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# Making food waste illegal in Sweden – Potential gains from enforcing best practice in the public catering sector

Mattias Eriksson [a], Jonas Christensen [b], Christopher Malefors [a,*]

[a] Department of Energy and Technology, Swedish University of Agricultural Science, Box 7032, 75007 Uppsala, Sweden
[b] Ekolagen Miljöjuridik AB, Östra Ågatan 53, 75322 Uppsala, Sweden

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ABSTRACT

Food waste is an inefficiency problem that needs to be reduced significantly to achieve a sustainable food system. Best practices and knowledge are available on how to reduce waste but large volumes of food are still wasted every year, so policies that support or enforce broader implementation of best practices are needed. One policy that could be used to push implementation and successful use of best practices to reduce food waste is the Swedish Environmental Code, which states that all actors must consider every possibility to reduce the amount of waste generated in any facility, unless this is unreasonably expensive. However, there is no clear definition on the actual waste reduction needed to comply with this requirement, so it is not enforced in practice.

This study explored the potential gains of applying the Environmental Code, potential benchmarking thresholds for illegal levels of food waste and best voluntary practices that can achieve low levels of food waste. The Environmental Code is applicable to most operator food handling systems, and was assessed here using the Swedish public catering sector as a case. All 290 Swedish municipalities were asked to provide raw data for the study and some agreed, resulting in a dataset covering 458 public catering units serving care homes, schools and preschools. The data were analysed to identify different permissible levels of food waste, while the best canteens provided information on their best practices to keep food waste low.

The results showed that with best voluntary practice for each type of catering unit, overall food waste would be reduced by up to 76 %. Best voluntary practices used by the best-performing canteens were identified as: 'reusing buffet leftovers', 'adjusting recipes based on previous consumption', 'advising guests to start with small tasting portions', 'setting goals for waste reduction' and 'serving smaller volumes in buffet containers and refilling more often'. All these actions can realistically be implemented as standard practices by public catering organisations. The present analysis could not confirm that all these actions have actually been implemented, or to what extent, but practical implementation of identified best voluntary practices meeting stated benchmarks is recommended.

The Environmental Code is technology-neutral and goal-oriented and participating food business operators are not forced by law or official regulations to introduce resource-saving measures, but this study shows that some measures can lead to a large reduction in food waste. The study does not show whether harsh, i.e. costly, measures can be enforced on businesses, which can only be determined by case law (court practice). However, in the specific cases in this study, measures that could have been enforced based on the Environmental Code would have led to at least 76 % reduction in food waste. This would be a major step towards a sustainable food system.



## 1. Introduction

Population growth is driving demand for expansion of food production, imposing increasing pressure on natural resources (FAO, 2019). Each year until 2050, global agriculture will have to feed an additional 40–86 million people (Fyles and Madramootoo, 2016). With increasing food demand, solutions must be found to secure food for everyone, in both current and future generations. This will require changes in the way food is produced, stored, processed, distributed and consumed, since the current system relies heavily on non-renewable resources. The best way to secure future global food supply is the subject of intense debate, but there seems to be consensus that food waste needs to be reduced drastically (Awan, 2020). The United Nations Sustainable

* Corresponding author.
*E-mail address:* christopher.malefors@slu.se (C. Malefors).

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Development Goals state that food waste should be halved by 2030, but some claim that this goal is not sufficiently ambitious and that a 75 % reduction needs to be in place by 2050, along with implementation of other options, to remain within safe planetary boundaries (Campbell et al., 2017; Springmann et al., 2018). However, regardless of the level of ambition, there is little chance of meeting any target if nothing is changed in the current food system.

Causes and risk factors for waste generation are often complex and interconnected in the food system, making them difficult to solve by single actions or solutions (Canali et al., 2014; Vittuari et al., 2015). Moreover, a solution that is suitable for one stakeholder may just shift the burden of food waste to another stakeholder (Eriksson et al., 2017a). What is needed is therefore not just measures to reduce food waste, but policy instruments that enforce or incentivise a behaviour where all stakeholders strive to reduce food waste. Such instruments can be either market-based mechanisms that make it more expensive to waste food or binding regulations that enforce a certain behaviour, or a combination of both types of instruments. Binding regulations force actors to meet specific standards, but detailed knowledge and insights are required to set appropriate standards and an authority is needed to monitor compliance (Baldwin et al., 2011). Knowledge is also required on where in the food chain regulations should be implemented in order to have the best effect and a minimum of unwanted side-effects (Christensen, 2000). The alternative, a softer and flexible system of market-based instruments, would create economic incentives through tax exemptions, refund schemes and deductions, with the purpose of triggering behavioural changes. Market-based instruments have the benefit of requiring less governance and could therefore be more cost-effective to implement than legal instruments. Economic incentives could also be iterated to fine-tune the level needed for compliance (Héritier, 2002). However, all economic incentives may fail to reduce waste if the stakeholders are motivated by factors other than finances (Bailey, 2002). A system that combines the cost-effective implementation and fine-tuning possibilities of economic instruments with the standards detailed through legislation could therefore be the best approach to drive the food system in the direction of less resource consumption.

Some previous studies have described policy implications or frameworks for food waste management in different parts of the food system (Papargyropoulou et al., 2014; Schanes et al., 2018; Thyberg and Tonjes, 2016), but little research attention has been devoted to the role of regulations and their interactions in meeting food waste goals. A well-known exception is the Good Samaritan Law in Italy (Law 155/2003), which limits the food safety liability exposure of companies donating food for charitable purposes to the level of food banks, and not to the consumers who receive food from food banks (Canali et al., 2014; Vittuari et al., 2015). Another example is the French legislation forcing supermarkets to have a contracted food bank that can receive their surplus food donations (Giordano et al., 2020; Mourad, 2015). Both these regulations may serve their purpose, or at least send a clear signal, but they only regulate the relationship between food donors and food banks, making food donations easier. This will increase sustainability, but is unlikely to be sufficient to meet the target of halving food waste generation (Bergström et al., 2020; Sundin et al., 2022).

In some circumstances, additional policies may not be needed to achieve transition towards reduced food waste generation. If the barriers to stakeholders imposed by existing policies were better understood, half the work might be done. One such example is the Swedish Environmental Code (Swedish Code of Statutes, SFS 1998:808), established in 1999 as the main environmental legislation in Sweden. It includes regulations on waste and management of natural resources and, in the perspective of food waste, aims to ensure that food handling takes place in such a way that environmental and health problems are minimised to the greatest extent possible and reasonably in relation to costs. Extensive food wastage must therefore in some cases be viewed as illegal in Sweden, but this is not enforced by the authorities and there are currently no practical limitations on food waste generation. However, since the Environmental Code is already in place, together with a network of authorities to enforce compliance, introduction of a legislative barrier to extensive food waste could be fairly simple.

The advantage with the Environmental Code is that it applies to all activities {*verksamheter*} and measures [*åtgärder*] in Sweden, including many kinds of food business operators. In the Code (ch. 2 s. 3), this is made clear by the addition: "Persons who pursue an activity or take a measure, or intend to do so, shall…" [*Alla som bedriver eller avser att bedriva en verksamhet eller vidta en åtgärd ska…*]. Specifically, the Code applies to all activities and measures that are relevant to the objectives of the Environmental Code, in parallel with other legislation governing relevant activities (Swedish Government, 1997). The General Consideration Rules in chapter 2 of the Code apply to all activities that may be of significance for achievement of the main goal of the Code (sustainable development) (Swedish Government, 1997). One important rule is the general provision on resource conservation (ch.2, sec. 5).

The Code includes the following basic provisions: Reverse burden of proof (ch. 2 s. 1), i.e. the operator must prove that the business complies with the law; a knowledge requirement (ch. 2, sec. 2), i.e. all operators must have sufficient relevant information about their own facility and the risks to human health and the environment; taking precautionary measures etc.; using the best possible technology (ch. 2, sec. 3); product selection; and resource conservation and ecocycling (ch. 2 s. 5). It is explicitly stated that the Code must be applied so that reuse and recycling and other management of materials, raw materials and energy are promoted, and ecocycling is achieved. Since the purpose of the Code is to achieve sustainable development (ch. 1 s. 1, with reference to the World Commission on Environment and Development, 1987), it aims to protect the environment and people in an indefinite future. It can be said that wasting natural resources (and energy) is an independent protection object for the Code, in parallel with pollution, degradation of biological diversity and risks to human health. All provisions of the Code must be interpreted in light of this overall picture, expressed in the portal section (ch. 1 s. 1).

The Environmental Code requires (ch. 2 s. 3) best possible technology to be used in professional activities. This is not exactly the same as best available technology, for example as defined in EU Directive 2010/75/EU art. 3.10. The Code states that (Swedish Government, 1997/98:45) "By best possible technology is meant technology that is economically and technically possible for the industry typically." This means the best technique globally, but taking into account the current economic situation of the specific Swedish sector in question (Michanek and Zetterberg, 2021). The term 'best possible technology' includes both the technology used and the way in which a facility is designed, built, maintained, operated and decommissioned (Swedish Government, 1997/98:45; Michanek and Zetterberg, 2021).

Despite the ambitious wording in the Swedish Environmental Code, there is a lack of clear definitions on what should be considered normal food waste and what should be considered best possible technology to reduce food waste. According to Escudero Saukko (2020), this is the main barrier to Swedish authorities applying the Environmental Code to force food business operators to reduce food waste. The authorities also argue that they lack the resources for monitoring compliance with the Code. It can therefore be argued that practical implementation of the Environmental Code in reducing food waste will have to build from scratch. This is certainly correct for all new types of business to which the Environmental Code is applied, but as legal decisions and court cases are appealed over time, guiding case law will emerge, as in other sectors in society. A type of general environmental regulation has existed in Sweden since 1969 when the Environment Protection Act [SFS 1969:387] entered into force, although requirements on resource management were first introduced with the Environmental Code in 1999. There is a lack of knowledge about whether stricter application of the Environmental Code could help reduce resource wastage in the food chain, simply because the relevant authorities have not yet attempted to apply the Code in this way.

In our opinion, the Environmental Code and established authority structures already provide a fairly solid basis for stricter application of the Code, which can be done in four steps: i) checks by the authorities, which can already be partly funded by environmental inspection fees paid by business operators, so there is an established way of acquiring the necessary economic resources; ii) forcing (ch. 26 s. 22) food business operators, with the support of rules on self-monitoring in the Code (ch. 26 s. 19), to quantify food waste, in order to gain sufficient information before applying the environmental code to the food chain, as is already common practice in many Swedish sectors (e.g. Eriksson et al., 2018a, 2018b); iii) identifying best practices and requiring their implementation; and vi) requiring reporting of level of compliance, which is unknown to the public but already known to the best-performing operators.

The aim of this study was to assess the food waste reduction that could be achieved by applying the Environmental Code to control food waste. In order to limit the scope of the analysis, the Swedish public catering sector was selected as an example. It was chosen because best voluntary practice is already in use and data are available for assessing the sector's potential for limiting food waste generation to certain benchmarks that are achievable with current technology. Specific research objectives were to: 1) Identify best voluntary practice and best available technology implemented in Swedish public catering; 2) find a benchmark for how much food waste is generated by the currently best-performing units in the Swedish public catering sector; 3) calculate the potential waste reduction that could be achieved if all units were to reach a certain benchmark; and 4) discuss how the findings could support practical implementation of the Swedish Environmental Code to control food waste generation, and thus reduce food waste.

## 2. Materials and Methods

The Environmental Code could be enforced at most stages of the food supply chain in Sweden, but there were practical limitations on what could feasibly be evaluated within the scope of this study.

The Environmental Code is already applied to parts of the food chain, e.g. slaughterhouses and other processing facilities for food products, in terms of their impact on the environment and human health. In many cases, these businesses also require a special environmental permit or notification to be established (see Ordinance on Environmental Permit Review and Notification, SFS 2013:251), besides approval under the food legislation. A novel aspect of the present study is that it examined application of the Environmental Code to other parts of the food chain that do not cause major disturbances to the environment or human heath, but where large amounts of food waste can be assumed to occur, e.g. shops, restaurants, commercial kitchens and other retailers.

Many businesses in Sweden quantify their food waste regularly (e.g. Brancoli et al., 2019, 2017; Eriksson et al., 2014, 2012), but the data obtained are generally considered a company secret. However, public sector catering organisations are normally obliged to share information relating to their performance, e.g. on food waste generation. Beside the possibility to access data in a standardised format well described in previous studies (e.g. Eriksson et al., 2020, 2018a, 2018b; Persson Osowski et al., 2022), the Swedish public catering sector is also a relevant example due to its relatively high level of food waste, normally around 20 % (Malefors et al., 2019) and to large variations in food waste generation between different catering units (Eriksson et al., 2017b).

This study comprised four steps (Fig. 1): i) Collecting data of sufficient quality from as many schools, preschools and elderly care homes as possible; ii) using these data to identify the best-performing catering units in terms of low food waste generation and contacting these catering units to identify their best available technology or practices; iii) developing food waste scenarios with different benchmarks and calculating the potential waste reduction for each scenario; and iv) calculating the potential food waste reduction if all catering units in Sweden were to generate the same low level of food waste as the best-performing units.

### 2.1. Food Waste Data Collection and Compilation

All food waste quantifications were performed by the participating public catering organisations themselves, with the focus on weighing waste masses using various kitchen scales. The results of quantification were documented manually on paper or in spreadsheet software, although some kitchens used dedicated food waste quantification online applications provided by different software companies, and some kitchens used a dedicated smart scale similar to the systems used in Obersteiner et al. (2021) and Eriksson et al. (2019). A feature in common for all participating catering organisations was that kitchen staff performed the data collection on-site. Recorded data on number of portions served were used to set the waste in relation to number of guests served. Data were summarised on a daily basis per meal for each kitchen unit and most data only covered lunch, although establishments such as care homes and hospitals typically serve other meals as well. Only observations on mass of serving waste, mass of plate waste and number of guests served were included in the dataset analysed in this study, according to the procedure suggested by Malefors et al. (2019).

In order to base the assessment on stable quantifications, only catering units with at least 100 days of complete observations during 2019–2021 were included. This resulted in a total dataset (available in the Appendix) of 458 catering units, covering pre-schools, primary schools, secondary schools and care homes. These units belonged to 32 different catering organisations, representing both large and small municipalities and urban and rural areas. The size of the dataset meant that it provided a good representation of the variation within organisations and sectors. The full dataset represented a total of 1226 tons of quantified food waste, and all waste reduction potential was assessed as a percentage of this mass. The calculated values are of course not relevant for all public catering units in Sweden, but were used here to compare different scenarios in which different catering units produced different amounts of food waste in absolute terms, even though they might produce a similar mass of waste. The food waste generated in the Swedish public catering sector is normally treated by anaerobic digestion, and to some extent composting or incineration, and there is therefore no waste to be diverted from landfills. While food waste prevention will compete with recovery options like anaerobic digestion, there are wider environmental benefits in preventing this food from being produced in the first place.

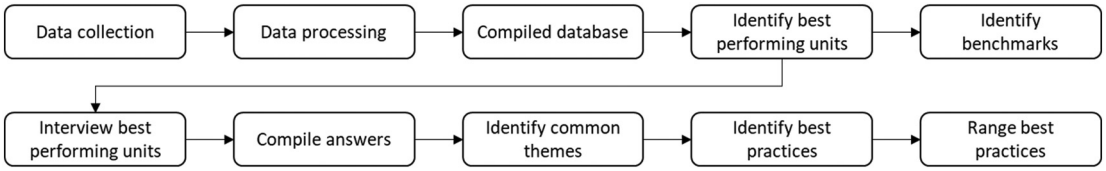


**Fig. 1.** Flow chart of the data collection and analysis process.

**Table 1**
Scenarios formulated and parameters tested in each scenario.

| Scenarios | Comparison with single best-performing unit | Comparison with 1st quartile best-performing unit | Comparison with median-performing unit |
|---|---|---|---|
| Comparison within the whole public catering sector | Scenario 1 | Scenario 2 | Scenario 3 |
| Comparison within each category | Scenario 4 | Scenario 5 | Scenario 6 |
| Comparison within each organisation | Scenario 7 | Scenario 8 | Scenario 9 |

### 2.2. Identification of Examples of Best Practice and Best Technology

The Environmental Code could be applied by authorities to force catering units to use best possible technology (ch. 2, sec. 3 and 7, h. 26 s. 9) in a broad perspective, similarly to what is normally referred to as best practice, i.e. it should achieve the same end-result but does not necessarily have to involve the exact same practices. The Code is technology-neutral and goal-oriented. Best possible technology refers to the best possible technology in use at full scale, in the same or similar sector at any site on the planet, so businesses cannot be forced to implement experimental techniques or innovations with low technology readiness level. This means that the types of routines, practices and solutions already implemented are the best possible voluntary technology. Best possible technology also means that the technology must not be unreasonably expensive in relation to its benefit.

For measures implemented voluntarily, it is not possible to determine whether they meet the requirements of the Environmental Code (ch. 2 s. 3) on best possible technology, because one cannot be sure that each individual food business operator has reached the limit at which measures can no longer reasonably be required under the Code (ch. 2 s. 7). It is important that the individual operator can demonstrate use of measures found to be possible and suitable by other food business operators. This shows that there are precautionary measures and limitations to setting requirements under the Code (ch. 2 s. 3). Best *voluntary* technology was chosen as a starting point in this study because none of the participating actors had adopted a goal or method based on an official requirement. The investigation was based entirely on measures introduced voluntarily by the participating food business operators at the time of data collection.

In order to identify best possible voluntary technology for the Swedish public catering sector, the 35 public catering units that generated the lowest level of total food waste per guest in the different sector segments (pre-school, primary schools, secondary school and care homes) were selected (10 of each except for elderly care, where five units were considered to provide a reasonable representations of best practice). As mentioned, the selection was limited to units with at least 100 days of food waste quantification during the period 2019–2021, in order to ensure consistency in the results and up-to-date data. All available data for each catering unit were used, in order to assess long-term stable performance rather than recent improvements that may only be temporary.

In a short telephone interview with each of the best-performing 35 public catering units, the kitchen manager was asked to specify the most important practices they use to keep food waste generation low. The managers were informed that these factors could be related to various areas such as routines, equipment, infrastructure, staff, incentives, goals/policy, support, menu and guests. The managers were also asked to state the greatest obstacles to reducing their food waste even further. Of the 35 catering units contacted, 31 agreed to answer the questions and participate in the study. Of the four non-participating units, two replied they did not have time to answer questions and two could not be reached despite multiple attempts by e-mail and telephone.

### 2.3. Design of Scenarios

To assess what could be considered excess food waste, scenarios with different benchmarks were developed and potential waste reduction was calculated for each scenario. The potential waste reduction was defined as all food waste above the benchmark for all units with food waste exceeding the benchmark in each scenario. Nine scenarios, divided into three groups and three levels of performance, were assessed (Table 1). The most obvious performance benchmark in practice would be the best-performing catering units and in theory it might be possible for all units to perform as well as these best-performing units, but in practice there might be obstacles and circumstances making this unreasonably costly to achieve. To create more achievable benchmarks, alternative scenarios were developed in which comparisons were made with

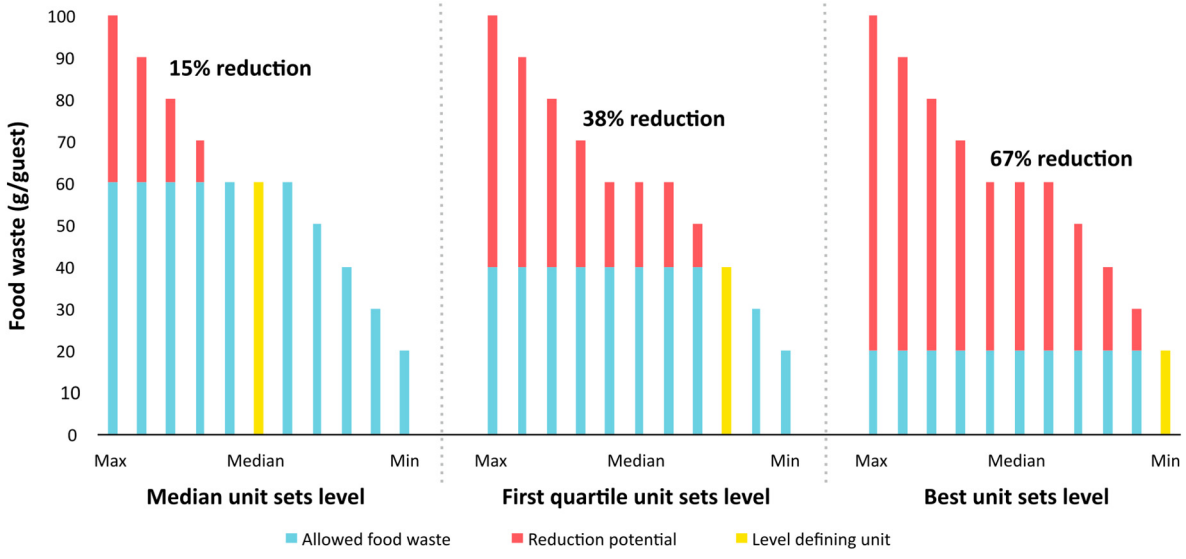


**Fig. 2.** Principle used for setting permissible food waste level, based on the public catering unit used for benchmarking, where the red area represents food waste reduction potential. Benchmarking based on (left) the median unit, (centre) the first quartile and (right) the best case, with food waste reduction potential of 15 %, 38 % and 67 %, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the 1st quartile and median-performing unit. The same principle was applied for the grouping of catering units. The most ambitious approach would be to compare all units as one group, but this might be an unrealistic comparison. Therefore, the comparisons were limited to within the same category of units or to groups of units within the same organisation (only for the 21 organisations with at least five units, while fulfilling all other requirements). The reduction potential in the latter scenarios was therefore in relation to the total mass of waste for these 21 organisations, which was 1186 tons.

As illustrated in Fig. 2, the principle on which the benchmark was based resulted in different amounts of deductible food waste. The food waste level was above the benchmark for approximately 50 % of the catering units when the median was used for benchmarking, for approximately 75 % of the units when the 1st quartile was used for benchmarking, and for all but one catering unit when the best case was used for benchmarking. The reduction potential was represented by the amount of food waste above the benchmark for each kitchen and unit, with a food waste level much higher than the benchmark offering larger reduction potential. Since the benchmark was set in relation to waste per number of guests served, canteens with a large number of guests also had greater reduction potential in absolute mass than canteens serving fewer guests.

## 3. Results

The results revealed large variations between the participating catering units in the amount of food waste they generated. The catering unit with the lowest level of daily food waste produced 11.4 g/guest on average, while the unit with the highest level produced 161 g/guest, i.e. a 14-fold difference. This variation can be taken to indicate reduction potential, which thus appears to be high in the Swedish public catering sector. The following sections examine practices that could be used to exploit this potential and assess the waste reduction potential for other levels of comparison than benchmarking against the best-performing unit.

### 3.1. Best Practice and Best Technology Identified

The best-performing unit in each sector had a food waste level of: 11–21 g/guest for primary schools, 17–27 g/guest for preschools, 31–61 g/guest for secondary schools and 32–48 g/guest for care homes. There were thus clear differences between the segments, with the best-performing secondary schools and care homes achieving a much lower level of food waste than preschools and primary schools.

The 31 best-performing catering units mentioned a total of 192 reasons or practices that (in their opinion) explained the low food waste levels. The most frequently mentioned practice was reusing leftovers, which was mentioned by all 31 respondents. When categorising the different answers into the categories planning, cooking, serving, communication with guests, and organisation and staff, it was clear that most of the participating catering units had similar practices in several of these categories (Fig. 3). The most commonly mentioned practice in the planning category was adjusting recipes based on previous consumption to cook the right amount (mentioned by 20 respondents), followed by the related practices of adjusting the menu to better fit local tastes (14 respondents) and acquiring precise information on number of expected guests in order to prepare the right amount of food (7 respondents). In connection with many of these statements, the respondents also mentioned the importance of trusting the plan or information and not adding an unnecessary large margin just to be on the safe side.

In the cooking category, the practice of cooking smaller batches was most frequently mentioned (8 respondents), but much less frequently than the planning practice of reusing leftovers. In the serving category, the most commonly mentioned practice was serving buffet food in smaller amounts and refilling often (mentioned by 17 respondents). This was followed by reducing the number and size of buffet containers or platters towards the end of the serving period to expose as little of the food as possible (8 respondents) and reducing the number of alternative dishes offered (4 respondents). In the category communication with guests, the most frequently mentioned practice for reducing food waste was advising guests to start with small tasting portions in order to avoid taking more than they want to eat (mentioned by 20 respondents) and informing guests about how much food is wasted through information boards or competitions (10 respondents). In the category organisation and staff, the most frequently mentioned practice was setting organisation-level goals for waste reduction or maximum food waste generation (mentioned by 20 respondents); five of the respondents mentioned that their organisation-level goal was to have less than 25 g of food waste per guest, but no other specific target was mentioned. The second most frequently mentioned practice in the category organisation and staff was collaboration with teaching staff, during the meal situation, where teachers act as role models, and during lessons on environmental awareness (including food waste reduction) (8 respondents).

| Process | Activity | Number of answers (n) |
|---|---|---|
| Planning | Adjust recipes based on previous consumption to cook the right amount | 20 |
| | Adjust menu to better fit local consumers´ taste | 14 |
| | Acquire precise knowledge of number of guests | 7 |
| | Tidy and well organised kitchen | 3 |
| Cooking | Reuse leftovers from buffet | 31 |
| | Cook in smaller batches to be flexible | 8 |
| Serving | Serve little on the buffet and refill often | 17 |
| | Reduce the number of buffet trays in the end of serving | 8 |
| | Reduce number of alternatives | 4 |
| | Sell leftovers as food boxes | 2 |
| | Serve vegetables in the simplest form | 1 |
| Communication with guests | Advise guests to start with small tasting portions | 20 |
| | Inform guests about how much food is wasted | 10 |
| | Build good relations with gurests | 8 |
| | Calm dining envrionment | 3 |
| | Present the food on a plate so guests can see what is served | 1 |
| | Put the waste bin behind a counter to make it more complicated to waste food | 1 |
| Organisation and staff | Goals for waste reduction or maximum food waste generation | 20 |
| | Collaboration with teaching staff | 8 |
| | Make staff aware of the food waste issue | 4 |
| | Personal responsibility for food waste | 1 |
| | Salary incentives for food waste reduction | 1 |

**Fig. 3.** Frequency of responses on different best practices and best available technologies used by the best-performing Swedish public catering units (n = 21) included in this study, divided into the categories planning, cooking, serving, communication with guests, and organisation and staff.

**Table 2**
Reduction potential in the different scenarios, expressed as percentage reduction in relation to the total mass of waste for all catering units in the dataset.

| Scenario | Comparison with single best-performing unit | Comparison with 1st quartile best performing unit | Comparison with median performing unit |
|---|---|---|---|
| Comparison within the whole public catering sector | −76 % | −28 % | −14 % |
| Comparison within each category | −71 % | −28 % | −15 % |
| Comparison within each organisation | −53 % | −23 % | −13 % |

Many of the practices and technologies mentioned by the respondents required e.g. proper equipment, competent staff, sufficient routines, support etc. and some of the respondents included these in their descriptions of the actions. The actions listed in Fig. 2 can therefore be viewed as simplifications, and in reality some are not possible to perform by all respondents (e.g. in a care home there are no pupils and no teaching staff to communicate with). However, all the actions are fairly simple and could be considered normal practice in a school canteen or similar establishment. This means that they might not represent best possible technology from a legal point of view, but rather "normal" (voluntary) practice, and should therefore be easier to enforce.

### 3.2. Potential Waste Reduction at Different Benchmarking Levels

The food waste reduction potential at different food waste benchmarking levels is displayed in Table 2. The results followed the expected pattern, with the strictest level of acceptable food waste resulting in the greatest reduction potential and dividing the material into subgroups resulting in smaller reduction potential. If all catering units were to reduce their food waste to that reported by the best-performing unit (11 g/guest), this would result in a 76 % reduction in the total mass of waste in the sector. The scenario where the best-performing unit within each segment was used as the benchmark was a close second in terms of waste reduction potential (71 %).

As can be seen from Table 2, selection of benchmark strongly influenced the results, with the comparisons with the best-performing units all giving greater reduction potential than comparisons with the first quartile unit. They in turn all gave greater reduction potential than comparisons with the median unit. This trend is further illustrated in Fig. 4, where the data have a 'tornado-shaped' distribution with high variation at the high and low end of the scale. The first quartile and median benchmarks were more similar to each other than to the best-performing unit. The same pattern applied to data organised in segments or based on organisations.

## 4. Discussion

This study examined the effects of voluntarily applying the principle of best possible technology, very close to best possible technology in the Swedish Environmental Code, which forbids generation of excessive food waste generation unless it is unreasonably expensive to reduce the waste. The Code has not yet been applied to the food chain, but the findings in this study confirm that its application could significantly reduce food waste generation among Swedish food business operators. The Environmental Code could be applied in a three-step process with the authorities focusing initially, but not solely, on the public catering *sec*tor.

The first step would be to force food business operators to record their food waste, in order to obtain sufficient knowledge. To simplify this, food waste recording routines could be a way of showing that the operator can meet the knowledge requirements of the Environmental Code (ch. 2 s. 1), and the requirement on self-monitoring (ch. 26 s. 19). The supervising authority could then compel a business operator to carry out investigations necessary for supervision (ch. 26 s. 22). It may be possible to include such investigations in the HACCP plans required by food legislation, but the fact that resource saving is not a subject for that legal area could be an obstacle. This would result in an interesting combination of requirements for HACCP work according to food legislation and self-monitoring requirements according to environmental legislation. The quantification standard established by the Swedish National Food Agency (2022) could be used as a minimum level. The 458 catering units represented in the dataset in this study provide clear evidence that it is possible to implement and maintain quantification data collection routines over time.

The second step in implementation of the Code would be to force food business operators, by law (ch. 26. sec 9), to adapt their operations so as to achieve the same level of waste minimisation as can be obtained using the best possible technology. However, authorities would only be able to require implementation of technology that is already operational at full scale and that can be implemented to a reasonable cost. It would

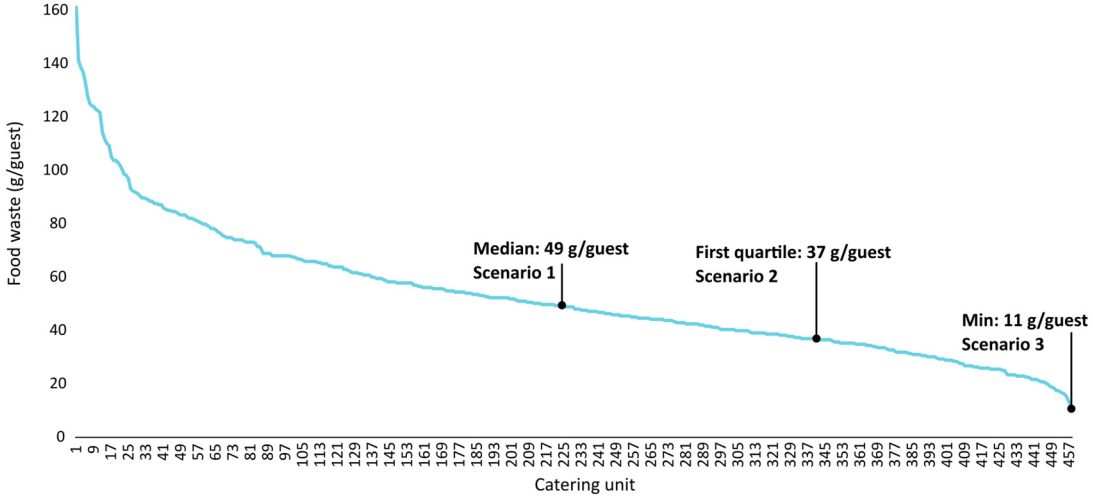


**Fig. 4.** Level of food waste in Swedish public catering establishments. The dots on the curve indicate the acceptable level of food waste defined in benchmarking against (right to left) the best-performing catering unit, median and 1st percentile.

also of course be easier for catering organisations to implement technologies that are both cheap and commonly available. In this study, the best-performing food business operators in the public catering sector (n = 21) considered best available technology to be: reusing buffet leftovers, adjusting recipes based on previous consumption, advising guests to start with small tasting portions, setting internal goals for waste reduction, and serving smaller volumes in buffet containers and refilling often, with all these practices mentioned by at least half of the respondents. All these practices are mentioned in the handbook on waste reduction published by the Swedish National Food Agency (2020), meaning that they can be considered well-known and 'normal' practice. They are also likely to be inexpensive to implement, as they can likely be performed with commonly available kitchen utensils and by staff with normal training for working in public catering, with no need for major investment.

The third step would be to force food business operators to reduce their food waste to below a certain benchmark level. This is probably the most complicated step in the process, as it requires knowledge of what is normal performance within the sector. This study demonstrated that different levels could be used as a benchmark and, with a greater level of openness about food waste data, appropriate information for benchmarking could become more publicly available in the future. Data availability is already good for the Swedish public catering sector, since the Swedish National Food Agency publishes annual quantifications on key performance indicators for food waste reduction (Fritz and Grausne, 2021). An updated best practice benchmark could easily be extracted from these reports.

If the Environmental Code were to be implemented in practice and the outcomes were as presented in this study, the potential for food waste reduction is high. If all catering units were banned from generating more food waste than the current best-performing unit, the reduction would be a staggering 76 % in comparison with the current level. If achieving the best-performing level is too extreme, a good starting point could be a less ambitious level, e.g. the median level (15 % reduction) or the first quartile level (28 % reduction). The benefit of these as benchmarks is that they are moving targets, i.e. they will become lower as catering units start to meet the required level of waste reduction, thus increasing the level of ambition over time. This will of course require a yearly update of the benchmark, but this can be considered a reasonable demand.

While the food waste reduction targets and best practices identified in this study seem very reasonable to achieve, it is still difficult to apply a new legal practice in an area where this has not been done previously, even though the legislation has been in place since 1999. Moreover, there are of course counter-arguments to the logic applied in this study, e.g. it might be more appropriate to increase the cost of food in order to avoid food waste, rather than to use the less fine-tuned legal approach. There are also methodological weaknesses with the study that could have affected the results. First, there is a risk that the data used are not representative for all public catering units in Sweden, as only public catering units that delivered data meeting several quality criteria were included in the study. However, it is very unlikely that the other catering units generate less food waste than those studied here, and in fact the risk is mainly that the potential was underestimated for the real-life situation. Second, the list of best practices reflected the respondents' opinions, but not necessarily their actions. They might have given responses that they believed the researcher wanted (potential social bias) or they may have described what they would like to do, rather than what they actually do. Since the replies were surprisingly similar to the recommendations made by the Swedish National Food Agency (2020), there is also a risk that these recommendations were taken by the respondents as the 'correct' answers. A third weakness, already mentioned above, is of course that best practice in this study is best voluntary practice. As long as the demands are not formally set by a court or authority, and have not been the subject of an examination in the Land and Environment Court of Appeal, the limit below which demands can be considered reasonable to make (ch. 2 s. 7) is not known.

However, the best practices identified corresponded well with findings in other studies, e.g. Wunder (2019) identified interventions that increase food management skills and interventions that involve regulation, economic instruments and nudging approaches. Similarly, a study in Brazil by Kinasz et al. (2015) created a checklist with actions kitchens could take as ways to reduce food waste, although those authors also pointed out that the actions they suggested need to be tested in canteens to see if they actually have the predicted reduction effect. In the present study, the respondents actually performed well in comparison with others and they would not have any reason to lie about the successful measures they have taken to achieve this.

Beside potential bias, the study is also limited by only including data from a single country, making the results less generalisable. However, if the ambition is to reduce food waste many kinds of regulation or economic incentive could be used to push this reduction, and it is likely that the use of best practice and goals to reach a certain benchmark would be crucial in realisation of this ambition. Therefore, different parts of the results of this study can be useful in different contexts outside Sweden. There is also a lack of other studies comparing the food waste levels in large numbers of canteens and actually identifying what the best-performing units are doing to reach a low level of food waste. Thus catering operators can benefit from applying the findings describing best practice and benchmarks in order to reduce their food waste, even if policy makers fail to enforce this practice. In times of increasing food prices, the incentive to reduce food waste should become stronger.

The reduction potential identified in this study was very high and of course all catering units cannot be expected to have exactly the same potential for reducing food waste. However, the literature contains examples of catering units reducing their food waste significantly (e.g. Thiagarajah and Getty, 2013; Kallbekken and Sælen, 2013; Antonschmidt and Lund-Durlacher, 2021; Cozzio et al., 2021), especially if they start at a high initial level of waste generation (Eriksson et al., 2019). Nudging has also been shown to be a successful measure in school canteens, where such strategies have been found to prevent 41 % of plate waste and result in 27.2 g of food waste per portion (Vidal-Mones et al., 2022). There are also examples of canteens that have implemented quite advanced measures to reduce food waste and have achieved food waste reductions of 44 and 34 g per portion from comparatively low initial levels of food waste (Malefors et al., 2022). The waste reduction potential identified in the present study can therefore be regarded as realistic, especially if the less ambitious median or first quartile level is used for benchmarking.

A policy recommendation that can be drawn from the findings in this study is that applying the Environmental Code to the food chain could be a cost-efficient way of significantly reducing food waste in Sweden. The principles in the Swedish Environmental Code are also well-known and could be adopted by other countries that lack such legislation, in order to reduce food waste in a larger perspective. For a change in current practice to occur, supervising authorities need to react and the findings in this paper could provide the information base for such action. Since the Environmental Code and food legislation are normally the responsibility of the same authority in Sweden, there is potential to simplify implementation of the Code, as food inspectors already visit food business operators and could be given the extra task of monitoring compliance with the Environmental Code. The drawback is that applying the Code more strictly could be seen as anti-business and, indirectly, anti-job opportunities, which might not be palatable for politicians. However, environmental legislation is not in place to pander to business, but to protect the life conditions for current and future generations, and limiting food waste generation is less controversial than other possible actions to improve sustainability. It is important to underline what is stated at the outset in the Swedish constitution (The instrument of Government, ch. 1. *sec.* 1.3), namely that

"Public power is exercised under the laws", i.e. application of the law must take place without political overtones.

## 5. Conclusions

Under the Swedish Environmental Code, it is in theory illegal to waste food in Sweden. However, the Code is not applied in practice and there are several knowledge gaps that need to be bridged to enable strict enforcement of its content. This study closed knowledge gaps for the Swedish public catering sector by identifying a list of low-cost best practices to reduce food waste, such as reusing leftovers from buffets, adjusting recipes based on previous consumption, advising guests to start with small tasting portions, setting organisation-level goals for waste reduction, and serving smaller volumes in buffet containers and refilling often. Banning catering units from generating more food waste than the median level would reduce food waste by 15 %, limiting waste generation to the first quartile would reduce food waste by 28 % and if all catering units generated as little as the best-performing unit, food waste would be reduced by 76 %. This food waste reduction is within reach, and the current failure to apply the Environmental Code is a wasted opportunity in this regard.

## 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.spc.2022.11.003.

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