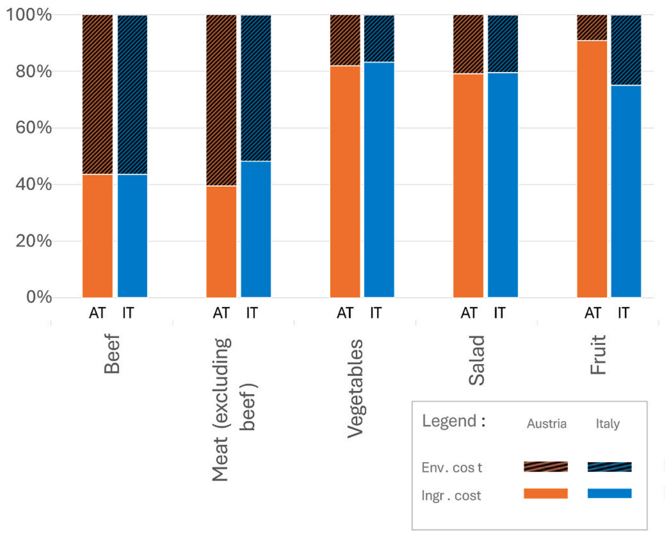


Fig. 4. Ingredients' market cost and environmental external cost (monetized impacts) of total food waste, for the Austrian and Italian sample, in 5 selected food categories.

such as grain crops and animal products.

3.6. Sensitivity analysis

While the results for the 5 sensitivity analyses are presented below, the charts illustrating results graphically are provided in SM3 (Supplementary Information 3.6, 3.7, 3.8, 3.9, 3.10),

Different databases - Choosing different databases – EI and EFF – instead of AGB led to significantly different environmental results. For both EI and EFF, meat causes higher impacts compared to AGB especially in EUm and EUfw, and in the human toxicity impact categories. This is visible also analysing the environmental costs of beef, which increased by 4 and 5 times when using EI and EFF respectively instead AGB. Interestingly, both EI and EFF resulted in a deflated impact of fish and plant-based proteins in all PEF impact categories besides WU - where plant-based proteins' effect on the overall impact is accentuated in EFF, and OD – where EI database leads to a significantly higher impact of fish. These results should however be interpreted with care, due to the difference in geographical scope, inventory availability and modelling in the three databases. As shown in SM3 (Supplementary Information 3.2), while AGB is modelled on a coherent geography (i.e. France), building on EI entailed the need to select inventories modelled for different countries. Moreover, while EFF allowed to select country-specific inventories, the confidence of background processes' representativeness is low for most impact categories (Merieux NutriSciences & RIVM, 2025). It is worth considering that 11 and 24 ingredients included in the tool where not available in EFF and EI respectively.

Different monetization factors - Following 100k simulations of different combinations of monetization factors, the sensitivity analysis showed that the total environmental costs could range from a minimum of €39.8 (€26.8), to a maximum of €367.5 (€237.20) in the AT-s (in the IT-s). Hence, by choosing different monetization factors, environmental costs could be under- or overestimated by 63% or 234% respectively. Most of the simulations range in a cluster between €80 and €150 (€60 and €100) and one between €275 and €325 (€175 and €210) in the AT-s (in the IT-s).

Different allocation approaches – The testing of different allocation strategies illustrated that the chosen combination of "Equal per Capita" and "Economic Value" approaches distributes the largest share of carrying capacities if compared to the 2 alternatives. "Capability to Reduce" combined with "Economic Value", and "Historical Responsibility" combined with "Economic Value" assigned respectively 19 and 34 times (13 and 24 times) smaller shares of all PEF categories'

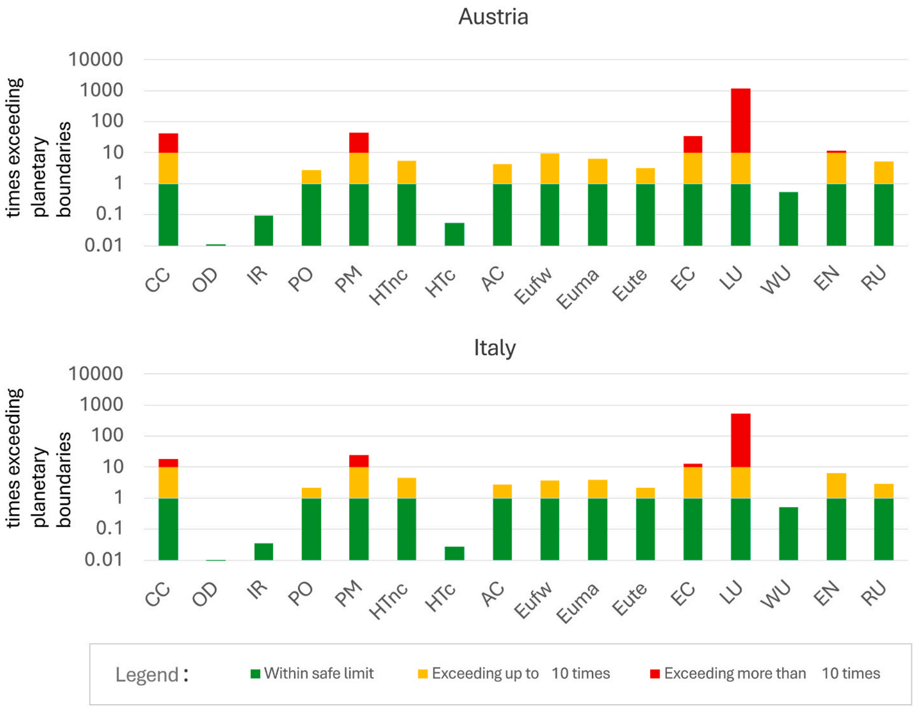


Fig. 5. Exceedance of planetary boundaries of total food waste environmental impacts, for the Austrian and Italian sample. AC = Acidification; CC = Climate change; EC = Ecotoxicity, freshwater; EN = Resource use, fossils; Eufw = Eutrophication, freshwater; Euma = Eutrophication, marine; Eute = Eutrophication, terrestrial; HTnc = Human toxicity, non-cancer; HTc = Human toxicity, cancer; IR = Ionising radiation, human health; LU = Land use; OD = Ozone depletion; PM = Particulate matter; PO = Photochemical ozone formation, human health; RU = Resource use, mineral and metals; WU = Water use. Results are presented on a log10 scale, where 1 is 100% (maximum carrying capacity). For interpretation of the colour references in this figure legend, the reader is referred to the web version of this article.

carrying capacities in the AT-s (in the IT-s).

Different meal prices - The sensitivity analysis on meal prices demonstrated that in the case of the AT-s choosing the lowest meal price retrieved for the allocation would produce a 17% increase in carrying capacity exceedance in all the impact categories, while in the IT-s the exceedance would be 113% higher. Using the maximum meal price retrieved for the carrying capacity allocation, the exceedance in all the impact categories would see a 42% decrease in the AT-s and 31% in the IT-s.

Environmental impacts' estimations of complex recipes – The analysis of complex recipes showed that for the selected samples, the tool is expected to estimate between 80 and 95% of the total impact generated by food waste in the most relevant impact categories - CC, PM, LU, EC, EN. This result is consistent with the overarching design of the tool, which includes impacts related to transportation, packaging and distribution of the raw ingredients, and those connected to transformation (cooking) and EoL (waste management). These findings should however be interpreted with prudence, as the analysis was conducted on a small sample of recipes.

4. Discussion

4.1. Quantification of FW impacts is instrumental in tailoring effective prevention strategies

Monitoring of FW impacts is essential to provide accurate diagnostics and inform decision-making (de Laurentiis et al., 2020). This work highlights how precise quantification, coupled with robust sustainability assessments through accessible tools, can better guide practitioners towards interventions that are suitable to their contexts and FW patterns.

First, standardizing food waste monitoring and sorting procedures is key, as methodological inconsistencies still challenge comparability across different school food environments and countries (Corrado et al., 2019). Collecting harmonized data allows for benchmarking with reference values, which enables practitioners to accurately interpret results. Second, identifying environmental hotspots and associating them with market costs of ingredients through environmental monetization can support the evaluation of trade-offs and better inform food service stakeholders to design FW reduction interventions.

The rapid assessment tool presented in this paper shows how FW's impacts can be linked also to dietary patterns and procurement decisions (Iori et al., 2022), not only to food service efficiency and behavioural drivers. The composition analysis of the waste streams in the two case studies underlines how the FW quantity and associated environmental impacts are directly linked to the menu composition and the food service operations, as the two case studies analysed differ in the FW hotspots. In the AT-s beef, dairy products, and soup contribute the most to overall impacts (especially CC, LU, Eut), while in the IT-s, starch-based fractions, fish, fruits and vegetables are the most impactful. Moreover, vegetables and salad waste in both countries is contributing significantly to specific impact categories, namely WU and EC. The prominence of PW in the IT-s' case studies, compared to the SW in the AT-s, highlights the importance of the organization of food service in understanding and preventing FW. The differentiation of waste hotspots hints also at the importance of establishing a transparent nomenclature for the various waste fractions occurring at food service or consumer level, together with appropriate quantification methodologies (van Herpen et al., 2019).

4.1.1. Targeting waste hotspots

The reduction of meat and dairy waste would yield environmental benefits for both countries, but in the case of the AT-s it would represent a particularly effective prevention strategy to decrease overall environmental burdens, as confirmed by other authors (Azarkamand et al., 2024; Arrigoni et al., 2023). The absolute sustainability analysis points to other potential actions related to menu composition, as a few environmental hotspots, such as LU, PM, CC, EC, surpass their allocated planetary boundaries in both case studies. These results can illustrate an inherent dependence on resource-intensive food products in the design of school menus in the analysed sample. Food production and consumption is normally linked to the exceedance of most of the planetary boundaries (Rockström et al., 2025), highlighting how transforming the globalized food system is key to contain the triple planetary crisis. As highlighted by te Wierik et al. (2025), containing food system within a safe operating space would entail a substantial decrease in greenhouse gas emissions (CC), limiting the conversion of natural land into agricultural land (LU), as well as limiting the excessive use of inputs such as mineral fertilizers and pesticides (EC).

Many actions have been proposed to reduce food's environmental burdens, such as shifting to foods coming from low input agrifood value chains (Boeraeve et al., 2020), or circular waste management (Mak et al., 2020). More in-depth modelling would also be necessary to better understand context-dependent interventions, especially by comparing foods coming from different farming systems and supply chains.

Improved menu design towards more plant-based diets, coupled with an analysis of the root drivers of meat and dairy waste, should also be considered in the design of FW prevention strategies for the AT-s sample. In the IT-s, the starch portion size and acceptability of fish and fruit and vegetable products should potentially be targeted.

These considerations are connected specifically to the sample included in the data collection, and the strategies proposed are directly related to the environments where the tool was tested. The suggestion of context-specific interventions is also informed by direct involvement by the lead author in the data collection and a comprehensive analysis of each environment. The results from the sustainability assessment should also be complemented with in depth analyses of the food environments where waste occurs to account for feasibility or specific drivers of waste (Reynolds et al., 2019).

4.1.2. *Food service organization*

The use of the rapid assessment tool in the foodCIRCUS case studies highlights the importance of food service organization in guiding the choice of FW prevention actions.

In the IT-s, most FW occurs at the plate level, whereas in the AT-s it is mostly comprised of serving waste, as shown in Fig. 2. While in absolute terms the FW per meal in the IT-s was lower, the fact that it mostly comes from PW makes it unsuitable for reuse or redistribution and underscores the need for interventions in reducing the portion size (Visschers et al., 2020; Richardson et al., 2021), careful forecasting as well as possible redesign of the physical food environment. Conversely, in the AT-s unserved food could potentially be redistributed with appropriate conservation measures (Damiani et al., 2021).

These results reinforce the argument for tailored FW prevention strategies in collective service settings (Candeal et al., 2023). By linking diagnostic tools to actionable guidance, strategies designed at school level could be coupled with more systemic policy interventions, promoting coordination and amplifying the impact of FW prevention strategies – as for instance portion adjustments (Damiani et al., 2021), menu optimization (Petruzzelli et al., 2023; Caputo et al., 2017; Goggins and Rau, 2016) or procurement of foods produced under lower-input systems (Casonato et al., 2024). Furthermore, in educational settings such as the schools analysed in this work, a more systemic analysis to explore the synergies between food waste, food literacy, nutrition education and multilevel drivers is necessary to fully grasp the peculiarities of each food environment (Malefors et al., 2026).

The outcomes of this analysis point mostly towards demand-side interventions which aim to either restructuring the choice environment (food service organization) and/or targeting the most impactful hotspots by limiting the consumption of animal-based products above all. However, food waste reduction endeavours should be embedded in a cohesive mix of policies and interventions, that target both the demand-side and supply-side of food systems to ensure effectiveness (Lohmann et al., 2026). The shift towards less resource-intensive foods in terms of land or harmful inputs also needs to be supported by appropriate agricultural policies and supply chain governance. Ultimately, food waste and its substantial environmental impacts are intertwined with wider food system dynamics, which also need to be accounted for.

4.2. *Limitations and future research*

Overall, the sensitivity analyses demonstrate that the tool's results are robust in relative terms but highly sensitive in absolute magnitude to key methodological choices. The selection of background databases (AGB vs. EI and EFF) substantially affects impact levels and monetized costs, particularly for meat-based products, which show markedly higher impacts in EI and EFF, underscoring the strong influence of database scope, geographical representativeness, and inventory availability. In addition, monetization of environmental externalities shows a very stark variability based on the factors and approach used. While the explanatory power of the translation of environmental impacts into economic terms is key to help stakeholders to turn insight into action (FAO, 2024), this variability might further hinder results' comparability. On a similar note, absolute sustainability assessment results are likely to reinforce the LCA distortion linked to background databases, while also being very dependent on the chosen allocation strategy. As illustrated in the sensitivity analysis, alternative allocation assumptions based on Capability to Reduce or Historical Responsibility drastically reduce the allocated carrying capacities compared to the equal per capita baseline, leading to much higher exceedances of planetary boundaries. Variations in meal price also affect carrying capacity allocation and exceedance, with lower prices increasing and higher prices decreasing exceedance across both case studies – AT-s and IT-s. These limitations are bound to the fact that absolute sustainability assessment is a novel methodology still lacking adequate standardisation (European Commission. Joint Research Centre, 2025): however, its high explanatory potential resulted in it being increasingly recognized as key to benchmark and interpret the sustainability performance of food products and systems (Chandrakumar et al., 2018; Goss and Sherwood, 2024). The analysis of the tool's suitability to capture the impact of complex recipes indicates that the tool correctly captures most of total impacts in the most relevant PEF impact categories, supporting the acceptability of simplified recipe modelling while highlighting residual uncertainties for highly processed dishes.

Additional methodological limitations not explored through the sensitivity analyses are primarily linked to the modelling choices for the food items included in the tool. Despite the raw-to-cooked weight change correction factor implemented in the tool, different cooking times and practices could result in ingredients being subjected to different weight changes to those that have been estimated. However, the possibility to differentiate the cooking methods (both for type and energy sources) was preferred over the modelling of already cooked ingredients to allow for greater tailoring of the cooking processes. Another limitation relates to specificities of the food items. For instance, soup was a very relevant waste category in the AT-s, but its water content inflates its share in waste mass. However, a trade-off is present as soup cooking is highly energy-intensive due to long cooking times. Future modelling efforts could focus on building more accurate inventories and provide quality regionalized environmental impact data.

The use of AGRIBALYSE, a France-specific LCI database, introduces uncertainties when applied to other European countries' contexts, where farming, transformation and supply chain dynamics might differ. The choice of AGRIBALYSE was determined by its open access and ease of use, but points to other limitations in the modelling of land use (using mostly global flows instead of regionalized ones). As shown in the sensitivity analysis, choosing alternative databases – as for instance ecoinvent ® v3.11 or the European Environmental Footprint of Food databases – do not solve these issues, as similar problems connected with geographical representativeness, inventory data quality and estimation confidence arise. Investing research and resources in open-access, country-specific inventories—starting with the most consumed products in each country—would greatly improve the robustness of results and their explanatory potential. Another limitation connected with modelling results from the exclusion of some relevant processes, such as food packaging and food transportation (after primary processing) from wholesaler to cooking centre, which may lead to an underestimation of environmental impacts. The use of background databases for the modelling of agricultural products can also be considered a limitation, as differences between management systems are not fully grasped by LCA (van der Werf et al., 2020), together with the complete omission of potential benefits coming from agriculture in the form of ecosystems services.

Another limitation connected to the tool's assessment strategy arise because the tool currently assesses ingredients rather than complex recipes, which could be an important next step for scaling its applicability in real-world catering. The analysis of a subset of complex recipes revealed that the AI-powered recipe analysis proposed by this paper only partially compensate this: more complex modelling could enhance the quality of ingredients' composition estimations by expanding the ingredients' library with recipe-level data from caterers, as well as information on context-specific food production. The practitioners' expertise in collective catering and knowledge of the context are key to obtain solid and defensible results, as the AI-inferred recipe composition estimations are likely to be subjected to hallucinations, and they should be treated as a first screening assistance, and not as a full-fledged inventory modelling tool.

At last, while the short timeframe and geographical scope of the two samples presented in the study are adequate to show the tool functionality, these limitations hampered representativeness and cross-country comparisons. We expect that the tool transferability to other collective catering contexts in the EU than those where it was tested would require little to no adaptation, as the ingredients' list is wide and likely to meet different recipes and standards. However, the tool scalability and replicability in other geographical contexts hinge on data availability. Regionalized, modelling- and time-homogeneous LCA and economic data would be needed to for scaling the tool beyond the EU context. As for economic data, automating data integration from FAOSTAT and EUROSTAT through Application Programming Interfaces (APIs) could allow for dynamic updating of food ingredients' prices, enhancing replicability across countries and in different years.

5. Conclusions

This study proposes a tool to analyse the environmental and economic impacts of FW in collective catering and provides evidence from testing in a sample of schools in Austria and Italy. Its findings further highlight the importance of monitoring FW quantities and composition as a key step towards FW prevention and reduction. The tool stands out for its capacity to translate complex sustainability metrics in actionable information for collective catering practitioners, requiring few input data, but allowing for tailored parametrisation when more precise data is available. The results of the rapid assessment tool can support food services and other decisionmakers to navigate the complexity of FW generation, identify opportunities and tailor effective interventions. Reducing FW is a key element of the overall transition to more sustainable food systems and in the case of food services it can also contribute to greater operational efficiencies.

Embedding the tool in food service operations would further enable its use as a decision-support system for sustainable procurement, helping schools and providers balance nutritional, economic, and environmental dimensions in meal provision.

CRediT authorship contribution statement

Simone Amadori: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Cecilia Casonato:** Writing – original draft, Visualization, Investigation, Formal analysis. **Gudrun Obersteiner:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Matteo Vittuari:** Writing – review & editing, Validation, Supervision, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT to have suggestions to improve readability of the methodological section. Moreover, a script was used to perform automatic analysis of meal composition; details of this use are described in the methodology, and the script is provided in SM3 (Supplementary Information 1). After using this tool, the authors carefully reviewed and edited the text and the content generated as needed and take full responsibility for the content of the published article.

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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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.indic.2026.101228.

Data availability

Data are available in the Supplementary Materials.

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Glossary

AC: Acidification
AESA: Absolute Environmental Sustainability Assessment
AGB: AGRIBALYSE
AT-s: Austrian sample
CC: Climate change
EC: Ecotoxicity, freshwater
EFF: European Environmental Footprint of Food database
EI: ecoinvent ® v3.11
EN: Resource use, fossils
Eufw: Eutrophication, freshwater
Euma: Eutrophication, marine
Eute: Eutrophication, terrestrial
FW: Food waste
GDP: Gross domestic product
HTc: Human toxicity, non-cancer
HTnc: Human toxicity, cancer
IR: Ionising radiation, human health
IT-s: Italian sample
LCI: Life cycle inventory
LU: Land use
NCE: National cumulated emissions
OD: Ozone depletion
PB: Planetary boundaries
PEF: Product Environmental Footprint
PM: Particulate matter
PO: Photochemical ozone formation, human health
PW: Plate waste
RU: Resource use, mineral and metals
SW: Serving Waste
WU: Water use