

3. Experimenting Approaches to Food Waste Reduction and Monitoring in Universities

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ABSTRACT

Food waste represents a critical challenge in the transition towards sustainable and equitable food systems. Beyond prevention, complementary actions are needed, and universities can play a key role by implementing food waste reduction strategies, including surplus food redistribution.

Aligned with POLIMI's Strategic Plan, the School of Management designed and tested a surplus food management strategy within its catering services, coupled with the development of a monitoring system to quantify recovered surplus food. The experimentation was implemented between July and December 2025, focusing on lunch services. Results show that surplus redistribution is effective and that the monitoring system enables systematic data collection on user participation, surplus quantities and types, and redistribution processes. Despite some limitations, the resulting dataset provides a valuable pilot for developing standardized monitoring frameworks to support university food waste reduction initiatives.

3.1 Food waste challenges and universities' responses

Research demonstrates that the global food system is unsustainable and generates significant externalities (Halpern *et al.*, 2022; Springmann *et al.*, 2018). It plays a central role in the transgression of key planetary boundaries – the ecological limits within which human societies can safely develop (Te Wierik *et al.*, 2025) – by accelerating resource depletion, biodiversity loss, and climate change. These pressures, in turn, exacerbate food insecurity, diet-related challenges, and food waste (Boakes *et al.*, 2024; Crippa *et al.*, 2021; Willett *et al.*, 2019). Food waste represents a particular critical issue. Indeed, global estimates indicate that it accounts for 8-10% of total greenhouse gas emissions across the food supply chain and imposes annual economic costs of around USD 1 trillion (IPCC, 2019). Figures that stand in stark contrast to the persistence of high levels of food insecurity, with more than 673 million people facing hunger in 2024 (FAO *et al.*, 2025).

In response to these challenges, international agreements, including the *2030 Agenda for Sustainable Development* (SDG 12.3) and the *Global Biodiversity Framework* (Target 16), together with supranational strategies such as the EU *Farm to Fork Strategy*, have outlined a coherent roadmap for food waste reduction, stressing the need for coordinated action among public institutions, businesses, and civil society. In this view, universities are well positioned to contribute to food system transformation and food waste management through education, research, and the implementation of innovative food policies and practices. In recent years, universities worldwide have increasingly pursued sustainability objectives across campus activities, including food-related initiatives. This engagement is driven both by the significant volumes of food waste generated by university food services and by the growing emphasis on social responsibility associated with the universities' Third Mission (Quaglia, 2026; Todd & Faour-Klingbeil, 2024). Consequently, many universities have introduced strategies and programmes aimed at reducing food waste through improved management practices (Ahmed *et al.*, 2018; Doherty *et al.*, 2011). This approach also extends to food procurement strategies to prevent waste, as well as approaches to reuse or redis-

tribute surplus food generated by campus food services (Quaglia *et al.*, 2024; Cline *et al.*, 2022).

However, despite the growing relevance of this topic in higher education, research on food waste and surplus food management in universities remains limited. As noted by Leal Filho *et al.* (2024), existing studies provide only partial insights into the effectiveness of intervention models and their monitoring. Addressing this gap, this chapter illustrates an experimental initiative at the *School of Management (SOM¹)* of the *Politecnico di Milano (POLIMI)* aimed at testing a pilot food waste monitoring system.

Note 1.
The POLIMI School of Management is composed by two distinct bodies: the Department of Management, Economics and Industrial Engineering and Graduate School of Management.

3.2 POLIMI’s sustainability commitment

In recent years, POLIMI has strengthened the sustainability of its institutional activities through new programmes, governance arrangements, and monitoring systems. While earlier initiatives were already in place (e.g. the *2019 CO₂ Emissions Mitigation Plan*), substantial progress was achieved with the adoption of the *Strategic Sustainability Plan 2023-2025*, POLIMI’s first comprehensive sustainability strategy, articulating a unified vision across environmental, social, educational, and equity-related dimensions. A core element of the Plan is a systemic approach to monitoring and managing resource consumption in line with circular economy principles, integrating improved management practices, technological innovation, and active community involvement through a “leading by example” perspective. With regard to food waste, the Plan identifies two main objectives concerning reduction and monitoring, as illustrated in Table 3.1.

Table 3.1.
Food waste-related objectives in POLIMI’s *Strategic Plan 2023-2025*.

Objective	Target	Actions
Reduction of food waste	<ul style="list-style-type: none"> Zero food waste in 100% of catering services 	<ol style="list-style-type: none"> Technological innovation: implementation of an advanced food reuse system Partnerships: establishment of partnerships with companies and Third Sector organizations specialized in the redistribution of surplus food
Monitoring and reduction of waste	<ul style="list-style-type: none"> Reuse of 60% of no longer useful goods Monitoring of waste produced within the university 	<ol style="list-style-type: none"> Reduction of single-use products Prevention and separate waste collection Ecological areas and waste monitoring Innovation initiatives: local management of organic waste with the production of compost and biogas/ biomethane

In line with this, the *School of Management's Sustainability Plan 2023-2025* aims to promote sustainability-oriented initiatives within the Department. The SOM's Plan is structured around five strategic priorities and translates the POLIMI-level strategy into a set of operational objectives at the department level. With regard to waste management, and food waste in particular, the Plan identifies the following contributions:

- Reduction of food waste in catering services by promoting POLIMI initiatives.
- Promotion of waste reduction through initiatives aimed at reuse-oriented initiatives.
- Implementation of monitoring systems for waste and water consumption.

More in detail, the SOM has defined targeted actions and Key Performance Indicators (KPIs) to ensure coherence with the POLIMI's strategic objectives, as shown in Table 3.2.

POLIMI's Strategic Plan objectives	Actions	SOM's KPI	SOM's expected results
Reduction of food waste	Promote POLIMI's initiatives by developing projects for the reuse of surplus food	1. Reduction of waste in DIG catering services 2. Reduction of waste in GSoM catering services	1. 100% of catering services adopting food waste reduction practices 2. 70% of catering services adopting food waste reduction practices
Monitoring and reduction of waste	Implementation of a waste monitoring system	Activation of a monitoring system	Monitoring system effectively implemented

Within the SOM a dedicated programme – i.e. the *SOM for Food Waste Reduction* – has been activated for recovering surplus food generated through internal catering services. This requires coordinated actions across the procurement and food service value chain. Accordingly, sustainable procurement practices based on collaborative supplier partnerships play a central role. To operationalize the programme, a collaborative model involving three key actors was established:

- Catering service supplier, responsible for ensuring the safe management of surplus food and its transfer to designated beneficiaries.

Table 3.2.
SOM's food sustainability objectives.

- Internal beneficiaries, namely members of the SOM community, who can receive surplus food recovered on-site.
- External beneficiaries, including local parishes and Third Sector organizations that redistribute surplus food to individuals in need.

This configuration establishes a comprehensive food waste prevention loop, with surplus food recovered through both internal and external channels, in line with procurement guidelines on waste reduction (Boyano Larriba *et al.*, 2019). However, after two years of piloting, a robust assessment of the programme required the quantification of both surplus food generated and recovered. To this end, a monitoring system was developed and tested within catering services at the *School of Management*, in collaboration with a single catering supplier.

3.3 Experimenting a monitoring system in catering services

To assess the programme's effectiveness, a structured data collection matrix was designed for catering services. As shown in Table 3.3, the matrix defines the KPIs included in the monitoring framework, specifying for each indicator its description, calculation method, unit of measurement, and analysis dimensions (e.g. food category).

To compute the indicators, a set of methodological assumptions were defined. First, the analysis was limited to lunch catering events, as these provide nutritionally balanced meals. Events such as coffee breaks and happy hours were excluded, as the food offered does not constitute a full meal.

CO₂ emissions avoided were estimated using the *FAO Food Waste Footprint* benchmark (FAO, 2013), applying a conversion factor of 2.5 kg CO₂e per kg of mixed food waste. Water footprint avoidance was calculated based on Mekonnen and Hoekstra (2012), assuming 1,000-2,000 litres of water per kg of mixed food, reflecting the composition of meals served. This estimate refers to the avoidance of wasting embedded water rather than direct production savings.

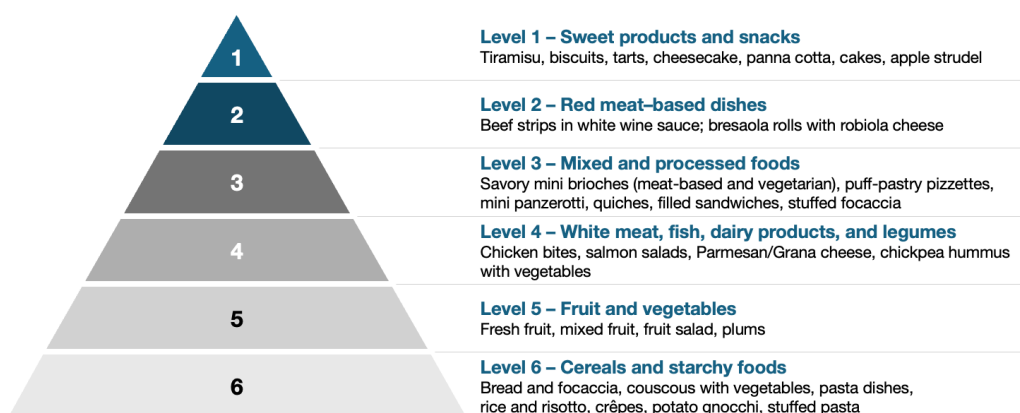
Moreover, equivalent meals donated were calculated using a standard factor of 500 g per meal, as defined by Fondazione Banco Alimentare (2024) and based on LARN guidelines (SINU, 2024).

KPI	Description	Metric	Unit of Measure	Analysis Dimension	Reference
Total amount of surplus food generated	Measures the quantity of food ordered for catering services that remains uneaten and becomes surplus	(Total amount of food provided)	[kg]	Food category (*)	
Total amount of surplus food reused	Measures the quantity of food ordered for catering services that is effectively recovered and redistributed for human consumption	(Total amount of food provided)	[kg]	Food category (*)	
Percentage of surplus food reused	Measures the proportion of surplus food that is effectively recovered and redistributed for human consumption	(Total amount of food recovered [kg] / Total amount of surplus food [kg]) * 100	Percentage (%)	Food category (*)	
CO₂ emissions avoided	Measures the reduction of CO ₂ emissions avoided by preventing food waste through redistribution	(2.50) * total amount of surplus food reused	CO ₂ equivalent	Food category (*)	<i>FAO Food Waste Footprint (2013)</i> assumed an average of 2.5 kg CO ₂ e per kg of food waste
Avoided water footprint	Liters or cubic meters of water embedded in food that would have been wasted if the food had been discarded	[1,000-2,000] * total amount of surplus food reused	Liters or cubic meters	Food category (*)	<i>Mekonnen and Hoekstra (2012)</i> assumed 1kg of mixed food requires 1,000-2,000 litres of water
Equivalent meals donated	Number of meal portions provided through redistribution	(Total amount of food redistributed / Average weight of a meal)	Absolute number	Food category (*)	<i>Fondazione Banco Alimentare (2024)</i> assumed an average meal weight of 500 g for the estimation
Total number of participants	Number of participants to be served by the catering service				

Table 3.3.
The data collection matrix tested.

Drawing on above assumptions, authors collaborated with the catering supplier to define standardized operational procedures. For each event, measurements were conducted onsite by a trained, dedicated student, temporarily hired for the experimentation, and carried out in compliance with food safety and hygiene protocols. At the end of each service, surplus food was weighed prior to distribution to internal or external recipients, distinguishing total surplus food from the share suitable for recovery. Food items were classified according to a six-level food pyramid (Figure 3.1), adapted from Romero-Tapiador *et al.* (2024), enabling the analysis of differences across food groups in surplus generation and recovery rates.

Figure 3.1.
Six-level food category pyramid (based on Romero-Tapiador *et al.*, 2024).



3.4 Results and implications

The monitoring covered 26 lunch events held at the SOM between July and December 2025 (see Table 3.4). Across all events, total surplus amounted to 115.39 kg, of which 111.16 kg were recovered, corresponding to a recovery rate of 96.3%. On average, each event generated 4.44 kg of surplus food, with 4.28 kg effectively recovered and redistributed.

Most recovered food was redistributed and consumed internally within the SOM community, with occasional external redistribution to local parishes. This arrangement reinforces the programme’s social purpose of the programme and is supported by trust-based agreements with external partners ensuring timely collection and compliance with food safety requirements.

Table 3.4.
Amount of surplus
food generated and
recovered.

Code event	Number of participants	Amount of surplus food [kg]	Amount of surplus food recovered [kg]	Percentage of surplus food reused (%)
1	40	3.3	3.3	100%
2	20	2.3	1.3	55%
3	50	5.5	3.6	66%
4	30	5.2	5.2	100%
5	35	7.0	7.0	100%
6	30	1.4	1.4	100%
7	30	5.7	5.7	100%
8	35	1.1	1.1	100%
9	20	4.6	4.6	100%
10	35	6.1	6.1	100%
11	40	5.0	5.0	100%
12	25	5.0	5.0	100%
13	20	1.9	1.9	100%
14	20	1.9	1.8	91%
15	15	3.8	3.8	100%
16	35	1.2	1.2	100%
17	25	7.5	7.5	100%
18	27	5.1	5.1	100%
19	60	5.4	5.4	100%
20	75	1.7	1.7	100%
21	50	0.1	0.1	100%
22	20	3.5	3.5	100%
23	90	6.9	6.9	100%
24	45	9.6	9.6	100%
25	40	5.0	5.0	100%
26	50	9.5	9.5	100%

Table 3.5 indicates that *Level 6* (cereals and starchy foods) and *Level 3* (mixed and processed foods) account for the largest share of re-covered surplus, reflecting their prominence in menu composition. Recovery rates are close to complete across all categories, except for *Level 5*, where approximately one-quarter of surplus remains unrecovered, likely due to the higher perishability of items such as fruits and vegetables.

Table 3.5.
Surplus food categories.

Food category	Surplus (kg)	Recovered (kg)	Recovery rate
Level 1	9.1	9.1	100.0%
Level 2	0.3	0.3	100.0%
Level 3	21.9	21.9	100.0%
Level 4	5.6	5.6	99.6%
Level 5	13.2	10.1	76.5%
Level 6	65.0	63.9	98.3%

With regard to the socio-environmental impacts of the programme, and considering recovered quantities only, the 111.16 kg of food recovered during the monitoring period correspond to around 278 kg of CO₂-equivalent emissions avoided. In terms of water use, this amount translates into estimated savings ranging from roughly 111,000 to 222,000 litres. When expressed in equivalent meals, using the Fondazione Banco Alimentare's standard of 500 grams per meal, the recovered surplus food corresponds to 222 meals redistributed.

Considering these figures and extrapolating the results to the total of 133 lunch catering events held at SOM in 2024 (excluding those held at the Graduate School of Management), authors estimate the programme's annual potential impact (Table 3.6). Indeed, assuming a constant recovery rate, the programme could generate approximately 502 kg of surplus food, of which about 483 kg would be recovered and redistributed. This would correspond to 1,207 kg of CO₂-equivalent emissions saved, a water footprint reduction of 490,000 and 960,000 litres, and the redistribution of around 965 equivalent meals.

Table 3.6.
Socio-environmental impacts of surplus food recovered.

KPI	Projected annual value	Assumption
Total amount of surplus generated	501.52 kg	<i>The annual number of lunch events was estimated at 133, drawing on historical data on lunches held at the SoM in 2024</i>
Surplus recovered	482.96 kg	<i>Constant recovery rate (96.3%)</i>
CO₂ emissions avoided	1,207.41 kg CO ₂ e	<i>FAO factor: 2.5 kg/kg</i>
Water footprint avoided	490.000-960.000 L	<i>Mekonnen & Hoekstra (2012): 1000-2000L per kg</i>
Equivalent meals	965 meals	<i>500 g/meal (Banco Alimentare)</i>

The monitoring system tested can be considered effective in providing a more granular understanding of the functioning of the *SOM for Food Waste Reduction programme*. By systematically measuring surplus food generated within internal catering services, the system produced evidence indicating that the programme enables the annual recovery of half a tonne of surplus food. This result reflects the effective implementation of redistribution measures by the actors involved and demonstrates significant socio-environmental benefits, while contributing to the objectives of the Strategic Sustainability Plans of both POLIMI and the SOM.

The experimentation also generated insights to inform potential refinements to SOM procurement and operational processes. Although overall recovery rates are high, surplus generation appears to be largely driven by structural factors inherent to catering services. Event-level data suggest that surplus is influenced by attendance variability and menu composition, whereby some categories (e.g. Levels 6 and 3) are supplied in larger quantities, while others (e.g. Level 5) are less suitable for redistribution due to higher perishability. Additional factors include portioning practices linked to precautionary over-preparation and buffet service formats requiring a perception of abundance. Taken together, these elements highlight the importance of more flexible, data-informed forecasting practices in food procurement to reduce surplus generation at source and improve overall efficiency.

Despite positive results obtained, this experimentation presents some limitations, primarily related to data collection. These include the limited availability of sensitive information that catering suppliers are not always willing or able to share (e.g. precise quantities of food served). Additional challenges emerged during the initial phase, notably operational constraints associated with weighing surplus food within the short time window between the end of the service and its internal or, in some cases, external redistribution. In this regard, future experimentation could expand the monitoring framework by incorporating additional analytical dimensions, such as participant characteristics (e.g. gender composition), attendance variability, and menu formats, and their influence on surplus food generation.

In this light, further development is needed to move from an experimental setup to a systematic and continuous monitoring system.

Although event-by-event measurement by a dedicated operator ensured high data accuracy, this method is unlikely to be scalable or economically viable if applied on a daily basis across all catering services. Future efforts should therefore focus on the design of a lightweight, periodic monitoring plan that combines different measurement strategies. For example, direct weighing could be applied to a sample of representative events, while routine events could rely on estimation models based on historical averages, participant numbers, and menu composition. Such a hybrid approach would ensure ongoing oversight of surplus food trends while substantially reducing the associated operational burden.

In conclusion, it is important to stress that the monitoring system should be understood as a component of a broader university strategy addressing sustainability in general and, more specifically, the development and implementation of University Food Policies. Its application may be relevant not only for other POLIMI departments but also for universities operating under different food waste prevention and surplus redistribution arrangements. Extending the recovery model and monitoring framework in other settings would enable cross-contextual comparisons, enhance institutional learning, and inform the formulation of a standardized university-wide approach.

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