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Final Report on the ReFoPlan 2021

Determination of food waste in Germany in 2020, fulfilment of the reporting obligation to the EU Commission in 2022 and derivation of recommendations for action

by:
Federal Statistical Office, Wiesbaden

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On behalf of the German Environment Agency

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Abstract: Determination of food waste in Germany in 2020, fulfilment of the reporting obligation to the EU Commission in 2022 and derivation of recommendations for action

The project covers in particular the mandatory EU reporting of food waste in the reporting year 2020 according to EU requirements. This involves determining the amount of food waste in Germany at the five stages of the food supply chain – from production to consumption. The methodology for measuring food waste generally focuses on the disposal of waste.

First, the Federal Statistical Office has formed a database based on national, official waste statistics. This contains amounts of waste according to waste codes, which generally also include food waste. In order to calculate the actual food waste from this database, a consortium of four institutes – consisting of the "Witzenhausen-Institut für Abfall, Umwelt und Energie GmbH", "ARGUS-Statistik und Informationssysteme in Umwelt und Gesundheit GmbH", the "Institut für Abfall, Abwasser und Infrastruktur-Management GmbH" and the "Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft der Universität Stuttgart" – determined the proportion of food waste in each waste code (waste coefficients). For this purpose, the consortium evaluated, among other things, waste sorting analyses and conducted a voluntary online survey of waste disposal facilities. In addition, the consortium identified recommendations for action to reduce food waste.

The study provides an up-to-date data set on food waste in Germany in the reporting year 2020 in the context of EU reporting. Furthermore, optimisation recommendations for future reporting are formulated.

Kurzbeschreibung: Ermittlung der Lebensmittelabfälle in Deutschland im Jahr 2020, Erfüllung der Berichtspflicht gegenüber der EU-Kommission im Jahr 2022 und Ableitung von Handlungsempfehlungen

Das Projekt umfasst insbesondere die verpflichtende EU-Berichterstattung von Lebensmittelabfällen im Berichtsjahr 2020 nach EU-Vorgaben. Dabei wird die Menge der Lebensmittelabfälle in Deutschland auf den fünf Stufen der Lebensmittelkette – von der Herstellung bis zum Verbrauch – bestimmt. Die Methodik zur Messung der Lebensmittelabfälle setzt generell bei der Entsorgung von Abfällen an.

Zunächst hat das Statistische Bundesamt eine Datenbasis auf Grundlage von nationalen, amtlichen Abfallstatistiken gebildet. Diese enthält Abfallmengen nach Abfallschlüsseln, die in der Regel auch Lebensmittelabfälle umfassen. Um die tatsächlichen Lebensmittelabfälle aus dieser Datenbasis herauszurechnen, hat ein Konsortium aus vier Instituten – bestehend aus dem Witzenhausen-Institut für Abfall, Umwelt und Energie GmbH, ARGUS-Statistik und Informationssysteme in Umwelt und Gesundheit GmbH, dem Institut für Abfall, Abwasser und Infrastruktur-Management GmbH und dem Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft der Universität Stuttgart – den Anteil der Lebensmittelabfälle pro Abfallschlüssel (Abfallkoeffizienten) bestimmt. Dazu hat das Konsortium unter anderem Abfallsortieranalysen ausgewertet und eine freiwillige Online-Befragung von Abfallentsorgungsanlagen durchgeführt. Zudem hat das Konsortium Handlungsempfehlungen zur Reduzierung von Lebensmittelabfällen aufgezeigt.

Die Studie liefert eine aktuelle Datengrundlage zu Lebensmittelabfällen in Deutschland im Berichtsjahr 2020 im Rahmen der EU-Berichterstattung. Des Weiteren werden Optimierungsempfehlungen für die zukünftige Berichterstattung formuliert.

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a	Year (annus)
AE	Waste disposal statistics (AE = Statistik der Abfallentsorgung)
AEU	Waste generation statistics (AEU = Statistik der Abfallerzeugung)
approx.	approximately
ARGUS	ARGUS-Statistik und Informationssysteme in Umwelt und Gesundheit GmbH, Berlin
Bill.	Billions
BImSchG	Federal Immission Control Act
BKG	Bundesgütegemeinschaft Kompost e. V. (German Quality Assurance Organisation for Compost)
BMEL	Federal Ministry of Food and Agriculture
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
BS	Statistics on the processing and recycling of construction and demolition waste
cf.	Compare
CO_2	Carbon dioxide
CPCI	Clopper-Pearson confidence interval
CW/H	Commercial waste collected together with household waste in residual waste bins
DepBau	Statistics on landfill construction measures (Statistik Deponiebaumaßnahmen)
e.g.	for example
etc.	et cetera
EU	European Union
EU Commission	European Commission
F2F	Farm to Fork Strategy
fee-based tech. systems	fee-based technological systems
forsa	Gesellschaft für Sozialforschung und statistische Analysen mbH
GfK SE	“Gesellschaft für Konsumforschung” (Society for Consumer Research)
GV	Statistics on the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (GV = Grenzüberschreitende Verbringung)
GVM	Gesellschaft für Verpackungsmarktforschung mbH (Society for Market Research on Packaging)
HC	Home composting
i	Inhabitants
i.e.	that is

incl.	including
INFA	Institut für Abfall, Abwasser und Infrastruktur-Management GmbH, Ahlen
JRC	Joint Research Centre
kg	Kilogramme
km²	Square kilometre
KPI	Key Performance Indicator
KrWG	Circular Economy Act (Kreislaufwirtschaftsgesetz)
LHE	Large housing estate
m³	Cubic metres
M.	Millions
MKUEM RLP	Ministerium für Klimaschutz, Umwelt, Energie und Mobilität RLP (Ministry for Climate Protection, Environment, Energy and Mobility Rhineland Palatinate)
MUNV NRW	Ministerium für Umwelt, Naturschutz und Verkehr NRW (Ministry of the Environment, Nature Conservation and Transport North Rhine-Westphalia)
n	Number (as a mathematical symbol)
No.	Number
NRW	North Rhine-Westphalia
OERE	Statistics on public waste disposal (household waste) (Erhebung der öffentlich-rechtlichen Abfallentsorgung (Haushaltsabfälle)
örE	Public waste disposal authorities (öffentlich-rechtlicher Entsorgungsträger)
P.	Page
R&D	Research and development
ReFoPlan	Departmental research plan
RLP	Rhineland Palatinate (Rheinland-Pfalz)
RN	Research number
RY	Reporting year
SDG	Sustainable Development Goal
SS	Subject to social security contributions
StBA	Statistisches Bundesamt (Federal Statistical Office), Wiesbaden
StLÄ	Statistical offices of the federal states
t	Tonnes (or metric ton)
TI	Thünen Institut (Thünen Institute), Braunschweig
UBA	Umweltbundesamt (German Environment Agency), Dessau
UStatG	Environmental Statistics Act
USTUTT	Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft (Institute for Urban Water Management, Water Quality Management and Waste Management) at the University of Stuttgart
WFD	Waste Framework Directive

WI	Witzenhausen-Institut für Abfall, Umwelt und Energie GmbH, Witzenhausen
WP	Work package
WRAP	Waste and Resources Action Programme in United Kingdom

Summary

Background

About eleven million tonnes of food are disposed of as waste along the food supply chain in Germany every year (StBA 2023a). Globally, this figure was around 1.3 billion tonnes in 2011 – about one third of the food produced (Gustavsson et al. 2011). The current figures from the Food and Agriculture Organization of the United Nations show that around 13.8 %[1] of food is lost as food losses (Food and Agriculture Organization of the United Nations 2019). The Food Waste Index Report (2021) estimates that the total food waste from households, retail establishments and the food service industry is around 931 million tonnes per year (United Nations Environment Programme 2021). The food that is not consumed uses up enormous amounts of agricultural land and causes about 8 % of greenhouse gas emissions (Mbow et al. 2019). Article 9 of the EU Waste Framework Directive (WDF) ("Waste Prevention") and Directive (EU) 2018/851 Recital Number 31, based on Sustainable Development Goal 12.3, aim to halve the per capita food waste at retail and consumer level and reduce food losses along the production and supply chains.

In 2019, the European Commission issued two supplementary decisions providing more clarification – Delegated Decision (EU) 2019/1597 on the methodology for the measurement of food waste and Implementing Decision (EU) 2019/2000 on the format for the submission of reports. Alongside the WDF, these EU legal acts require member states to measure the mass of food waste on a yearly basis and report to the EU Commission, for the first time by June 30, 2022 for the reporting year 2020. Based on these legal provisions, Germany had to comply with its first reporting obligation on food waste for the reporting year 2020 by June 30, 2022. Thereafter, Germany must continue to record the mass of food waste annually and report to the EU Commission.

For the first reporting year 2020, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and the German Environment Agency (UBA) have commissioned the Federal Statistical Office (StBA) with the task of reporting to the EU on food waste as part of this research project.

Objective of the research project

The objective of the research project is to prepare the first report to the EU Commission on food waste for the reporting year 2020. The StBA is required to submit the results (including the quality control report) to the EU Commission by June 30, 2022 in accordance with EU specifications. In addition, suggestions for optimising reporting should be developed and instruments and measures for further reducing food waste identified. As part of the research project, it is necessary to derive reliable data – with the aid of waste coefficients – on the proportion of food waste in the different types of waste that may contain food.

The national, official statistics can show the potential but not the actual amount of food waste in Germany. These surveys do not determine how high the proportion of food waste is in the total amount of waste for each waste code. The reason for this is that no distinction is made between food waste and non-food waste for the waste codes according to the European List of Waste. In order to calculate the total amount of food waste, the amounts of waste in each waste code (according to the data set) must therefore be multiplied by waste coefficients. The waste coefficient indicates the proportion of food waste (e.g. 45 %) that the waste code typically contains.

[1] This information relates to the areas of primary production, processing and manufacturing as well as wholesale.

The waste coefficients and the amount of food waste utilised for home composting were determined by a subcontractor within the research project. The subcontractor also identified recommendations for action to reduce food waste. This subcontractor was a consortium consisting of the "Witzenhausen-Institut für Abfall, Umwelt und Energie GmbH (WI)", "ARGUS-Statistik und Informationssysteme in Umwelt und Gesundheit GmbH (ARGUS)", the "Institut für Abfall, Abwasser und Infrastruktur-Management GmbH (INFA)" and the "Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft der Universität Stuttgart (USTUTT)".

Legal basis

The definition of "food" laid down in Regulation (EC) No. 178/2002 of the European Parliament and Council encompasses food as a whole, along the entire food supply chain from production to consumption.

According to Delegated Decision (EU) 2019/1597, the reporting must cover at least the waste codes from the European List of Waste for those types of waste that usually also contain food waste. All types of waste to be considered in the reporting are listed in Annex II.

Creation of the data set

In the first step, the StBA examined the national, official waste statistics for their relevance to food waste. Subsequently, the StBA used selected official waste statistics, as well as the data they collected on the relevant waste codes that may contain food waste, to produce a data set for the calculations and the reporting of the amounts of waste. Delegated Decision (EU) 2019/1597 provides guidance on which waste codes from the European List of Waste should be included. The StBA used the following four national, official sets of waste statistics to determine the amount of waste:

- Waste disposal statistics (Abfallentsorgung – AE)
- Statistics on the processing and recycling of construction and demolition waste (Bauschutt – BS)
- Statistics on landfill construction measures (Deponiebau – DepBau)
- Statistics on the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Grenzüberschreitenden Verbringung – GV).

The StBA then allocated the waste to the respective economic sectors that generated this waste on the basis of other official waste statistics. The StBA considered the following national, official waste statistics for this process:

- Statistics on public waste disposal (household waste) (OERE)
  - These amounts of waste are allocated to households
- Waste disposal statistics (Abfallentsorgung – AE)
  - Waste collected from companies is allocated to the economic sector of the respective company or disposal facility
- Waste generation statistics (Abfallerzeugung – AEU)
  - Waste for which no information exists about its origin was allocated to the different waste codes for the economic sectors according to the percentage distribution of the extrapolated amounts from the waste generation statistics.

The amounts of waste allocated to the economic sectors were then assigned to the five stages of the food supply chain. Delegated Decision 2019/1597 indicates which economic sectors or activities belong to which stages of the food supply chain: (1) “Primary production”, (2) “Processing and manufacturing”, (3) “Retail and other distribution of food”, (4) “Restaurants and food services” and (5) “Households”. The amounts of waste were then added up at the level of the stages (balancing).

Modifications: Consideration of additional waste codes and commercial waste

The StBA modified the data set in two areas to take national circumstances into account.

The first modification involved the consideration of additional waste codes at stages of the food supply chain which are not expressly prescribed by Delegated Decision (EU) 2019/1597. Annex II of Delegated Decision (EU) 2019/1597 specifies which waste codes should be assigned to which stages of the food supply chain. The national, official waste statistics show that some waste codes also occur in stages of the food supply chain or in economic sectors that are not specifically named in Delegated Decision (EU) 2019/1597. These results can probably be attributed to the fact that, in addition to the primary economic activity, amounts of waste can also be generated through secondary activities of companies. These are allocated to the economic sector of the main activity, even if the types of waste do not match the main activity. In addition, it is possible that companies do not always classify their waste using the European List of Waste strictly according to its origin.

In order to give as complete a picture as possible of the amount of food waste in Germany, the StBA also considered these amounts of waste and assigned them to the respective stages of the food supply chain. No new or additional waste codes were used for this purpose; instead, the stages of the food supply chain were merely expanded to include waste codes that already occur at other stages and which can contain food waste.

A further modification was to remove commercial waste from stage 5 of the food supply chain and redistribute this amount to stages 1 to 4 of the food supply chain. Household waste and, to a small extent, biowaste also always include a proportion of waste of commercial origin, so-called commercial waste. This is collected together with household waste or biowaste from households. This is waste that is collected from small businesses such as engineering offices, tax consultants, lawyers, etc. It is disposed of in the bins provided by the public waste disposal authorities (örE). This applies to the residual waste bin (waste code 20 03 01 01 – household waste[2]) and the biowaste bin (waste code 20 03 01 04 – biowaste[3]). Therefore, the “Households” stage (stage 5 of the food supply chain) contains some commercial waste, which originates from various economic sectors in stages 1 to 4 of the food supply chain.

The amount of commercial waste is calculated as the difference between the amounts of waste reported by the örE and the extrapolated amount of household waste from households. Commercial waste was removed from stage 5 of the food supply chain and redistributed to stages 1 to 4 of the food supply chain based on the national, official waste statistics (waste generation statistics). The same methodology described in the subchapter “Creation of the data set” was used for this redistribution process.

Waste coefficients for mixed municipal waste

The data collected by the StBA contains the amount of potential food waste in Germany, taking into account the requirements in Delegated Decision (EU) 2019/1597. In order to calculate the

[2] In this report, “household waste” is understood to mean the waste code “20 03 01 01 – household waste, commercial waste similar to household waste collected together via public waste disposal”.

[3] In this report, “biowaste” is understood to mean the waste code “20 03 01 04 – waste from biowaste bins”.

total amount of food waste, the amounts of waste in each waste code (according to the data set) must therefore be multiplied by waste coefficients. The waste coefficient indicates the proportion of food waste (e.g. 45 %) that the waste code typically contains. The StBA has subcontracted the task of determining the waste coefficients within the research project to a consortium consisting of four institutes.

Mixed municipal waste essentially comprises waste code 20 03 01. This includes household waste (20 03 01 01), commercial waste similar to household waste (20 03 01 02), non-differentiable mixed municipal waste (20 03 01 00) and biowaste (20 03 01 04).

The base amounts from the municipal collections of household waste are reported in the annual survey of public waste disposal by each public waste disposal authority in the federal states, while the amounts of biowaste are taken from the waste balances reported by the federal states. The base amounts for commercial waste similar to household waste are taken from the waste balances compiled by the StBA.

The consortium determined the waste coefficients for the reporting year 2020 using secondary analyses from 2017 to 2022 (household waste and biowaste), evaluations of applicable literature and estimates by the consortium (commercial waste similar to household waste).

The consortium determined the absolute amounts, the amounts per inhabitant and the percentage distributions by campaign and stratum using the statistics for the mixed municipal waste collected by municipalities and commercial enterprises and the material compositions based on secondary analyses and data in applicable literature and used this information to calculate the waste coefficients for the waste streams "household waste", "commercial waste similar to household waste" and "biowaste".

The evaluation and extrapolation methods for household waste and biowaste used by the consortium are the same as the methodological procedure described in the "Bundesweite Hausmüllanalyse" (Nationwide Household Waste Analysis) (Dornbusch et al. 2020, Chapter 5, p. 44 to 83). The investigation plan that was used as the basis for the Nationwide Household Waste Analysis and included representative random samples (containers at the premises at an örE level and örE at the federal level) was adopted for household waste and biowaste. When planning for this study, it was important to ensure that random samples for all strata and campaigns were available for evaluation and extrapolation.

Table 1 shows the determined amounts and compositions of the types of mixed municipal waste in condensed form. The amounts of waste for reporting year 2019 were used to determine the waste coefficients because amounts for reporting year 2020 were not yet available at the time the waste coefficients were calculated. A total of 21,915,753 t of waste was recorded for waste codes 20 03 01 01, 20 03 01 04 and 20 03 01 02 in the reporting year 2019. This corresponds to an annual amount of waste on average of 264 kilogrammes per inhabitant for these waste codes. A total of 6,457,356 t of food waste was recorded in these waste codes in the reporting year 2019. This corresponds to an annual amount of waste on average of 78 kilogrammes per inhabitant for these waste codes in the reporting year 2019.

The average weighted proportion of food waste (waste coefficient for mixed municipal waste) is 29 %. The calculations resulted in a waste coefficient of 33 % for household waste, 36 % for biowaste and approximately 4 % for commercial waste similar to household waste. At the time of the evaluation, there was no information available on the composition of the waste code "non-differentiable mixed municipal waste – 20 03 01 00". Therefore, the average weighted proportion of food waste of 29 % was adopted for this eight-digit waste code. The waste coefficients were multiplied by the amounts of waste for the reporting year 2020 to calculate the amounts of food waste for the reporting year 2020.

Table 1: Waste coefficients for mixed municipal waste according to the waste code numbers (20 03 01) in the reporting year 2019

Waste streams	Annual amount t/year	Annual amount per inhabitant kg/(inhabitant*year)	Composition mass %
Household waste (20 03 01 01)[1]	12,942,801	155.6	100.0
Organic	4,886,675	58.8	37.8
Food waste	4,290,937	51.6	33.2
Kitchen waste[2]	2,196,516	26.4	17.0
Food scraps[3]	1,309,520	15.7	10.1
Packaged food (net)	784,901	9.4	6.1
Biowaste (20 03 01 04)[4]	5,701,952	68.6	100
Organic	4,566,878	54.9	80.1
Food waste	2,035,579	24.5	35.7
Kitchen waste[2]	1,396,957	16.8	24.5
Food scraps[3]	607,679	7.3	10.7
Packaged food (net)	30,943	0.4	0.5
Commercial waste similar to household waste (20 03 01 02)[5]	3,271,000	39.3	100
Organic	327,100	3.9	10
Food waste	130,840	1.6	4
Non-differentiable mixed municipal waste (20 03 01 00)[6]	-	-	29
Total (20 03 01)	**21,915,753**	**263.5**	**-**
Food waste (20 03 01)	**6,457,356**	**77.6**	**-**

[1] From the OERE statistics from the federal states in the reporting year 2019 (StBA 2021), rounded values.
[2] Kitchen waste = food waste before consumption e.g. fruit peels.
[3] Food scraps = food waste “after” consumption e.g. leftovers.
[4] From the waste balances submitted by the federal states for the reporting year 2019, rounded values.
[5] From the waste balance of the StBA for the reporting year 2019 (StBA 2022), rounded values.
[6] At the time of the investigation, there was no information available on the composition of this waste code.
Sources: Waste balances of the federal states 2019; StBA 2021; StBA 2022; own research, WI, ARGUS, INFA, USTUTT

Evaluations relating to influencing variables such as “settlement structure”, “separately collected amount of biowaste” or “level of access to the separate collection of biowaste”, “fee system” and “building structure” for household waste and biowaste showed that the amount of waste and thus the associated amount of food waste were mainly influenced by settlement and building structures.

The average amount of household waste per capita, as well as the food waste it contains, increases noticeably as the population density and building density increases. The opposite is true for biowaste. For food waste from households, this means that there are only small differences in the disposal of food waste between these strata. It can be assumed that the strata "separately collected amount of biowaste", "fee system" and the "level of access to the separate collection of biowaste" have an intercorrelation with settlement and building structure and similar behaviour can thus be expected.

Waste coefficients for other waste codes

In addition to waste coefficients for mixed municipal waste, the consortium examined the waste streams for the areas "primary production", "processing and manufacturing", "retail and other distribution of food" and "restaurants and food services" and determined their waste coefficients (with the exception of the waste code 20 03 01 "mixed municipal waste").

In order to ensure that the baseline data for fulfilling the future reporting obligation was as reliable as possible, USTUTT conducted surveys of associations and companies in the waste management sector using an online questionnaire. The questionnaire was sent out via email to a total of 748 recipients on February 18, 2022. The deadline for responses was March 14, 2022. The respondents were companies in the German waste management sector or operators of waste disposal facilities in Germany – e.g. waste incineration plants, biowaste fermentation plants, composting plants and mechanical-biological waste treatment plants. In the online survey, USTUTT asked about amounts and waste coefficients for the other waste codes. This included all waste codes specified in Delegated Decision (EU) 2019/1597, with the exception of waste code 20 03 01 (mixed municipal waste). In addition, eight of the specified waste codes were not included in the online survey because they were not quantitatively relevant[4] in the reporting year 2019.

The response rate to the survey was 13.5 % or 101 completed questionnaires, of which 49 (6.6 %) contained usable data. USTUTT evaluated the results of the study and defined waste coefficients for the relevant waste codes. The results showed that the surveyed companies in the waste management sector can make an important contribution to defining the waste coefficients for a large proportion of the waste codes. The responses to the online survey did not provide any usable information for a total of 13 waste codes. In view of the response rate, the existing gaps in the data and the state of the data available to the respondents, the online survey cannot meet the requirements of a representative sample. Nevertheless, the data collected was the best available information at the time of the survey, since the German waste management sector was surveyed for the first time in calendar year 2022 about amounts of food waste.

Home composting

In accordance with the Eurostat guidance, it was also necessary to consider the amounts of food waste recycled through home composting in the food waste calculations for the reporting year 2020. Due to the fact that the data available was reliable to a rather limited extent, this could only be done by making a rough estimate of an approximate order of magnitude.

To estimate the food waste utilised in home composting, the consortium considered the results of two studies. They examined a study by the "Gesellschaft für Konsumforschung" (GfK SE – Society for Consumer Research) on the amount of food waste from households (Hübsch 2021), as well as the study "Baseline 2015" (Schmidt et al. 2019) published by the Thünen Institute.

[4] Waste codes with less than 1,000 t of waste in the 2019 reporting year were classified as irrelevant in terms of their amounts.

In particular, the consortium used the figure for the proportion of the total amount of food waste generated in households that is utilised in home composting stated in the GfK SE study. The total amount of food waste that is generated in households was taken from Baseline 2015. Following an evaluation of both studies, the food waste recycled through home composting was thus estimated at 1.117 million t per year or an average of 13.6 kg per inhabitant.

Result

Multiplying the results of the modified data set by the respective waste coefficients gives the total amount of food waste in Germany for the reporting year 2020, while taking into account the amounts of waste utilised in home composting. Table 2 below shows the food waste broken down into each stage of the food supply chain.

Table 2: Food waste in Germany in the reporting year 2020[1]

Stage of the food supply chain – number	Stage of the food supply chain – designation	Food waste in 1000 t	Food waste in %
1	Primary production	178	2
2	Processing and manufacturing	1,594	15
3	Retail and other food distribution	774	7
4	Restaurants and food services	1,877	17
5	Households	6,496	59
	Total	**10,919**	**100**

[1] These are corrected values that were calculated on the basis of expert assessments made by the consortium. These deviate from the results reported to the EU Commission on June 30, 2022.
Source: StBA 2023a

Recommendations for optimising reporting

The consortium also identified aspects of the reporting that could be optimised and issued corresponding recommendations.

The EU food waste reporting for the reporting year 2020 only considers the waste recorded as part of the waste management system. Therefore, the data may not be complete in this regard. Another gap in the data is the amount of moisture that is potentially lost before the waste is measured.

The waste coefficients for biowaste and household waste must be determined regularly, i.e. at least every four years. The methodology in the Nationwide Household Waste Analysis (Dornbusch et al. 2020) has been used up to now for calculating the waste coefficients for biowaste and household waste. The consortium believes that the method used to determine the waste coefficients for household waste and biowaste for the initial report can be used for future reports to ensure that the waste coefficients are kept up to date.

According to the consortium, the data set on the composition of commercial waste similar to household waste that is delivered or collected separately from household waste (20 03 01 02) is very incomplete. In order to define a reliable and up-to-date waste coefficient for this waste code, it will be necessary to either carry out new waste sorting analyses or to use a different methodology for the survey (see “Waste coefficients for other waste codes”). The same recommendation applies to the waste code “non-differentiable mixed municipal waste” (20 03 01 00).

Another gap in the data exists regarding the composition of the other waste codes. There is an urgent need for further research in this area. In general, the consortium recommends carrying out further surveys, research and analyses for future reporting in order to define the waste coefficients for the other waste codes. In the process, it is necessary to improve the data by carrying out physical surveys and using a larger sample size. According to the consortium, a framework concept first has to be developed and defined so that it is possible to make valid statements regarding the sample size for waste sorting analyses in stages 1 to 4 of the food supply chain. Overall, it is especially important to take a systematic approach to planning the sampling process and analysis methods.

Recommendations for future reporting

The consortium recommends using all available data sources for future reporting, while giving preference to more thoroughly validated data in each case. Physical data, such as waste statistics, supplemented by physical information on the composition of the waste, represent the most reliable data set in this context.

Recommendations for action to reduce food waste

In addition to defining the waste coefficients, the consortium has developed recommendations for action for reducing food waste.

Due to the many different ways for potentially avoiding food waste, the Joint Research Institute of the EU recommends defining more specific targets for the respective areas of the food supply chain and for individual sectors in line with the generally formulated targets of Sustainable Development Goal 12.3. Developing and updating a comprehensive data set is therefore key to optimising the system in the long term. According to the JRC, sector and industry-specific waste avoidance targets should be defined, which are based on, among other things, the actual waste avoidance potential. The goals should be “SMART” (specific, measurable, achievable, relevant, time-bound) and measured using performance indicators. Performance indicators could, for example, monitor the amount of food waste and food losses in relation to the amounts of food produced so that the efficiency of processes can be measured. This is already being implemented to some extent in Germany by, amongst others, the “dialogue forums” to collect corresponding data.

Zusammenfassung

Hintergrund

Rund elf Millionen (Mio.) Tonnen (t) Lebensmittel (LM) werden in Deutschland jedes Jahr entlang der Lebensmittelkette (LMK) als Abfall entsorgt (StBA 2023a). Weltweit waren es 2011 ca. 1,3 Milliarden (Mrd.) Tonnen – etwa ein Drittel der produzierten LM (Gustavsson et al. 2011). Aus den aktuellen Zahlen der Food and Agriculture Organization of the United Nations geht hervor, dass ca. 13,8 %[5] LM als LM-Verluste verloren gehen (Food and Agriculture Organization of the United Nations 2019). Der Food Waste Index Report (2021) schätzt Lebensmittelabfälle (LMA) aus den Bereichen Haushalt, Einzelhandel und der Lebensmittelindustrie auf insgesamt ca. 931 Mio. t pro Jahr (United Nations Environment Programme 2021). Die nicht verzehrten LM verbrauchen enorme Agrarflächen und verursachen ca. 8 % der Treibhausgasemissionen (Mbow et al. 2019). Die EU-Abfallrahmenrichtlinie (AbfRRL) Artikel 9 („Abfallvermeidung“) und die Richtlinie (EU) 2018/851 Erwägungsgrund Nummer (Nr.) 31 sehen in Anlehnung an das Sustainable Development Goal (SDG) 12.3 vor, die auf Ebene des Einzelhandels und auf Verbraucherebene pro Kopf anfallenden LMA zu halbieren und die Verluste von LM entlang der Produktions- und Lieferketten zu reduzieren.

Die Europäische Kommission (EU-Kommission) hat im Jahr 2019 zwei konkretisierende Beschlüsse erlassen, den Delegierten Beschluss (EU) 2019/1597 zur Methodik der Messung von LMA und den Durchführungsbeschluss (EU) 2019/2000 zum Übermittlungsformat der Berichte. Diese EU-Rechtsakte verpflichten neben der AbfRRL die Mitgliedstaaten, die Masse der LMA jährlich zu messen und der EU-Kommission zu berichten, und zwar erstmals bis zum 30. Juni 2022 für das Berichtsjahr (BJ) 2020. Aufgrund dieser rechtlichen Bestimmungen musste Deutschland seiner erstmaligen Berichtspflicht zu LMA für BJ 2020 zum 30. Juni 2022 nachkommen. Danach muss Deutschland weiterhin jährlich die Masse der LMA erfassen und der EU-Kommission berichten.

Für das erste BJ 2020 haben das Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV) und das Umweltbundesamt (UBA) das Statistische Bundesamt (StBA) für die EU-Berichterstattung zu LMA im Rahmen dieses Forschungsprojektes beauftragt.

Zielsetzung des Forschungsprojekts

Zielsetzung des Forschungsvorhabens ist die Erarbeitung des ersten Berichts an die EU-Kommission zu LMA für das BJ 2020. Das StBA soll die Ergebnisse (einschließlich Qualitätskontrollbericht) entsprechend den EU-Vorgaben zum 30. Juni 2022 an die EU-Kommission übermitteln. Darüber hinaus sollen Vorschläge zur Optimierung der Berichterstattung erarbeitet sowie Instrumente und Maßnahmen zur weiteren Reduzierung von LMA aufgezeigt werden. Im Rahmen des Forschungsprojekts soll die Ableitung belastbarer Anteile von LMA mit Hilfe von Abfallkoeffizienten (AKO) für die Abfälle, die LMA enthalten können, ermittelt werden.

Die nationalen, amtlichen Statistiken können die potenzielle, aber nicht die tatsächliche Menge an LMA in Deutschland ausweisen. Bei diesen Erhebungen wird nicht ermittelt, wie hoch der Anteil an LMA an der Gesamtabfallmenge des jeweiligen Abfallschlüssels ist. Dies liegt darin begründet, dass für die Abfallschlüssel nach dem europäischen Abfallverzeichnis keine Unterscheidung in LMA und Nicht-LMA vorgesehen ist. Zwecks Berechnung der LMA müssen die Abfallmengen je Abfallschlüssel (gemäß der ermittelten Datenbasis) deshalb mit AKO

[5] Diese Angabe bezieht sich auf die Bereiche Primärproduktion, Verarbeitung und Herstellung sowie den Großhandel.

multipliziert werden. Der AKO gibt den Anteil der LMA an (z. B. 45 %), den der Abfallschlüssel typischerweise enthält.

Die Ermittlung der AKO und der eigenkompostierten LMA sowie das Aufzeigen von Handlungsempfehlungen zur Reduzierung von LMA erfolgte durch einen Unterauftrag innerhalb des Forschungsprojekts. Diese Aufgaben hat ein Konsortium – bestehend aus dem Witzenhausen-Institut für Abfall, Umwelt und Energie GmbH (WI), ARGUS-Statistik und Informationssysteme in Umwelt und Gesundheit GmbH (ARGUS), dem Institut für Abfall, Abwasser und Infrastruktur-Management GmbH (INFA) und dem Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft der Universität Stuttgart (USTUTT) – übernommen.

Rechtsgrundlagen

Die Definition von „Lebensmittel" ist in der Verordnung (EG) Nr. 178/2002 des Europäischen Parlaments und des Rates beschrieben und umfasst LM als Ganzes, entlang der gesamten LMK von der Erzeugung bis zum Verbrauch.

Gemäß dem Delegierten Beschluss (EU) 2019/1597 umfasst die Berichterstattung mindestens die Abfallschlüssel aus dem Europäischen Abfallverzeichnis für Abfallarten, die in der Regel auch LMA umfassen. Alle zu berücksichtigenden Abfälle sind in Anhang II des Beschlusses aufgelistet. Alle zu berücksichtigenden Abfälle sind in Anhang II des Beschlusses aufgelistet.

Erstellung der Datenbasis

Im ersten Schritt hat das StBA die nationale amtliche Abfallstatistik auf ihre Relevanz für LMA untersucht. Anschließend hat das StBA die Berechnungsgrundlage bzw. die Bilanzierung der Abfallmengen auf Basis ausgewählter amtlicher Abfallstatistiken und der dort erhobenen relevanten Abfallschlüssel, die LMA enthalten können, erstellt. Hierbei gibt der Delegierte Beschluss (EU) 2019/1597 die einzubeziehenden Abfallschlüssel aus dem Europäischen Abfallverzeichnis als Orientierung vor. Das StBA hat die vier folgenden nationalen amtlichen Abfallstatistiken für die Ermittlung des Aufkommens verwendet:

- Erhebung der Abfallentsorgung (AE),
- Erhebung über die Aufbereitung und Verwertung von Bau- und Abbruchabfällen (BS),
- Erhebung der Deponiebaumaßnahmen (DepBau) und
- Erhebung der Grenzüberschreitenden Verbringung von notifizierungspflichtigen Abfällen gemäß dem Basler Übereinkommen (GV).

Das StBA hat anschließend die so ermittelten Abfälle anhand weiterer amtlicher Abfallstatistiken auf die Wirtschaftszweige (WZ) verteilt, die den jeweiligen Abfall erzeugt haben. Bei der Verteilung berücksichtigte das StBA die Ergebnisse folgender nationaler amtlicher Abfallstatistiken:

- Erhebung der öffentlich-rechtlichen Abfallentsorgung (Haushaltsabfälle) (OERE)
  - die Abfallmengen werden den privaten Haushalten zugeordnet,
- Erhebung der Abfallentsorgung (AE)
  - betriebseigene Abfälle werden dem WZ des jeweiligen Betriebs bzw. der Entsorgungsanlage zugeordnet und

- Erhebung der Abfallerzeugung (AEU)
  - Abfälle, zu deren Herkunft keine Hinweise vorliegen, werden entsprechend der prozentualen Verteilung von hochgerechneten Mengen der AEU-Erhebung der einzelnen Abfallschlüssel den WZ zugeordnet.

Die auf die WZ verteilten Abfallmengen wurden anschließend den fünf Stufen der LMK zugeordnet. Der Delegierte Beschluss 2019/1597 gibt an, welche WZ zu welchen Stufen der LMK gehören: 1. „Primärerzeugung", 2. „Verarbeitung und Herstellung", 3. „Einzelhandel und andere Formen des Vertriebs von Lebensmitteln", 4. „Gaststätten und Verpflegungsdienstleistungen" sowie 5. „Private Haushalte". Anschließend wurden die Abfallmengen auf Ebene der Stufen addiert (Bilanzierung).

Modifikationen: Berücksichtigung zusätzlicher Abfallschlüssel und Geschäftsmüll

Das StBA hat die Datenbasis bei deren Erstellung in zwei Punkten hinsichtlich der nationalen Gegebenheiten modifiziert.

Die erste Modifikation besteht in der Berücksichtigung von Abfallschlüsseln auf Stufen der LMK, die der Delegierte Beschluss (EU) 2019/1597 nicht ausdrücklich vorsieht. Anhang II des Delegierten Beschlusses (EU) 2019/1597 gibt vor, welche Abfallschlüssel welchen Stufen der LMK zugeordnet werden sollen. Die Ergebnisse der nationalen, amtlichen Abfallstatistiken zeigen, dass einige Abfallschlüssel auch in Stufen der LMK bzw. in WZ vorkommen, die der Delegierte Beschluss (EU) 2019/1597 nicht ausdrücklich benennt. Diese Ergebnisse lassen sich wahrscheinlich darauf zurückführen, dass neben der Tätigkeit im wirtschaftlichen Schwerpunkt auch Abfallmengen bei Nebentätigkeiten anfallen können. Diese werden dem WZ der Haupttätigkeit zugeordnet, auch wenn die Abfallarten nicht zur Haupttätigkeit passen. Zudem besteht die Möglichkeit, dass Betriebe ihren Abfall nicht immer strikt nach dessen Herkunft dem Europäischen Abfallverzeichnis zuordnen.

Um ein möglichst vollständiges Bild des LMA-Aufkommens in Deutschland zu zeichnen, hat das StBA auch diese Abfallmengen berücksichtigt und den jeweiligen Stufen der LMK zugeordnet. Hierbei wurden keine neuen bzw. zusätzlichen Abfallschlüssel herangezogen, sondern lediglich die Stufen der LMK um bereits auf anderen Stufen vorhandene Abfallschlüssel, die LMA erhalten können, erweitert.

Eine weitere Modifikation bestand in dem Herausrechnen des Geschäftsmülls auf Stufe 5 der LMK und der Umverteilung dieser Mengen auf die Stufen 1 bis 4 der LMK. Der Hausmüll und in geringem Umfang auch der Bioabfall umfassen immer auch einen Anteil an Abfällen gewerblicher Herkunft, den sogenannten Geschäftsmüll. Dieser wird gemeinsam mit dem Hausmüll bzw. dem Bioabfall aus privaten Haushalten eingesammelt. Hierbei handelt es sich um Abfälle, die bei kleineren Gewerbebetrieben, z. B. Ingenieurbüros, Steuerberater, Anwälte, etc. anfallen. Diese werden in den vom öffentlich-rechtlichen Entsorgungsträger (örE) bereit gestellten Tonnen mit entsorgt. Dies betrifft die Restabfalltonne (Abfallschlüssel 20 03 01 01 – Hausmüll [6]) sowie die Bioabfalltonne (Abfallschlüssel 20 03 01 04 – Bioabfall [7]). Geschäftsmüll wird also bei den Haushalten (Stufe 5 der LMK) miterfasst, entstammt jedoch verschiedenen WZ der Stufen 1 bis 4 der LMK.

Die Menge an Geschäftsmüll berechnet sich aus der Differenz der Abfallmengen der örE und der hochgerechneten Menge an Hausmüll aus privaten Haushalten. Der Geschäftsmüll wurde aus der

[6] In diesem Bericht wird unter „Hausmüll" der Abfallschlüssel „20 03 01 01 – Hausmüll, hausmüllähnliche Gewerbeabfälle gemeinsam über die öffentliche Müllabfuhr eingesammelt" verstanden.

[7] In diesem Bericht wird unter „Bioabfall" der Abfallschlüssel „20 03 01 04 – Abfälle aus der Biotonne" verstanden.

Stufe 5 der LMK herausgerechnet und anhand der Ergebnisse der nationalen, amtlichen Abfallstatistiken (AEU) auf die Stufen 1 bis 4 der LMK umverteilt. Dabei wurde der gleichen Verteilungsmethodik gefolgt, die im Unterkapitel „Erstellung der Datenbasis“ beschrieben wurde.

Abfallkoeffizienten für gemischte Siedlungsabfälle

Die vom StBA ermittelte Datenbasis enthält, unter Berücksichtigung der Vorgaben des Delegierten Beschlusses (EU) 2019/1597, die Menge an potenziellen LMA in Deutschland. Zwecks Berechnung der LMA müssen die Abfallmengen je Abfallschlüssel (gemäß der ermittelten Datenbasis) deshalb mit AKO multipliziert werden. Der AKO gibt den Anteil der LMA an (z. B. 45 %), den der Abfallschlüssel typischerweise enthält. Das StBA hat die Ermittlung der AKO innerhalb des Forschungsprojekts als Unterauftrag vollständig an ein Konsortium, bestehend aus vier Instituten, vergeben.

Der Bereich der gemischten Siedlungsabfälle umfasst im Wesentlichen den Abfallschlüssel 20 03 01. Dazu gehören der Hausmüll (20 03 01 01), der hausmüllähnliche Gewerbeabfall (20 03 01 02), nicht differenzierbare gemischte Siedlungsabfälle (20 03 01 00) und der Bioabfall (20 03 01 04).

Die Basismengen der kommunalen Erfassung für Hausmüll werden in den jährlichen OERE der Bundesländer je örE berichtet. Die Abfallmengen für den Bioabfall entstammen den Abfallbilanzen der Bundesländer. Die Basismengen für hausmüllähnliche Gewerbeabfälle werden der Abfallbilanz des StBA entnommen.

Das Konsortium hat die AKO für das BJ 2020 über Sekundäruntersuchungen aus den Jahren 2017 bis 2022 (Hausmüll und Bioabfall), über Literaturauswertungen und über Abschätzungen des Konsortiums (hausmüllähnliche Gewerbeabfälle) bestimmt.

Aus den Ergebnissen der kommunal und gewerblich erfassten gemischten Siedlungsabfälle und den stofflichen Zusammensetzungen aus Sekundäranalysen und Literaturdaten hat das Konsortium die absoluten Mengen, die einwohnerspezifischen Mengen und die prozentualen Zusammensetzungen nach Kampagnen und Schichten ermittelt und daraus die AKO für die Abfallströme „Hausmüll“, „hausmüllähnlicher Gewerbeabfall“ und „Bioabfall“ berechnet.

Die Auswertungs- und Hochrechnungsmethode für Hausmüll und Bioabfall hat das Konsortium analog der in der Bundesweiten Hausmüllanalyse beschriebenen methodischen Vorgehensweise durchgeführt (Dornbusch et al. 2020, Kapitel 5, S. 44 bis 83). Die für die Bundesweite Hausmülluntersuchung zugrunde gelegte Untersuchungsplanung mit repräsentativen Stichproben (Behälter am Grundstück auf örE-Ebene und örE auf Bundesebene) wurde für den Hausmüll und den Bioabfall übernommen. In den Planungen für die vorliegende Studie wurde sichergestellt, dass Stichproben für alle Schichten und Kampagnen für die Auswertung und Hochrechnung verfügbar waren.

In Table 1 sind die ermittelten Mengen und Zusammensetzungen der Abfallarten der gemischten Siedlungsabfälle in komprimierter Form dargestellt. Für die Ermittlung der AKO wurden die Abfallmengen für das BJ 2019 herangezogen, da die Abfallmengen des BJ 2020 zum Zeitpunkt der Ermittlung der AKO noch nicht vorlagen. Insgesamt wurden im BJ 2019 21.915.753 t Abfälle für die Abfallschlüssel 20 03 01 01, 20 03 01 04 und 20 03 01 02 erfasst. Dies entspricht einer jährlichen Abfallmenge von durchschnittlich 264 kg je Einwohner für diese Abfallschlüssel. An LMA wurden im BJ 2019 in diesen Abfallschlüsseln insgesamt 6.457.356 t erfasst. Dies entspricht einer jährlichen Abfallmenge von durchschnittlich 78 kg je Einwohner für diese Abfallschlüssel im BJ 2019.

Der durchschnittliche gewichtete Anteil an LMA (AKO für gemischte Siedlungsabfälle) beträgt 29 %. Im Hausmüll liegt der AKO bei 33 %, im Bioabfall bei 36 % und im hausmüllähnlichen Gewerbeabfall annäherungsweise bei ca. 4 %. Für den Abfallschlüssel „gemischte Siedlungsabfälle, nicht differenzierbar – 20 03 01 00" lagen zum Zeitpunkt der Untersuchung keine Informationen über die Zusammensetzung dieses Abfallstroms vor. Aus diesem Grund wurde für diesen Achtsteller der durchschnittlich gewichtete Anteil an LMA von 29 % übernommen. Die AKO wurden für das BJ 2020 mit den Abfallmengen des BJ 2020 multipliziert, um die LMA-Mengen zu berechnen.

Tabelle 1 Abfallkoeffizienten für die gemischten Siedlungsabfälle nach Abfallschlüsselnummern (20 03 01) im Berichtsjahr 2019

Abfallströme	Jahresmenge t/Jahr	Einwohnerspezifische Jahresmenge kg/(Einwohner*Jahr)	Zusammensetzung Masse %
Hausmüll (20 03 01 01)[1]	**12,942,801**	**155.6**	**100.0**
Organik	4,886,675	58.8	37.8
Lebensmittelabfälle	4,290,937	51.6	33.2
Küchenabfälle[2]	2,196,516	26.4	17.0
Nahrungsabfälle[3]	1,309,520	15.7	10.1
verpackte Lebensmittel (netto)	784.901	9.4	6.1
Bioabfall (20 03 01 04)[4]	5,701,952	68.6	100
Organik	4,566,878	54.9	80.1
Lebensmittelabfälle	2,035,579	24.5	35.7
Küchenabfälle[2]	1,396,957	16.8	24.5
Nahrungsabfälle[3]	607.679	7.3	10.7
verpackte Lebensmittel (netto)	30.943	0.4	0.5
Hausmüllähnlicher Gewerbeabfall (20 03 01 02)[5]	3,271,000	39.3	100
Organik	327.100	3.9	10
Lebensmittelabfälle	130.840	1.6	4
gemischte Siedlungsabfälle, nicht differenzierbar (20 03 01 00)[6]	-	-	29
Summe (20 03 01)	**21,915,753**	**263.5**	-
Lebensmittelabfälle (20 03 01)	**6,457,356**	**77.6**	-

[1] Aus den OERE der Bundesländer BJ 2019 (StBA 2021), gerundete Werte.

[2] Küchenabfälle = LMA vor Verzehr, z.B. Obstschalen.

[3] Nahrungsabfälle = LMA „nach" Verzehr, z.B. Speisereste.

[4] Aus den Abfallbilanzen der Bundesländer BJ 2019, gerundete Werte.

[5] Aus der Abfallbilanz des StBA BJ 2019 (StBA 2022), gerundete Werte.

[6] Zum Zeitpunkt der Untersuchung lagen keine Informationen über die Zusammensetzung dieses Abfallschlüssels vor.
Quellen: Abfallbilanzen der Bundesländer 2019; StBA 2021; StBA 2022; eigene Darstellung, WI, ARGUS, INFA, USTUTT

Die Auswertungen bezüglich der Einflussgrößen „Siedlungsstruktur", „getrennt erfasste Bioabfallmenge" bzw. „Anschlussgrad an die getrennte Bioabfallsammlung", „Gebührensystem und Bebauungsstruktur für Hausmüll und Bioabfall" zeigten, dass das Abfallaufkommen und damit auch zusammenhängend das LMA-Aufkommen überwiegend durch die Siedlungs- und Bebauungsstruktur geprägt wurden.

Das durchschnittliche Pro-Kopf-Hausmüllaufkommen wie auch die darin enthaltenen LMA nehmen mit der Siedlungsdichte sowie mit dichter werdender Bebauungsstruktur erkennbar zu. Für Bioabfall verhält es sich umgekehrt. Für die LMA aus Privathaushalten bedeutet dies, dass sich nur geringe Unterschiede im Wegwerfverhalten von LMA zwischen diesen Schichten ergeben. Für die nach Schichten getrennt erfasste Bioabfallmenge, Gebührensystem und Anschlussgrad an die getrennte Bioabfallsammlung kann eine Interkorrelation mit der Siedlungs- und Bebauungsstruktur angenommen und damit ähnliches Verhalten vermutet werden.

Abfallkoeffizienten für übrige Abfallschlüssel

Neben AKO für die gemischten Siedlungsabfälle hat das Konsortium unter anderem die Abfallströme für die Bereiche „Primärerzeugung", „Verarbeitung und Herstellung", „Einzelhandel und andere Formen des Vertriebs von Lebensmitteln" sowie „Gaststätten und Verpflegungsdienstleistungen" untersucht und AKO ermittelt (mit Ausnahme des Abfallschlüssels 20 03 01 „gemischte Siedlungsabfälle").

Um eine möglichst belastbare Ausgangsbasis für die Erfüllung der anstehenden Berichtspflicht zu gewährleisten, hat die USTUTT Verbands- bzw. Unternehmensbefragungen der Entsorgungswirtschaft mithilfe eines Online-Fragebogens durchgeführt. Der versendete Fragebogen wurde am 18. Februar 2022 per E-Mail an insgesamt 748 Empfänger versendet. Die Frist für die Beantwortung endete am 14. März 2022. Bei den Befragten handelt es sich um Unternehmen aus der deutschen Entsorgungswirtschaft bzw. um Betreiber*innen von Abfallentsorgungsanlagen in Deutschland, z. B. Müllverbrennungsanlagen, Bioabfallvergärungsanlagen, Kompostanlagen und mechanisch-biologische Abfallbehandlungsanlagen. In der Online-Umfrage hat die USTUTT die Mengen und AKO der übrigen Abfallschlüssel abgefragt. Diese umfassen alle Abfallschlüssel, die der Delegierte Beschluss (EU) 2019/1597 vorgibt, mit Ausnahme des Abfallschlüssels 20 03 01 (gemischte Siedlungsabfälle). Außerdem wurden acht der genannten Abfallschlüssel nicht in der Online-Befragung berücksichtigt, da sie im BJ 2019 keine mengenmäßige Relevanz[8] aufwiesen.

Die Rücklaufquote der Befragung lag bei 13,5 % bzw. 101 beantworteten Fragebogen, von denen 49 (6,6 %) verwertbare Datensätze enthielten. Die USTUTT hat die Ergebnisse der Untersuchung ausgewertet und AKO in Bezug auf die relevanten Abfallschlüssel gebildet. Dabei zeigte sich, dass die befragten Unternehmen aus der Abfallwirtschaft einen wichtigen Beitrag zur AKO-Ermittlung für einen Großteil der Abfallschlüssel liefern können. Für insgesamt 13 Abfallschlüssel lagen keine verwertbaren Angaben in den Rückmeldungen der Online-Befragung vor. In Anbetracht der Rücklaufquote, der vorhandenen Datenlücken und des bei den Befragten vorliegenden Datenbestandes kann die Online-Befragung die Anforderungen einer repräsentativen Stichprobe nicht erfüllen. Gleichwohl handelt es sich bei den erhobenen Daten um die bestverfügbaren Informationen zum Zeitpunkt der Erhebung, da die deutsche

[8] Abfallschlüssel, deren Abfallmenge im BJ 2019 weniger als 1.000 t betrug, wurden als mengenmäßig irrelevant eingestuft.

Entsorgungswirtschaft im Kalenderjahr 2022 erstmals hinsichtlich des Lebensmittelabfallaufkommens befragt wurde.

Eigenkompostierung

Darüber hinaus mussten bei der LMA-Berechnung für das BJ 2020 nach Eurostat-Vorgaben die über die Eigenkompostierung (EK) verwerteten LMA-Mengen berücksichtigt werden. Aufgrund einer lediglich bedingt belastbaren Datenlage konnte dies nur als Annäherung, also als grobe Abschätzung einer annähernden Größenordnung, erfolgen.

Zur Abschätzung der eigenkompostierten LMA hat das Konsortium die Ergebnisse zweier Studien berücksichtigt. Einerseits ist dies eine Studie der Gesellschaft für Konsumforschung (GfK SE) zum LMA-Aufkommen aus privaten Haushalten (Hübsch 2021). Ergänzend wurde die vom Thünen-Institut (TI) veröffentlichte Studie „Baseline 2015“ (Schmidt et al. 2019) hinzugezogen.

Konkret wurde der Anteil der eigenkompostierten LMA an allen LMA, die in privaten Haushalten anfallen, aus der GfK SE-Studie verwendet. Die Gesamtmenge der LMA, die in privaten Haushalten anfallen, wurde der Baseline 2015 entnommen. Dementsprechend wurden, als Auswertung beider Studien, die über die EK verwerteten LMA auf jährlich 1,117 Mio. t bzw. durchschnittlich 13,6 kg je Einwohner geschätzt.

Ergebnis

Durch die Multiplikation der Ergebnisse der modifizierten Datenbasis mit den jeweiligen AKO ergibt sich unter Berücksichtigung der eigenkompostierten Mengen die gesamte Menge an LMA in Deutschland für das BJ 2020. Die folgende Table 2 stellt diese pro Stufe der LMK dar.

Tabelle 2 Lebensmittelabfälle in Deutschland im Berichtsjahr 2020[1]

Stufe der Lebensmittelkette – Nummer	Stufe der Lebensmittelkette – Bezeichnung	Lebensmittelabfälle in 1000 t	Lebensmittelabfälle in %
1	Primärerzeugung	178	2
2	Verarbeitung und Herstellung	1.594	15
3	Einzelhandel und andere Formen des Vertriebs von Lebensmitteln	774	7
4	Gaststätten und Verpflegungsdienstleistungen	1.877	17
5	private Haushalte	6.496	59
	Insgesamt	**10.919**	**100**

[1] Hierbei handelt es sich um korrigierte Werte, die auf Basis der Gutachterlichen Einschätzung des Konsortiums berechnet wurden. Hieraus resultieren Abweichungen zu den Ergebnissen, die zum 30. Juni 2022 an die EU-Kommission berichtet wurden.

Quelle: StBA 2023a

Empfehlungen zur Optimierung der Berichterstattung

Daneben hat das Konsortium Optimierungspunkte der Berichterstattung ermittelt und -empfehlungen formuliert.

In der EU-Berichterstattung für das BJ 2020 wurden lediglich diejenigen Abfälle berichtet, die im Rahmen des Abfallmanagementsystems erfasst werden. Daher ist die Datenlage in dieser

Hinsicht ggf. nicht vollständig. Eine weitere Datenlücke besteht u. a. bei der Menge an Feuchtigkeit, die potenziell vor der Messung der Abfälle verloren geht.

Die AKO von Bioabfall und Hausmüll müssen regelmäßig, d. h. mindestens alle vier Jahre, ermittelt werden. Bisher basieren die AKO für Bioabfall und Hausmüll auf der Methodik der Bundesweiten Hausmüllanalyse (Dornbusch et al. 2020). Um eine AKO-Fortschreibung zu gewährleisten, kann laut dem Konsortium die für die erstmalige Berichterstattung verwendete Methode zur Ermittlung der AKO für Hausmüll und Bioabfall für die zukünftigen Berichterstattungen angewandt werden.

Die Datenbasis zur Zusammensetzung der getrennt von Hausmüll angelieferten oder eingesammelten hausmüllähnlichen Gewerbeabfälle (20 03 01 02) ist laut dem Konsortium sehr lückenhaft. Um einen belastbaren und aktuellen AKO für diesen Abfallschlüssel zu ermitteln, sollten entweder neuere Abfallsortieranalysen durchgeführt oder eine andere Erhebungsmethodik (siehe „übrige Abfallschlüssel") verwendet werden. Die gleiche Empfehlung gilt für den Abfallschlüssel „gemischte Siedlungsabfälle nicht differenzierbar" (20 03 01 00).

Eine weitere Datenlücke besteht bei der Zusammensetzung der übrigen Abfallschlüssel. Hier besteht dringender Forschungsbedarf. Generell empfiehlt das Konsortium für die zukünftige Berichterstattung, weitere Erhebungen, Recherchen und Analysen zur Ermittlung der AKO der übrigen Abfallschlüssel durchzuführen. Dabei sei es notwendig, die Datenlage durch physische Erhebungen und einen größeren Stichprobenumfang zu verbessern. Um valide Aussagen bzgl. des Stichprobenumfangs von Abfallsortieranalysen in den Stufen 1 bis 4 der LMK treffen zu können, müsste laut Konsortium zunächst ein Rahmenkonzept erarbeitet und definiert werden. Insgesamt sei die Entwicklung eines systematischen Vorgehens bezüglich der Stichprobenplanung und Analysemethode an dieser Stelle besonders wichtig.

Empfehlungen für die zukünftige Berichterstattung

Für die zukünftige Berichterstattung wird die Nutzung aller verfügbaren Datenquellen empfohlen, wobei jeweils den validierten Daten der Vorzug gegeben werden sollte. Physische Daten, wie zum Beispiel Abfallstatistiken, ergänzt um physische Angaben zur Abfallzusammensetzung, repräsentieren in diesem Zusammenhang die verlässlichste Datengrundlage.

Handlungsempfehlungen zur Reduzierung von Lebensmittelabfällen

Neben der Ermittlung der AKO hat das Konsortium Handlungsempfehlungen zur LMA-Reduzierung erarbeitet.

Angesichts der unterschiedlichen Vermeidungspotenziale von LMA empfiehlt sich laut dem Joint Research Institute (JRC) der EU eine Spezifizierung der relativ allgemein formulierten Zielvorgaben von SDG 12.3 für die jeweiligen Bereiche der LMK sowie für einzelne Branchen. Die Erarbeitung und Fortschreibung einer umfassenden Datenbasis ist deshalb der Schlüssel für eine nachhaltige Systemoptimierung. Laut JRC sollen sektor- und branchenspezifische Vermeidungsziele definiert werden, die sich unter anderem an den tatsächlichen Vermeidungspotenzialen orientieren. Die Ziele sollen „SMART" (Spezifisch, messbar, ausführbar, relevant, terminiert) sein und anhand von Leistungsindikatoren gemessen werden. Leistungsindikatoren können zum Beispiel durch ein Monitoring von Abfall- und Verlustmengen in Bezug auf Produktionsmengenformuliert werden, um dadurch die Effizienz von Prozessen messbar zu machen. Dieses Vorgehen wird in Deutschland unter anderem von den Dialogforen teilweise umgesetzt und entsprechende Daten erhoben.

1 Background

About eleven million tonnes of food are disposed of as waste along the food supply chain in Germany every year (StBA 2023a). Globally, this figure was around 1.3 billion tonnes in 2011 – about one third of the food produced (Gustavsson et al. 2011). The current figures from the Food and Agriculture Organization of the United Nations show that around 13.8 %[9] of food is lost as food losses (Food and Agriculture Organization of the United Nations 2019). The Food Waste Index Report (2021) estimates that the total food waste from households, retail establishments and the food service industry is around 931 million tonnes per year (United Nations Environment Programme 2021). The food that is not consumed uses up enormous amounts of agricultural land and causes about 8 % of greenhouse gas emissions (Mbow et al. 2019). Article 9 of the EU Waste Framework Directive (WDF) ("Waste Prevention") and Directive (EU) 2018/851 Recital Number 31, based on Sustainable Development Goal 12.3, aim to halve the per capita food waste at retail and consumer level and reduce food losses along the production and supply chains.

In 2019, the European Commission issued two supplementary decisions providing more clarification – Delegated Decision (EU) 2019/1597 on the methodology for the measurement of food waste and Implementing Decision (EU) 2019/2000 on the format for the submission of reports. Alongside the WDF, these EU legal acts require member states to measure the mass of food waste on a yearly basis and report to the EU Commission at the latest 18 months after the end of the reporting year (for the first time by June 30, 2022 for the reporting year 2020).

Reducing food waste is also part of the new circular economy action plan from the EU Commission (2020) and is currently being implemented through the "Farm to Fork Strategy".

In response to a proposal by the Federal Ministry of Food and Agriculture (BMEL), the German government agreed a "National Strategy for Food Waste Reduction" in February 2019. This aims to establish sector-specific dialogue with companies from the areas of primary production, processing and manufacturing, retail and other distribution of food, restaurants and food services and households (dialogue forums), and coordinating bodies. In the revision of the Circular Economy Act (KrWG – Kreislaufwirtschaftsgesetz) in October 2020, Article 9 (1) g) of the WFD (SDG 12.3) was adopted as Article 33 (3) no. 2 g) of the KrWG. This article states: "The waste prevention programme […] 2. shall provide for at least the following waste prevention measures: […] g) the reduction of food waste in primary production, processing and manufacturing, in retail and in other forms of food distribution, in restaurants and in catering, as well as in private households, in order to contribute to the United Nations sustainable development goal to halve per capita global food waste at the retail and consumer levels by 2030 and reduce food losses along production and supply chains, including post-harvest losses, […]." (KrWG Article 33 (3) No. 2 g)).

In order to fulfil one of the requirements of the National Strategy, an interdisciplinary working group on indicator SDG 12.3 – comprising the BMEL, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), the Thünen Institute, the German Environment Agency (UBA) and the Federal Statistical Office (StBA) – developed a method paper on reporting. During the discussions held by this working group, a monitoring concept was developed, which is used for the disposal of waste. The starting point is the so-called "Food Waste Plug-In", in which the StBA provides data to the EU Commission on a voluntary basis every two years for the reporting years 2012 to 2020. The StBA has thus voluntarily provided Eurostat with data on the amounts of waste that could contain food waste.

[9] This information relates to the areas of primary production, processing and manufacturing as well as wholesale.

In accordance with the guidance provided by Eurostat, the StBA did not provide data on the proportion of actual food waste as part of the Food Waste Plug-In due to a lack of data (especially waste coefficients). The Food Waste Plug-In thus differs from the newly developed monitoring concept in this respect. In addition, the Food Waste Plug-In and the current monitoring approach also differ with respect to the different types of waste and economic sectors covered.

The BMUV and UBA have commissioned the StBA with the task of fulfilling the EU reporting obligation for food waste for the first time for reporting year 2020. The UBA transferred this responsibility to the StBA in the form of a research project in the ReFoPlan 2021 (Departmental research plan) on the theme "Determination of food waste in Germany in 2020, fulfilment of the reporting obligation to the EU Commission in 2022 and derivation of recommendations for action".

2 Definitions

We define the following terms to avoid any misunderstandings and make the report easier to understand.

- Biowaste
  - Biowaste describes waste that is collected via biowaste bins by the corporate bodies responsible for waste management (public waste disposal authorities (örE)) or by companies commissioned by them. Biowaste can also contain small amounts of commercial biowaste.
    In the waste statistics, the amounts of waste from biowaste bins are recorded under the eight-digit waste code “20 03 01 04 – waste from biowaste bins”.
- Campaign
  - Campaigns are repeats of already completed tests carried out to analyse the impact over time or to establish plausibility. In analyses of household waste and biowaste, the impact of seasonal changes is taken into account through one testing campaign in low vegetation and one in rich vegetation periods. A campaign begins with the start of an analysis on site and ends at the conclusion of the analysis (Intecus 2016).
- Commercial waste
  - Household waste and, to a small extent, biowaste also always include a proportion of waste of commercial origin, so-called commercial waste, which is collected together with household waste and biowaste from private households.
- Commercial waste similar to household waste
  - Standard commercial waste differs from commercial waste similar to household waste because standard commercial waste is disposed of in waste containers that are exclusively provided to commercial companies and which are collected separately from household waste.
- Consortium
  - The waste coefficients and the amount of food waste utilised for home composting were determined by a subcontractor within the research project. The subcontractor also identified recommendations for action to reduce food waste. This subcontractor was a consortium consisting of the “Witzenhausen-Institut für Abfall, Umwelt und Energie GmbH (WI)”, “ARGUS-Statistik und Informationssysteme in Umwelt und Gesundheit GmbH (ARGUS)”, the “Institut für Abfall, Abwasser und Infrastruktur-Management GmbH (INFA)” and the “Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft der Universität Stuttgart (USTUTT)”.
- Dialogue forums
  - The aim of the sector-specific dialogue forums initiated by the BMEL is to bring together stakeholders from the food sector, from organisations within civil society, responsible government authorities and from science for the purpose of reaching agreements on reducing food waste and developing specific measures for their respective sector. The dialogue forums focus on the entire food supply chain in order to identify the best

possible starting points for reducing food waste and promoting the implementation of sector-specific action plans (BMEL 2021).

- Economic sector
  - An economic sector describes a group of companies or facilities that produce similar products or provide similar services as part of economic activities (StBA 2023b). The economic sectors or activities are classified in Delegated Decision (EU) 2019/1597 according to the codes in NACE Rev. 2 (2008).
- Food waste
  - The definition of "food" laid down in Regulation (EC) No. 178/2002 of the European Parliament and of the Council encompasses food as a whole, along the entire food supply chain from production until consumption. Food also includes inedible parts, where those were not separated from the edible parts when the food was produced, such as bones attached to meat destined for human consumption. Hence, food waste can comprise items which include parts of food intended to be ingested and parts of food not intended to be ingested.
- Household waste
  - Household waste is waste primarily from private households that is regularly collected, transported and prepared for disposal by the municipal authorities responsible for waste disposal or by third parties commissioned by them (German government 1993). Household waste is usually disposed of in residual waste bins and recorded under waste code 20 03 01 01.
- Material groups
  - In order to determine the composition of the waste, it is split into its different fractions (material groups). This process is carried out by screening (visual division) or sorting (manual division) (Intecus 2016).
- Mixed municipal waste
  - Municipal waste is waste from private households and comparable premises, as well as commercial and industrial waste similar to household waste. This municipal waste includes household and bulky waste, organic and garden waste, and materials such as paper and packaging (Ministry of the Environment, Nature Conservation and Transport (MUNV) North Rhine-Westphalia (NRW) 2022; BMUV 2020). Mixed municipal waste is recorded under waste code 20 03 01.
- Native organic waste
  - Native organic waste is processed and unprocessed kitchen waste and food scraps, garden waste and other organic waste (Dornbusch et al. 2020).
- Other waste codes
  - "Other waste codes" are understood in this investigation as all waste that is recorded under the waste codes listed in Annex II of Delegated Decision (EU) 2019/1597. An exception is waste code 20 03 01 (mixed municipal waste). This is investigated separately.

- Stages of the food supply chain
  - The stages of the food supply chain cover all steps from the production of food through to its consumption by the end consumer. Delegated Decision (EU) 2019/1597 defines the following five stages of the food supply chain: 1. Primary production, 2. Processing and manufacturing, 3. Retail and other distribution of food, 4. Restaurants and food services and 5. Households.
- Strata
  - Strata are subpopulations of an overall population (Dornbusch et al. 2020).
  - In order to analyse household waste and biowaste, a multilevel stratified random sampling method was used to collect the data. This stratified approach, in which the overall population is split into several subpopulations (so-called strata), makes it possible to investigate the influence of assumed variables (Dornbusch et al. 2020).
  - The following influencing parameters for stratifying the overall population were taken into account when planning the random sampling for the household waste analyses: Settlement structure (federal level), fee structure (federal level), separate collection of biowaste (federal level), building structure (örE level).
- Waste type/waste stream
  - According to the German Waste Catalogue Ordinance (AVV), waste must be allocated to a particular waste type that consists of a six-digit waste code and a waste description. There are 842 different types of waste in total (BMUV 2023).
- Waste code (from the European List of Waste)
  - The European List of Waste is the authoritative list for the designation of waste in the EU. It mainly classifies the wastes according to their origin. Waste is classified by allocating it to a waste type with a waste code. The aim of this waste classification process is to develop uniform waste designations across Europe (UBA 2016).
  - The waste codes are usually listed in the European List of Waste as six-digit numbers. Eight-digit numbers are sometimes used in Germany for more detailed classification purposes.
- Waste coefficient
  - The waste coefficient indicates the proportion of food waste in the total amount of waste for the respective waste code (e.g. 45 %).

3 Objective of the research project

The objective of the research project is to prepare the first report to the EU Commission on food waste for the reporting year 2020. The StBA submitted the results (including the quality control report) to the EU Commission by June 30, 2022 in accordance with EU specifications. In addition, this research project aims to develop suggestions for optimizing reporting and identify tools and measures for further reducing food waste. Moreover, the aim is to derive reliable data – with the aid of waste coefficients – on the proportion of food waste in the different types of waste that may contain food.

The national, official statistics can show the potential but not the actual amount of food waste in Germany. These surveys do not determine how high the proportion of food waste is in the total amount of waste for each waste code. The reason for this is that no distinction is made between food waste and non-food waste for the waste codes according to the European List of Waste. In order to calculate the total amount of food waste, the amounts of waste in each waste code (according to the data set) must therefore be multiplied by waste coefficients. The waste coefficient indicates the proportion of food waste (e.g. 45 %) that the waste code typically contains.

The waste coefficients and the amount of food waste utilised for home composting were determined by a subcontractor within the research project. The subcontractor also identified recommendations for action to reduce food waste. This subcontractor was a consortium of institutes – WI, ARGUS, INFA and USTUTT.

3.1 Project content

The following chapter presents the content of this research project. The data submitted to the EU Commission for the reporting year 2020 exclusively covers the obligatory information specified in Delegated Decision (EU) 2019/1597. For this reason, the data is not broken down further, such as by product group, waste code nor is any information provided about data collected voluntarily on waste. Therefore, this research project will not draw any conclusions about the avoidable proportion of food waste.

3.1.1 Gathering data from official waste statistics

The first step was to examine the national, official waste statistics for their relevance to food waste. A selection of official waste statistics, as well as the data they contain on the relevant waste codes that may contain food waste, were then used to produce a data set for the calculations and the reporting of the amounts of waste. Delegated Decision (EU) 2019/1597 lists the waste codes that should be included in this process. It was then necessary to allocate the identified amounts of waste to the relevant economic sector or activity using the latest results from the official statistics because this information is not available in complete form as primary data. In addition, information on the proportion of packaging in food waste from packaged food also had to be collected.

3.1.2 Evaluating the research results and determining the coefficients

The consortium commissioned as a subcontractor by the StBA was then responsible for determining waste coefficients for all of the relevant waste codes. The aim was to base this derivation, where possible, on regionally weighted results so as to produce representative average values for the whole of Germany. The waste sorting analyses mainly focussed on household waste and biowaste because these classifications contained the largest amounts of waste. The waste coefficients can be determined not only with the aid of the consortium's own waste sorting analyses but also using literary research, questionnaires and feedback from the dialogue forums.

3.1.3 Calculating the reporting data, submitting it to Eurostat and deriving recommendations for action to reduce food waste

Last but not least, it was necessary to collect together the results of the previous work steps and prepare it for the reporting. The data to be reported had to be calculated in accordance with the requirements stipulated in Delegated Decision (EU) 2019/1597 and Implementing Decision (EU) 2019/2000. For this purpose, the waste coefficients determined by the consortium for the data collected had to be assigned to the respective stages of the food supply chain. All data had to be submitted to Eurostat – the statistical office of the EU Commission – by June 30, 2022.

4 Legal regulations

4.1 Definition of food waste

The definition of "food" laid down in Regulation (EC) No. 178/2002 of the European Parliament and of the Council encompasses food as a whole, along the entire food supply chain from production until consumption. Food also includes inedible parts, where those were not separated from the edible parts when the food was produced, such as bones attached to meat destined for human consumption. Hence, food waste can comprise items which include parts of food intended to be ingested and parts of food not intended to be ingested.

Food waste does not include losses at stages of the food supply chain where certain products have not yet become food as defined in Article 2 of Regulation (EC) No 178/2002, such as edible plants which have not been harvested. In addition, it does not include by-products from the production of food that fulfil the criteria set out in Article 5 (1) of Directive 2008/98/EC, since such by-products are not waste (e.g. feathers and pig bristles). To improve the precision of the measurement of food waste, non-food materials mixed together with food waste (e.g. packaging) should be excluded from the mass of the food waste to the extent possible.

Types of food that are usually discarded as or with wastewater were not considered in this research project. It is not obligatory to measure this type of food waste. The amounts of food waste were measured in tonnes (or metric tons) of fresh mass. The legal regulations also require that food waste is measured separately for each stage of the food supply chain.

4.2 Legal basis

The WFD (2008/98/EG) introduced an annual reporting obligation on the amount of food waste from the baseline year of 2020. The purpose of reporting is to monitor the implementation of food waste prevention measures by the member states of the European Union on the basis of a common methodology. In addition, it will enable an evaluation of the measures through the measurement of food waste at the different stages of the food supply chain.

Article 9 of the WFD ("Prevention of waste") aims – in line with Sustainable Development Goal (SDG) 12.3 – to halve the per capita food waste at retail and consumer level and reduce food losses along the food production and supply chains.

The EU Commission issued two supplementary decisions providing more clarification in 2019 – Delegated Decision (EU) 2019/1597 on the methodology for the measurement of food waste and Implementing Decision (EU) 2019/2000 on the format for the submission of reports. These EU legal acts require EU Member States to measure the mass of food waste on a yearly basis and report to the EU Commission, for the first time by June 30, 2022 for the reporting year 2020.

In addition, the EU Commission has also published a guidance document on this subject (European Commission 2022). This guidance document aims to support the harmonised reporting of data on food waste and surplus food by providing information and explanations on the basis of the provisions in the legal act and the methodological framework. It is anticipated that this guidance document will be updated by the EU Commission on an annual basis.

5 Generating the data set

The following chapter explains the first calculation steps for the research project. It covers the creation of the data set using the national, official waste statistics.

As already described, the national, official statistics can show the potential – but not the actual – amount of food waste in Germany. These surveys do not determine how high the proportion of food waste is in the total amount of waste for each waste code. The reason for this is that no distinction is made between food waste and non-food waste for the waste codes according to the European List of Waste. In order to calculate the total amount of food waste, the amounts of waste in each waste code (according to the data set) must therefore be multiplied by waste coefficients. The waste coefficient indicates the proportion of food waste (e.g. 45 %) that the waste code typically contains. Chapter 6 describes how the waste coefficients are determined.

5.1 Methodology

5.1.1 Data set according to the requirements of Delegated Decision (EU) 2019/1597

The data set was compiled using various different national, official waste statistics that are collected in accordance with the Environmental Statistics Act (UStatG) (see Table 3). In order to reduce the burden on those bodies responsible for this reporting, surveys are sent mainly to operators of waste disposal facilities, construction waste processing plants, companies that generate waste and the municipal authorities. The statistical offices of the federal states use online questionnaires to survey these operators and then transfer the results for their state to the StBA.

The waste codes specified in Annex II of Delegated Decision (EU) 2019/1597 were taken into account by the StBA when generating the data set. Food waste monitoring for European reporting purposes involves adding together the amounts of waste (in tonnes of fresh mass) for the relevant waste codes. The following four national, official sets of waste statistics were used to determine the amount of waste:

- Waste disposal statistics (Abfallentsorgung – AE)
- Statistics on the processing and recycling of construction and demolition waste (Bauschutt – BS)
- Statistics on landfill construction measures (Deponiebau – DepBau)
- Statistics on the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Grenzüberschreitenden Verbringung – GV).

In Germany, the amounts recorded in these statistics are measured by weighing the waste immediately when it arrives at the waste treatment plants. Therefore, the measurements are carried out directly after the waste is collected, i.e. before any treatment such as drying. The statistics include the inputs at all registered waste disposal facilities and the amount of waste that is disposed of in each facility for each type of waste delivered there from within Germany (i.e. generated in Germany).

The waste disposal statistics collected annually from registered operators of waste disposal facilities also cover information about the type, origin and fate of the processed waste. This also includes waste that is disposed of in company-owned disposal facilities. Data on waste streams that are handled outside of approved waste treatment plants are not collected.

For completeness, the StBA included the BS statistics in the total amounts of waste, despite the fact that the results of this survey are only expected to contain very low amounts of food waste. The BS statistics are collected as a full survey every two years in accordance with the UStatG. The results from the previous year are used in the intermediate years. The StBA also took the DepBau statistics into account in the calculation of the amounts of waste for the sake of completeness. It was also expected that these statistics would also only contain low amounts of food waste. The DepBau statistics are collected as a full survey every year in accordance with the UStatG.

The amounts of waste in the GV statistics was also added to the data collected from the AE, BS and DepBau[10] statistics. The GV statistics cover the amount of notifiable waste that is exported abroad (direct export) or imported into Germany. This waste is monitored in accordance with the Basel Convention, statistically evaluated in Germany by the UBA and passed on to the StBA. The food waste monitoring for reporting year 2020 only takes into account the waste exported from Germany in the GV statistics. The complete data for these statistics can be viewed under the following link: https://www.umweltbundesamt.de/themen/abfall-ressourcen/grenzueberschreitende-abfallverbringung.

The amounts of waste containing food waste that were calculated in this way were then allocated to the economic sectors or activities stated in Annex I of Delegated Decision (EU) 2019/1597. Some of the waste codes named in the Delegated Decision are also found in Germany in other stages of the food supply chain or in other economic sectors that are not expressly prescribed in Delegated Decision (EU) 2019/1597. Further information on this subject can be found in Chapter 5.1.2.1.

The process of allocating the waste that could contain food waste was carried out using three national, official sets of waste statistics that contain information on the economic sectors of the generators of the waste:

- Statistics on public waste disposal (household waste) (OERE)
- Waste disposal statistics (Abfallentsorgung – AE)
- Waste generation statistics (Abfallerzeugung – AEU)

The OERE statistics collected by the StBA record the amounts of waste from households that are collected, recycled and disposed of each year by the örE. This data is broken down at federal and state levels. The OERE statistics for the federal states also include data at a district level. This includes household waste from commercial and nonprofit collections, if such data is available. Household waste exclusively comprises certain types of waste in category 20 (municipal wastes) and group 15 01 (packaging) in the European List of Waste, which were defined as being primarily of a household nature by a working group consisting of representatives of the highest waste authorities at a state level, the BMUV, UBA, StBA and statistical offices of the federal states. Household waste can be broken down into the main waste streams of household waste, bulky waste, separately collected biowaste (biowaste bin), separately collected materials, old electrical appliances and other separately collected waste. These types of waste are each recorded using eight-digit waste codes that are not listed in the European List of Waste. Based on the OERE statistics, the amounts of waste from 20 03 01 01 (household waste) and 20 03 01 04 (biowaste) were deducted from the higher-level six-digit code 20 03 01 (mixed municipal waste) and assigned to the stage “households” for the food waste monitoring for reporting year 2020. The remainder of waste code 20 03 01 – consisting of the two eight-digit codes “20 03 01 00 – non-

[10] There were no potential amounts of food waste in the DepBau statistics in the reporting year 2020.

differentiable mixed municipal waste" and "20 03 01 02 – commercial waste similar to household waste that is delivered or collected separately from household waste" – were then assigned to stages 1 to 4 of the food supply chain based on the percentages derived from the AEU statistics.

Based on the AE statistics, the amounts of waste disposed of in company-owned disposal facilities were allocated to the economic sectors of the respective company or waste disposal facility for food waste monitoring for reporting year 2020. For example, the amounts of waste recorded in the AE statistics for waste code 02 03 05 (Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Sludges from on-site effluent treatment) were directly allocated to the economic sector 10.3 (Processing and preserving of fruit and vegetables). These specific amounts of waste were thus allocated directly as originating in economic sector (10.3) for the food waste monitoring for reporting year 2020.

The AEU statistics are collected every four years as part of a full survey with cut-off thresholds. According to the UStatG, the survey may only be sent to a maximum of 20,000 companies. The size of the surveyed companies varies based on the economic sector, although they must have at least 50 employees subject to social security contributions. Surveying larger companies who have more than a certain number of employees ensures that the survey covers the largest possible amount of waste generated in Germany and also reduces the burden on smaller companies. The results from the previous survey are used in each of the intermediate years. The data for the EU reporting in the reporting year 2020 was taken from reporting year 2018. The AEU statistics indicate which percentage of the waste in each waste code should be allocated to each economic sector. The results of the AEU (indicating the percentage of waste in each waste code that can be allocated to each sector) were used to allocate the remaining waste from the AE, BS, DepBau and GV statistics, for which there was no other information on its origin, to the economic sectors. This subsequent step was necessary because the origin of the waste (economic sector) was not always known for all amounts of waste. Therefore, the AEU statistics do not contribute to the total amounts of waste but are exclusively used to allocate the wastes from the AE, BS, DepBau and GV statistics to economic sectors for food waste monitoring for reporting year 2020. According to the AEU statistics, for example, 99 % of the waste in waste code 02 06 99 (Wastes from the baking and confectionery industry: Wastes not otherwise specified) comes from economic sector 10.7 (Manufacture of bakery and farinaceous products) and 1 % from economic sector 10.8 (Manufacture of other food products). This percentage distribution is used as the basis for allocating the measured and accumulated totals for the waste from the AE, BS, DepBau and GV statistics to the originating economic sectors.

The national, official waste statistics used to calculate the amount of food waste are validated by and subject to constant quality management by the group of participating statistical offices of the federal states. Following a manual verification process, all of the data submitted by the federal states is subject to an automated verification process. The reported data is compared, for example, with the results from previous years and also undergoes other plausibility checks. In the event of any discrepancy, the statistical offices of the federal states consult the respondents to the survey. The individual checks are examined and, if necessary, amended on an annual basis by the StBA in consultation with the statistical offices of the federal states based on empirical values and new developments.

Classifying the types of waste using codes comparable to the waste codes in the European List of Waste has a decisive influence on the quality of the waste statistics. Checking the classification of the types of waste to the waste codes using plausibility checks is only possible to a limited extent. The statistical offices of the federal states remain in close contact with respondents. By querying data with them, comparing it to previous years and carrying out automated plausibility checks they are able to achieve a high level of quality in the data.

Detailed information on the quality of the data and on the methodology used for the surveys described above can be found in the quality reports published by the StBA at https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Abfallwirtschaft/_inhalt.html#sprg414834.

Table 3: Data set from the national, official waste statistics for the reporting year 2020

AE - RY 2020	BS - RY 2020	DepBau - 2020	GV - RY 2020	AEU - RY 2018	OERE - RY 2020
Waste disposal statistics	Statistics on the processing and recycling of construction and demolition waste	Statistics on landfill construction measures	Statistics on the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal	Waste generation statistics	Statistics on household waste from the public waste disposal authorities
§ 3.1 UStatG	§ 5.1 UStatG	§ 3.1 UStatG	§ 4.2 UStatG	§ 3.3 UStatG	§ 3.2 UStatG
Annual, full survey	Biennial, full survey (even-numbered years)	Annual, full survey	Annual, full survey	Quadrennial, partial survey	Annual, full survey
Use: Calculating amount of waste	Use: Calculating amount of waste	Use: Calculating amount of waste	Use: Calculating amount of waste	-	-
Use: Allocation to economic sector	-	-	-	Use: Allocation to economic sector	Use: Allocation to economic sector

Source: Own illustration, StBA

The amounts of waste allocated to the economic sectors were then assigned to the five stages of the food supply chain. Annex I of Delegated Decision 2019/1597 indicates which economic sectors belong to which stages of the food supply chain. The amounts of waste were then added up at the level of the stages (balancing).

5.1.2 Modifications to the data set

The StBA made the following modifications to the data set in order to fulfil its European reporting obligation for the first reporting year 2020 as well as possible:

1. Consideration of some waste codes stated in Delegated Decision (EU) 2019/1597 at other stages of the food supply chain which were not expressly prescribed by this decision. The waste codes and corresponding stages of the food supply chain were selected on the basis of the results of the national, official waste statistics.
2. Removing the commercial waste from stage 5 of the food supply chain and then redistributing it to stages 1 to 4 of the food supply chain.

5.1.2.1 Consideration of additional waste codes

Annex II of Delegated Decision (EU) 2019/1597 specifies which waste codes should be assigned to which stages of the food supply chain. The StBA has access to the information from the national, official waste statistics that some waste codes also occur in stages of the food supply chain or in economic sectors not expressly prescribed by Delegated Decision (EU) 2019/1597. According to Delegated Decision (EU) 2019/1597, for example, the six-digit code "20 03 01 – Mixed municipal waste" originates in stages 3 to 5 of the food supply chain. Based on the results from the AEU, the StBA determined that the six-digit code "20 03 01 – Mixed municipal waste" also originates in stages 1 and 2 of the food supply chain in reporting year 2020. This can probably be attributed to the fact that, in addition to the primary economic activity, amounts of waste can also be generated by secondary activities of companies. These amounts of waste were allocated to the economic sector of the main activity, even if the types of waste do not match the main activity. In addition, it is possible that companies do not always classify their waste using the European List of Waste strictly according to its origin.

In order to give as complete a picture as possible of the amount of food waste in Germany, the StBA also considered these amounts of waste and assigned them to the corresponding stages of the food supply chain. The StBA did not use any new or additional waste codes; instead, the stages of the food supply chain were expanded to include waste codes that already occur at other stages and that can contain food waste. Annex C contains a full list of the additional waste codes that were taken into account for each stage of the food supply chain.

Furthermore, two waste codes were not allocated to stage 5 of the food supply chain despite the fact that Delegated Decision (EU) 2019/1597 actually assigns them to this stage. These two waste codes are "20 01 08 – Biodegradable kitchen and canteen waste" and "20 01 25 – Edible oil and fat". They were not taken into account for stage 5 of the food supply chain because the amounts of waste in the German waste management system for this waste code are usually not generated by private households. Therefore, the StBA has assigned these two waste codes exclusively to stages 1 to 4 of the food supply chain as part of its monitoring of food waste. The amounts of waste from these two waste codes – collected from the AE, BS, DepBau and GV statistics – were allocated to the economic sectors and thus the stages of the food supply chain on the basis of the AEU statistics.

5.1.2.2 Commercial waste

Household waste and to a lesser extent biowaste (biowaste bin) always include a proportion of commercial waste that is collected together with the household waste and biowaste from private households. Commercial waste is waste that is generated in small businesses such as engineering offices, tax consultants, lawyers, etc. and is disposed of in the bins provided by the örE (residual waste bin: waste code "20 03 01 01, biowaste bin: waste code "20 03 01 04"). Accordingly, commercial waste is included in households (stage 5 of the food supply chain), but originates from various economic sectors in stage 1 to 4 of the food supply chain.

The amount of commercial waste is calculated as the difference between the amounts of waste reported by the örE and the extrapolated amount of household waste from households. Further information can be found in Chapter 6.1.

Commercial waste was removed from stage 5 of the food supply chain and then redistributed to stages 1 to 4 of the food supply chain based on the national, official waste statistics. Further information on the redistribution of the waste to the different stages of the food supply chain is provided in Chapter 5.1.1.

5.2 Results

Table 4 contains the data set as collected before applying the waste coefficients for the reporting year 2020 for each stage of the food supply chain. Detailed results for each waste code can be found in Table 38 in the annex.

Table 4: Data set for monitoring food waste, reporting year 2020

Stage of the food supply chain	Potential amount of food waste[1] in tonnes (without applying the waste coefficients)	Potential amount of food waste[1] in % (without applying the waste coefficients)
1	491,329	2
2	2,629,684	10
3	2,225,165	8
4	4,666,965	17
5	16,931,835	63
Total	**26,944,977**	**100**

[1] Including home composting in stage 5 of the food supply chain and the modifications, rounded values.

Source: Own research, StBA

6 Determination the waste coefficients

In order to fulfil the requirements for the measurement of food waste according to Annex III of Delegated Decision (EU) 2019/1597, waste coefficients had to be applied to the results (data set) collected by the StBA. In contrast to the process for generating the data set, the waste coefficients could not be derived from the results of national, official surveys. There is thus no legal obligation for those being surveyed to provide this information.

The following chapter describes how the waste coefficients were demined for mixed municipal waste (20 03 01) and the other waste codes from Annex II of Delegated Decision (EU) 2019/1597. The StBA commissioned a consortium of four institutes with the task of determining the waste coefficients. An overview of the results of this process is presented in Annex F.

6.1 Mixed municipal waste (20 03 01)

Municipal waste is waste from private households and comparable premises, as well as commercial and industrial waste similar to household waste. Municipal waste includes household and bulky waste, organic and garden waste, and materials such as paper and packaging (MUNV NRW 2022; BMUV 2020). Mixed municipal waste is recorded under the waste code "20 03 01". This includes household waste (20 03 01 01), commercial waste similar to household waste (20 03 01 02), non-differentiable mixed municipal waste (20 03 01 00) and biowaste (20 03 01 04). In the reporting year 2020, there was a total of 22,429,665 t of waste in waste code 20 03 01 before application of the waste coefficient. This corresponds to approx. 83 % of the potential food waste before application of the waste coefficient (total amount: 26,944,977 t[11]).

Household waste (20 03 01 01) and to a lesser extent biowaste (20 03 01 04) always includes a proportion of commercial waste that is collected together with the household waste (residual waste bins) and the biowaste from private households (biowaste bins). Household waste and biowaste that include commercial waste will be referred to below simply as household waste and biowaste.

Standard commercial waste differs from commercial waste similar to household waste because standard commercial waste is disposed of in waste containers that are exclusively provided to commercial companies and which are collected separately from household waste. The term "biowaste" is used here to describe the amounts of biowaste that are collected by the örE or on behalf of the örE in biowaste bins. Biowaste can also contain small amounts of commercial biowaste.

The methodology used to derive the waste coefficients for household waste and biowaste from private households and for commercial waste similar to household waste will be summarised below and then described in more detail in the same order in subsequent subchapters.

6.1.1 Household waste including commercial waste (20 03 01 01)

6.1.1.1 Nationwide Household Waste Analysis

6.1.1.1.1 Collection of data and the data set taken from the Nationwide Household Waste Analysis

The Nationwide Household Waste Analysis commissioned by the UBA and published in 2020 is the most comprehensive data set currently available (Dornbusch et al. 2020). The data collected

[11] Including home composting in stage 5 of the food supply chain and the modifications.

and the methodological approach utilised for the analysis form the basis for determining the waste coefficient for the eight-digit code “20 03 01 01 – household waste, commercial waste similar to household waste collected together via public waste disposal” (household waste). This code covers the contents of the residual waste bin. Of the four institutes in the consortium, three of them had also participated previously in the project for the Nationwide Household Waste Analysis.

The results of the Nationwide Household Waste Analysis show the amount and composition of household waste from households in Germany. The analyses were carried out in 14 collection areas across the country (örE). Breaking down the analyses into different strata (stratification) made it possible to highlight the influence of various factors on the composition of the household waste and understand their effect.

The aim of the Nationwide Household Waste Analysis was to close any gaps in the data on the composition of residual household waste in the Federal Republic of Germany with sufficient precision. The term “municipal residual waste” describes the waste from households that was collected via the services operated by the corporate bodies responsible for waste management.

Native organic waste is the largest material group in household waste. It includes kitchen waste and food scraps, garden waste, other organic waste and packaged food (including the packaging). Kitchen waste covers uncooked waste such as the unused parts of fruit and vegetables, coffee filters, potato peelings, eggs shells, etc. Cooked and prepared kitchen waste – such as leftover food, fish, meat and milk products – is allocated to the subgroup “food scraps”.

Food as defined in Regulation (EC) No 178/2002 of the European Parliament and of the Council (2) also includes inedible parts, where those were not separated from the edible parts when the food was produced, such as bones attached to meat destined for human consumption. Hence, food waste can comprise items which include parts of food intended to be ingested and parts of food not intended to be ingested. These inedible components can thus be found in the fractions “kitchen waste and food scraps”.

Accordingly, the data collected in the Nationwide Household Waste Analysis for kitchen waste and food scraps and for packaged food were added together to determine the fraction “food waste”. The proportion of this waste accounted for by packaging was then subtracted (see Chapter 6.1.1.2.2).

6.1.1.1.2 Methodology used for the Nationwide Household Waste Analysis

The material composition of the household waste that was used for calculating the waste coefficient was determined based on the Nationwide Household Waste Analysis carried out in the period from 2017 to 2019. Therefore, the methodology used for this analysis is briefly explained below.

The Nationwide Household Waste Analysis used a multi-stage stratified extrapolation method to calculate the amount and composition of the waste. The amounts of waste in the different strata (different aspects of the analysis based on various influencing factors) at the örE level were extrapolated to the federal level. The data was extrapolated for each of the strata according to the numbers of inhabitants served by the household waste disposal system.

This research project, which was carried out on behalf of the UBA, analysed 14 representative collection areas across the country (örE) at 12 strata at the federal level and four strata at the örE level (see Table 7). The sample unit for the analysis was defined as the waste container (e.g. bin) made available for collection at the property (Dornbusch et al. 2020).

By using a stratified approach, it was possible to investigate the significance of different factors on the amount and composition of household waste from private households. This stratification process divides a heterogeneous population into homogeneous subpopulations. The sampling units for the overall population were allocated to the strata based on defined stratification criteria (Dornbusch et al. 2020).

The following influential parameters were taken into account for planning the sampling process for the Nationwide Household Waste Analysis (Dornbusch et al. 2020):

- Seasonal influences
- Building structure (public waste disposal authority level)
- Settlement structure (federal level)
- Fee structure (federal level) and
- Separately collected biowaste (federal level).

The amount and composition of municipal residual waste can vary during the course of the year and this was taken into account by carrying out the sampling campaigns at different times of the year. Four sampling campaigns were carried out throughout the year (spring, summer, autumn, winter analyses) in accordance with national sorting regulations (e.g. Saxony (Intecus 2016), Brandenburg (State Office for the Environment Brandenburg 1998) or NRW (State Office for the Environment NRW 1998)) (Dornbusch et al. 2020). Seasonal influences were taken into account by carrying out one sampling campaign in the low vegetation phase and one in the rich vegetation phase. As the Nationwide Household Waste Analysis was planned and implemented as a representative nationwide study, the consortium did not consider any other household waste analyses that had been carried out since it was completed.

The study defined a total of twelve strata at the federal level with the stratification parameters “settlement structure”, which was based on the population density (rural, densely populated rural area and urban/metropolitan), “fee system” for the collection of the residual waste (scheduled collection[12] and fee-based technological systems[13]) and “separately collected biowaste” (< 25 kg/(inhabitants) (i) * Year (a)) or ≥ 25 kg/(i*a). Stratum 10 (urban, fee-based technological systems, < 25 kg/(i*a)) had a very low population (0.4 % of inhabitants, see Table 6) and the two public waste disposal authorities in this stratum were thus moved into stratum 6 (densely populated rural area, fee-based technological systems, < 25 kg/(i*a)).

An additional four strata were defined at the örE level based on the parameter “building structure”: Large housing estates (LHE), condensed urban structures (City), suburban structures and rural structures (Outskirts) and public waste disposal authority overall (örE). The suburban structures and rural structures were combined into one stratum for the presentation of the results. These strata were assigned based on the number of apartments per building.

As the Nationwide Household Waste Analysis included 504 sampling units, it can be assumed that the data has sufficient statistical power (test strength) for defining the waste coefficients precisely enough for this study. Therefore, the target parameters can be assumed to have a precision in the single-digit percentage range.

[12] Scheduled collection: Fee based on the volume of the waste bin and regular collections (e.g. every 14 days)

[13] Fee-based technological systems: Fee based on individually defined collection intervals with a minimum number of collections

A detailed description of the methodology used to plan the sampling campaigns (sampling units) and evaluate and extrapolate the findings can be found in Chapter 5 of the Nationwide Household Waste Analysis on pages 44 to 83 (Dornbusch et al. 2020).

6.1.1.2 Methodological approach to derive the waste coefficients

6.1.1.2.1 Collection of data

The data used to determine the waste coefficients for household waste are presented below.

In accordance with the requirements of Delegated Decision (EU) 2019/1597, results from waste sorting analyses and other data sources from the years 2017 to 2021 were used for the EU reporting for the reporting year 2020. The amounts of waste from national, official statistics for the reporting year 2019 were used because the amounts of waste for the reporting year 2020 were not yet available at the time the waste coefficients were calculated.

The material composition of the household waste was determined based on the Nationwide Household Waste Analysis carried out in the period from 2017 to 2019. The initial data for the evaluation and extrapolation process were taken from the weekly amounts of household waste per inhabitant from the örE broken down by stratum. The amounts of household waste are measured every year by the örE and reported to the StBA via the statistical offices of the federal states. Refer to Table 7 of the Nationwide Household Waste Analysis for information on how the sampling units were allocated to the strata (for each sampling campaign) (Dornbusch et al. 2020).

The peripheral data necessary for the statistical analysis and extrapolating the waste coefficients were taken from the waste analyses carried out by the örE and from official statistics. The waste coefficient for household waste (20 03 01 01) was calculated on the basis of the amounts of waste collected in each örE, which were sourced from the combined regional OERE statistics for the federal states for the reporting year 2019. The regional data is combined in a coordinated process by the Central Information Service of the StBA (StBA 2021). The number of sampling campaigns and the definitions for the strata were taken from the methodology used for the Nationwide Household Waste Analysis. Using adjusted peripheral data (numbers of inhabitants, allocation to a particular stratum, definitions of material groups, etc.) from 2019, which was the year with the most recent OERE statistics from the federal states at the time of the calculation process, the same stratified multi-stage methodology used in the Nationwide Household Waste Analysis was reapplied to extrapolate the data.

This meant it was not necessary to comprehensively plan the sampling process as is usually necessary when carrying out representative studies. For household waste, this can nevertheless be considered a representative study because the same örE were included that were included in the Nationwide Household Waste Analysis and there have been no significant changes since 2017 to the factors influencing the amounts of waste.

The extrapolation process for the sampling parameters at a federal level begins with the composition of household waste within the strata at an örE level. This data was taken from secondary studies (Nationwide Household Waste Analysis) and extrapolated based on the peripheral data (number of inhabitants and strata) adjusted for the reporting year 2020.

This extrapolation process gives the amount and composition of the household waste primarily from private households. Alongside the waste from private households, household waste also includes amounts of waste from businesses and trades (commercial waste). The amount of commercial waste is calculated as the difference between the amounts of waste reported by the örE and the extrapolated amount of household waste from households. The process used for deriving the extrapolated amount of household waste from private households is explained in Chapter 6.1.1.2.4.

The Nationwide Household Waste Analysis determined the composition of household waste for the waste that is primarily collected from private households. The commercial waste was assumed to have approximately the same composition as the household waste from private households. The Nationwide Household Waste Analysis did not measure the composition of this commercial waste due to the large variance in the types of commercial companies and because this would only have been possible at considerable financial cost.

Estimating the composition of the commercial waste based on the composition of the household waste from private households is permitted according to the sorting regulations in Brandenburg, NRW and Saxony (Intecus 2016, State Office for the Environment Brandenburg 1998, State Office for the Environment NRW 1998) and has been validated in a series of studies (e.g. in the waste analysis for Berlin for 2014, in which the waste compositions from private households and commercial enterprises were analysed separately) (ARGUS 2015). Moreover, the margin of error is considered to be low because commercial waste usually only accounts for between 10 % and 30 % of total household waste.

The composition of commercial waste was thus not investigated separately in this study due to time, economic and factual reasons (similar composition). Commercial waste collected together with household waste in residual waste bins is presented in the results as its own stratum (CW/H)[14]. It is calculated as the difference between the amount of waste in the OERE statistics from the StBA for the reporting year 2019[15] and the extrapolated amount of household waste from private households. Inhabitant equivalents (IE) are used to determine the amounts of commercial waste per inhabitant. It is assumed here that an IE corresponds to the average value for one inhabitant of a private household.

6.1.1.2.2 Ensuring consistency in the secondary data

It was assumed that the secondary studies were carried out in accordance with the sorting guidelines in the various federal states and thus satisfied the requirements for representative data. In order to generate a uniform data set for the evaluation and extrapolation processes in this study, it was necessary to make sure that the secondary data was consistent.

The following criteria had to be examined as part of this unification process:

- Subject of the study
- Number of sorting campaigns
- Sample size
- Stratification according to settlement/building structure
- Material groups for the sorting process a) definitions, b) allocation to the main material groups.
- Actuality of the analyses (a maximum of five years old),

[14] CW = Commercial waste; H = Household

[15] These values are the result of combining regional OERE data from the federal states for the reporting year 2019. This process was coordinated regionally by the Central Information Service of the StBA in 2021 (StBA 2021).

- No allocation of the sorted middle fraction[16] or the fraction <40 mm to the different material groups.

The following rules were applied where necessary to unify the data:

- Studies with no allocation of the sorted middle fraction to the different material groups were supplemented using estimates made from existing secondary data in the same stratum.
- The totals for the material group aggregates, main material groups and the overall total sums for the evaluation were retained. The sole exception: If material groups were not sorted under the main material groups for this study, they were redistributed under other material groups to keep the totals for these material subgroups constant.
- The amounts per inhabitant for an örE from the same stratum were used first and foremost to make estimates. If this led to additional amounts, the other material groups were reduced accordingly. Alternatively (e.g. if there was no data available for the same stratum for an örE), the average weighted amounts per inhabitant from other public waste disposal authorities were used.
- Material groups that were themselves aggregates and which were not broken down further were broken down using the proportions taken from those örE with data available.
- Estimates were made based only on sampled values and not on already estimated values or closed gaps in the data.

For household waste, the study used waste analyses carried out as part of the Nationwide Household Waste Analysis in 14 public waste disposal authorities. This ensured that this data set was already consistent. It was only necessary to make the material groups consistent (the proportion of packaging had to be removed from kitchen and food waste).

The majority of food waste is disposed of in household waste in an unpackaged state. For the material group “packaged waste”, the proportion accounted for by packaging was determined later on for the secondary analyses. The proportion of packaging was determined here based on the method defined by the Bundesgütegemeinschaft Kompost e. V. for area analyses (2018, Annex 4). In addition, the consortium based this evaluation on experience taken from its own studies.

The mass of packaged food was split into the material groups “plastic”, “glass” and “metal” and then multiplied by the packaging percentages stated in Table 5. The result gave the mass of packaging and the difference between this figure and the total mass was recorded as the actual mass of the food. The basis for the calculation is given in Table 5.

In addition, the Gesellschaft für Verpackungsmarktforschung mbH (GVM) collected data on the amount of packaging used for food[17] and this data was used to check the plausibility of the results (data from: Hübsch 2021; Hübsch & Adlwarth 2017).

[16] The middle fraction is the proportion of analysed waste with a size of between 10 and 40 mm.

[17] The plausibility of the proportions of waste accounted for by packaging was already checked by the BGK when defining its method for area analyses in 2018 and was thus adopted in the evaluations carried out by the consortium.

Table 5: Proportion of packaging in packaged food by packaging material

Material group	Proportion of packaging Main fraction	Proportion of packaging Secondary fraction
Packaged food, unopened, plastic	8	-
Packaged food, unopened, glass	30	3 (metal lid)
Packaged food, unopened, metal	15	-

Source: Bundesgütegemeinschaft Kompost e. V. 2018, own research, WI, ARGUS, INFA, USTUTT

6.1.1.2.3 Data management

All of the data relevant to the evaluation was managed in a database in Microsoft Excel format. This database was split according to different thematic areas. The core of the database comprised the data from the primary and secondary analyses at an örE level (results in kilogramme (kg)/(i*a) by strata and campaign and the extrapolated results by strata and campaign for the federal level). The database also contained data on the nationwide structures (municipalities, districts, örE) that was necessary to manage the multi-stage extrapolation process (above all data on inhabitants and on other structures for defining the strata). The last part of the database consisted of tables for the classification of the strata and their characteristics that were needed for the evaluations at an örE and federal level. The key variables in the database were the values per inhabitant for the örE, for the strata and for the material groups.

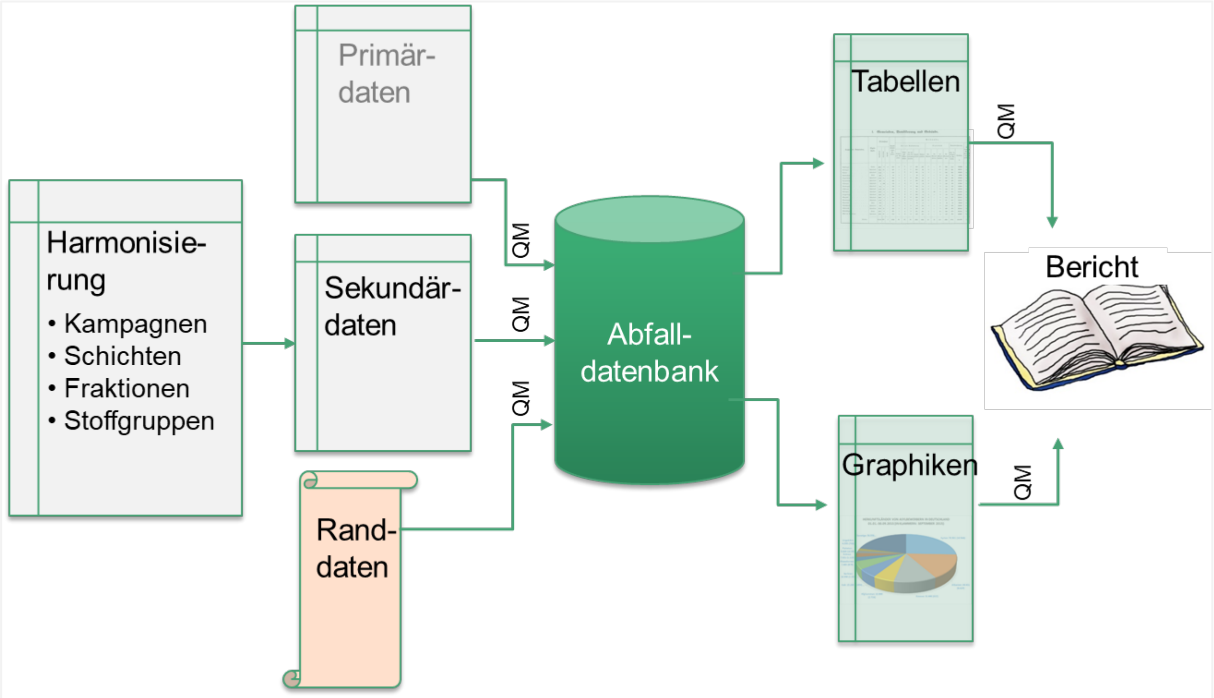
The data from the secondary studies used in this project (kg per inhabitant and week at the level of the örE strata) were imported into the database from standardised tables via an automated import function. The imported data included all figures for the sorted material groups and estimates for any missing fractions (10-40 mm, < 10 mm). Queries were used to check the data imported into the database for quality assurance purposes.

All relevant örE data (inhabitants, structural data, amounts of waste, etc.) was sourced from the OERE statistics from the federal states[18] and the waste balances from the federal states for reporting year 2019, and were transposed hierarchically according to the waste codes.

Test queries based on the most important characteristics of the key data required to evaluate the sampling results were developed to check the quality of the database. Figure 1: Evaluation schema and database illustrates how the waste database is integrated into the evaluation schema.

[18] These values are the result of combining the regional OERE data from the federal states for the reporting year 2019. This process was coordinated regionally by the Central Information Service of the StBA in 2021 (StBA 2021).

Figure 1: Evaluation schema and database



Source: Kern et al. (2022)

6.1.1.2.4 Statistical analysis/extrapolation

The extrapolations and estimates were made using the same methods described in the Nationwide Household Waste Analysis. The calculations were made simpler by the fact that the extrapolation process was not based on secondary analyses carried out at the property level (collected waste container) but rather at an örE level. A pre-defined algorithm was used for the extrapolation calculation. Evaluation and extrapolation files were developed for this purpose. The results of the extrapolation process are presented in clearly structured tables and graphics in Chapter 6.1.1.2.5. The multi-stage stratified ratio estimator method was selected as an appropriate extrapolation method for calculating the composition of the household waste[19].

The results of the 14 secondary studies at an örE level for each campaign and vegetation period together with the inhabitants per stratum in 2019 were adapted for the reporting year 2020. Initially, the weekly values per inhabitant for each vegetation period were determined for the extrapolation from örE level to federal level. If a federal stratum included multiple public waste disposal authority samples, the average weekly values were determined and then weighted using the respective number of inhabitants for the örE samples.

These weekly values were then extrapolated using the number of inhabitants in the strata matrix (see Table 6) to produce an estimate for the absolute weekly amount for the different building structures and strata at a federal level. This process was carried out separately for the campaigns in the low vegetation and rich vegetation periods. In the strata with a lower settlement density (see Table 6 and Table 7, rural settlement structure (< 150 i/km^2) and strata numbers 1 to 4), only the building structures Outskirts and City were reported. The latter includes the stratum for the LHE[20] in this case. The next step was to extrapolate annual data from the weekly data. For this, the values for all material groups in the rich vegetation and low

[19] A more detailed explanation of the stratified ratio estimator method can be found in Dornbusch et al. 2020.

[20] In rural areas, there are generally no notable LHEs. However, LHEs may account for some of the building structures in a few cases. This was then allocated to the stratum "City".

vegetation periods were weighted at a ratio of 2:1[21]. This gives the estimated values for the annual amounts of household waste from private households. The difference between these values and the total amounts of waste from the OERE statistics from the federal states[22] was then calculated for each federal stratum and reported as the proportion of commercial waste that is recorded together with the household waste from private households. The amounts of packaged food in the secondary data was split between food waste and packaging (see Table 5) using a flat-rate packaging ratio of 15 % (average amount for plastic, metal and glass). Finally, the amounts of household waste in each of the federal strata were then aggregated to calculate the total amounts and compositions for household waste in Germany (also see Figure 2).

Table 6: Compilation of the data from the public waste disposal authorities (örE) on the proportion of waste in each of the strata in the reporting year 2019

Settlement structure	Separately collected biowaste	Fee system	Number of örE	Proportion by strata in %	Inhabitants (As of 31/12/2019)	Proportion of inhabitants in %
Rural (<150 i/km²)	Low < 25 kg/i*a	Regular	11	2.8	1,672,955	2.0
		fee-based tech.	33	8.5	5,392,270	6.5
	High ≥ 25 kg/i*a	Regular	52	13.3	7,629,948	9.2
		fee-based tech.	46	11.8	6,226,266	7.5
Densely populated rural area (150-750 i/km²)	Low < 25 kg/i*a	Regular	8	2.1	2,073,200	2.5
		fee-based tech.	6	1.5	1,519,521	1.8
	High ≥ 25 kg/i*a	Regular	84	21.5	19,721,751	23.7
		fee-based tech.	54	13.8	9,336,360	11.2
Urban/metropolitan (>750 i/km²)	Low < 25 kg/i*a	Regular	17	4.4	3,812,581	4.6
		fee-based tech.	2[1]	0.5	333,468	0.4
	High ≥ 25 kg/i*a	Regular	65	16.7	22,010,387	26.5
		fee-based tech.	12	3.1	3,438,004	4.1
Total			**390**	**100.0**	**83,166,711**	**100.0**

[1] The stratum: "Urban/metropolitan (>750 i/km²) – low separately collected biowaste – fee-based tech. systems (fee-based technological systems)" was combined with the stratum "Densely populated rural areas (150-750 i/km²) – low separately collected biowaste – fee-based tech. systems" for subsequent evaluations due to its low number of inhabitants (see Table 7).

Sources: Waste balances of the federal states 2019; own research, WI

[21] The rich vegetation period was defined as March to October (8) and the low vegetation period as November to February (4).

[22] These values are the result of combining the regional OERE data from the federal states for the reporting year 2019. This process was coordinated regionally by the Central Information Service of the StBA in 2021 (StBA 2021).

The amounts for the material groups relevant to food waste and finally the proportions of the total amount of household waste for reporting year 2019 were calculated using this data. It is important to note here that stratum 10 was added to stratum 6 due to its low number of inhabitants (see Table 7).

Table 7: Strata matrix for the twelve federal strata and the three örE strata – number of inhabitants in the overall population in reporting year 2019

Strata no. federal level	Number of inhabitants in overall population (federal and örE strata)				Number of inhabitants in sample (federal and örE strata)			
	Total	Outskirts	City	LHE	Outskirts	City	LHE	Total
h_d	Y_{h_d}	$Y_{h_ö}$			$y_{h_ö}$			y_{h_d}
1	1,672,955	1,180,047	379,258	113,650	624	452	258	1,334
2	5,392,270	3,817,427	1,182,300	392,543	1,139	859	399	2,396
3	7,629,948	6,106,106	1,257,078	266,764	306	324	240	870
4	6,226,266	4,551,574	1,284,616	390,076	575	543	250	1,367
5	2,073,200	1,309,046	582,004	182,150	334	350	373	1,057
6	1,852,989	1,124,314	514,425	214,250	899	976	328	2,203
7	19,721,751	14,001,574	4,161,146	1,559,031	1,116	943	539	2,597
8	9,336,360	6,697,059	1,935,683	703,618	393	339	309	1,042
9	3,812,581	1,922,280	1,645,274	245,027	704	522	377	1,603
10	(added to stratum 6 due to the low number of inhabitants)							
11	22,010,387	9,307,303	9,662,700	3,040,385	1,079	521	544	2,144
12	3,438,004	1,508,937	1,472,711	456,356	622	367	145	1,134
Total result[1]	**83,166,711**	**51,525,667**	**24,077,193**	**7,563,851**	**7,790**	**6,196**	**3,760**	**17,746**

Values have been rounded.

Sources: Waste balances of the federal states 2019; own illustration, ARGUS

6.1.1.2.5 Multi-stage stratified ratio estimator

When determining the waste coefficients using a representative sample of solid household waste, the main challenge is how to select the representative sample from the total household waste for the area under investigation of approx. 12 to 13 million t (overall population) as the basis for determining the total amount and composition of this waste. The solution is to use a sampling method that gradually reduces the total quantity of waste in the area under investigation to an economically and technically analysable level using a multi-stage process and applying comprehensive knowledge of the total population. A suitable method for determining the composition of the waste based on material groups is multi-stage stratified random sampling (Dornbusch et al. 2020).

This multi-stage method for determining a representative sample uses estimates for the parameters “total” and “mean” being investigated and associated variances at every stage of the selection process. The following generally applicable equations 1 and 2 describe the estimators for “total” and “variance”.

$$\theta \approx \widehat{\Theta} = f(X) = f_1(f_2 \dots \left(f_Q(X)\right)) \quad (1)$$

$$var\left(\widehat{\Theta}\right) = var(f(X)) = var\left(f_1(f_2 \dots \left(f_Q(X)\right)\right)) \quad (2)$$

θ:	*the unknown parameter for the overall population*
$\widehat{\Theta} = \widehat{\Theta}(X)$	*the estimator for θ with the probability distribution* $P\{\widehat{\Theta}\}$
X:	*Random variable with* $X = X_1, X_2, \dots, X_n$
Q:	*Number of stages in the multi-stage process*
f(X):	Estimator consisting of the partial estimators $(f_1, f_2, \dots, f_Q)$ for Q stages

In the multi-stage selection model, the total sum X_Σ (and hence the total amount of food waste to be determined in the R&D project $X_{\Sigma LMA}$) is estimated based on the sampling units for the lowest stage across all units:

$$X_\Sigma \approx \hat{X}_\Sigma = \frac{N_I}{n_I} \cdot \sum_{i=1}^{n_I} \frac{N_{II,i}}{n_{II,i}} \sum_{j=1}^{n_{II,i}} \dots \frac{N_{Q,q-1}}{n_{Q,q-1}} \sum_{q=1}^{n_{Q,q-1}} \dot{X}_{ij\dots q} \quad (3)$$

If the sampling fraction *f* is constant at every selection stage

$$\left(f_{II,i} = \frac{N_{II,i}}{n_{II,i}} = const. \text{ für } alle\ i\ bis\ f_{Q,q-1} = \frac{N_{Q,q-1}}{n_{Q,q-1}} = const. \text{ für } alle\ q\right), \quad (4)$$

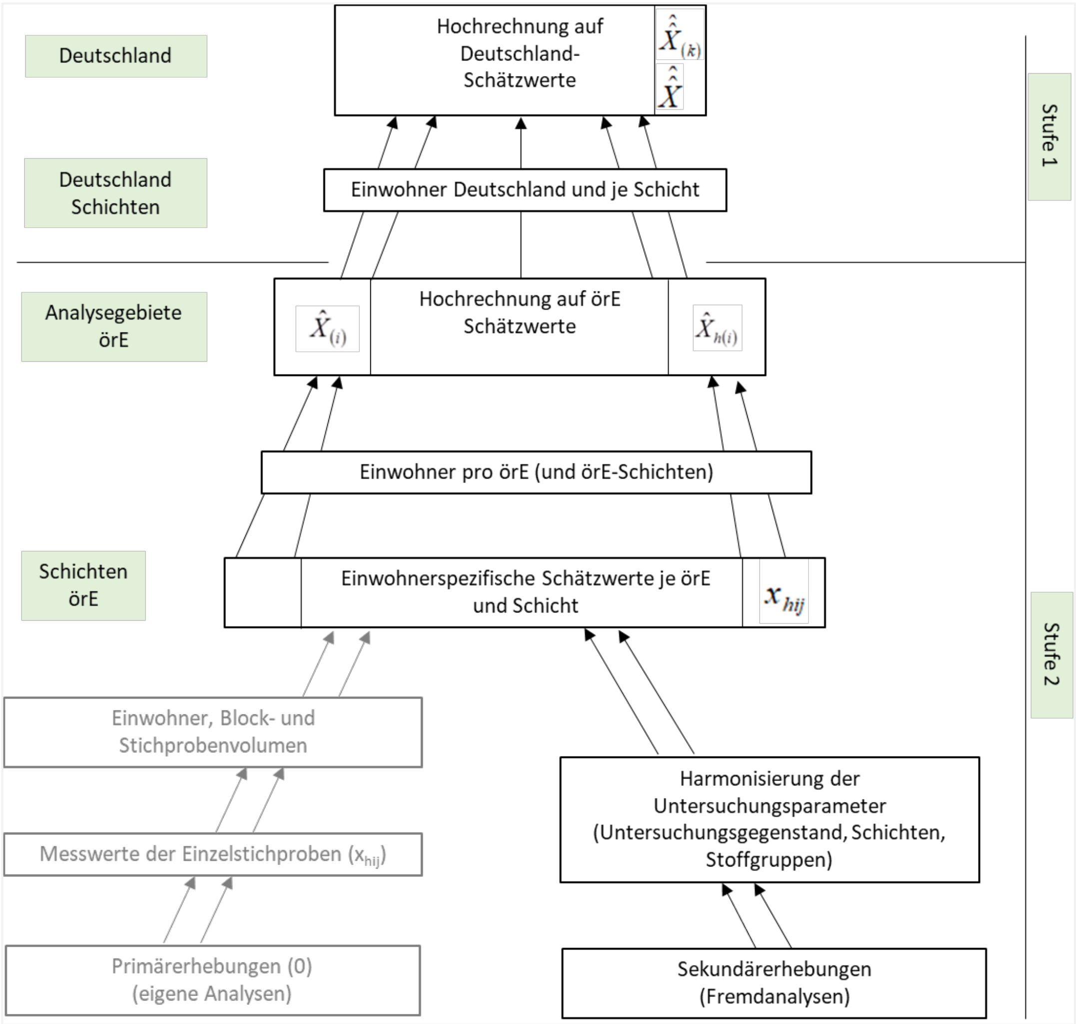
then equation 3 simplifies to:

$$X_\Sigma \approx \hat{X}_\Sigma = \frac{N_{\Sigma Q}}{n_{\Sigma Q}} \cdot \sum_{i=1}^{n_I} \sum_{j=1}^{n_{II}} \dots \sum_{q=1}^{n_Q} \dot{x}_{ij\dots q} \quad (\text{für } f_{II} \dots f_Q = const.)$$

X_Σ:	*Total sum of the investigated characteristic – real value –*
$\hat{X}_\Sigma$:	*Total estimated value for the sum of the investigated characteristic*
N_I:	*Number of primary units in the overall population*
n_I:	*Number of primary units in the sample*
$N_{II,i}$:	*Number of secondary units in the i-th primary unit in the overall population*
$n_{II,i}$:	*Number of secondary units in the i-th primary unit in the sample*
n_{II}:	*Number of secondary units in the i-th primary unit in the sample (*n_{II}*=const. For all i)*
$N_{Q,q-1}$:	*Number of units in the lowest stage in the q-1-th unit in the overall population*
$n_{Q,q-1}$:	*Number of units in the lowest stage in the q-1-th unit in the sample*
N_Q:	*Number of units in the lowest stage in the q-1-th unit in the overall population (*N_Q*=const. For all q)*
n_Q:	*Number of units in the lowest stage in the q-1-th unit in the sample (*n_Q*=const. For all q)*
$N_{\Sigma Q}$:	*Number of units in the lowest stage in the total population* $N_{\Sigma Q} = N_I \cdot N_{II} \cdot \dots \cdot N_Q$
$n_{\Sigma Q}$:	*Number of units in the lowest stage in the sample* $n_{\Sigma Q} = n_I \cdot n_{II} \cdot \dots \cdot n_Q$
$\dot{x}_{ij\dots q}$:	*Sampling characteristic for the q-th subunit*

To illustrate this process in more detail, Figure 2 shows the extrapolation steps based on the data from secondary analyses across all selection stages.

Figure 2: Extrapolation schema



Source: Kern et al. (2022)

6.1.1.2.6 Quality management

The data management process included quality assurance measures in order to guarantee the consistency of the data and also the plausibility of the results. These played an important role especially with respect to the interfaces for data exchange and after completing intermediate steps of the evaluation.

The quality of the data from the secondary surveys was audited and then prepared in the required data formats for the evaluation before being integrated into the evaluations.

After the data had been prepared for evaluation and extrapolation to calculate household waste, the calculations and mathematical accuracy were audited by a second person (four-eye principle). The data was approved after any necessary adjustments had been made and only then imported into the database (see Chapter 6.1.1.2.3) and made available for further evaluation.

There was another interface for the subsequent evaluation of the data in the spreadsheet applications. Comprehensive audits of the data retrieved from the database were also carried out at this stage, i.e. with respect to the completeness of the data, data transfer errors or compliance with the required data formats and strata parameters. This audit of the data included, in particular, ensuring the allocation of material groups was consistent, quantitative compliance with the transferred secondary data in its original state and the correct allocation of the data according to strata and time of year.

Any issues with respect to quality – which need to be clarified later on or which may have necessitated a revision of already prepared data – were logged as the data was evaluated. A before/after comparison at different stages of the evaluation process was used to identify changes in the dataset and monitor the impact on the results.

Finally, the quality of the evaluations for all types of waste was subject to another internal audit in order to validate the results and ensure their plausibility. In particular, this process involved a comparison with the figures produced in other studies. After any necessary corrections, the results were once again audited by a second person (four-eye principle).

6.1.1.3 Presentation and evaluation of the results

The extrapolated results for the federal territory based on the sampling areas will be presented and discussed below. Chapter 6.1.1.3.1 presents the results for the federal territory extrapolated from the individual results of the sampling areas, while taking into account the relative percentages of each of the strata in the overall population. The principles behind the calculation method are described in detail in Chapter 6.1.1.2.5.

Irrespective of the annual amounts to which the waste coefficients are applied, the waste coefficients remain unchanged because they were determined on the basis of material composition and the proportions in the waste from private households and commercial waste were assumed to have the same composition.

For the purposes of this study, the differentiated results for the material groups from the sampling areas (samples from the örE) were aggregated into eight material groups at three different levels “total household waste”, “organic” and “food waste”: “residual material in household waste”, “organic, garden waste”, “other organic waste”, “food waste”, “kitchen waste”, “food scraps” and “packaged food (net)”. This was for the purpose of highlighting the relevance of food waste in household waste.

The total amount of household waste including commercial waste that was recorded by the örE was 12,943 million t[23]. Based on the population in 2019, this corresponds to an average specific amount of household waste of 155.6 kg/(i*a). The household waste from private households, which was estimated by extrapolating the data for the different strata from the samples at an örE level to the federal level, was around 10.506 million t. Per inhabitant, this corresponds to an average specific amount of household waste of 126.3 kg/(i*a).

The commercial waste recorded in the household waste logistics was included in this study. The consortium estimates that the difference of around 19 % between the total amounts of waste for the OERE statistics from the federal states[24] and the extrapolated annual amount based on the results of the analyses reflects the amount of commercial waste in the municipal household waste in Germany. It was assumed that the amounts of commercial waste had the same composition as the composition of the household waste from private households calculated from the extrapolated data. This proportion of commercial waste (and its composition) corresponds in its order of magnitude to empirical values taken from reports on numerous individual analyses carried out by the consortium.

[23] These values are the result of combining the regional OERE data from the federal states for the reporting year 2019. This process was coordinated regionally by the Central Information Service of the StBA in 2021 (StBA 2021).

[24] These values are the result of combining the regional OERE data from the federal states for the reporting year 2019. This process was coordinated regionally by the Central Information Service of the StBA in 2021 (StBA 2021).

6.1.1.3.1 Composition of household waste and the food waste it contains

Native organic waste is the largest material group in the household waste with approx. 58.8 kg/(i*a) in 2019. Alongside the recyclable wastes suitable for separate collections, this includes food in the form of kitchen waste, food scraps and food waste in packaged form or in partially empty packaging, less the mass of the packaging.

The target figure is the accumulated amount of the food waste in the material groups "kitchen waste", "food scraps" and "packaged food (net)". The total amount of food waste in household waste including commercial waste is 4.291 million t. Per inhabitant, the amount of food waste is 51.6 kg/(i*a). This corresponds to a percentage by mass of 33 %. The largest proportion of food waste is accounted for by kitchen waste at 17 %, followed by food scraps at 10 % and packaged food (net) at 6 % (see Table 8 and Figure 3).

Table 8: Composition of household waste and the food waste it contains in Germany in the reporting year 2019

Material group	Annual amount t/a	Annual amount per inhabitant kg/(i*a)	Composition (mean value) mass %
Residual material in household waste	8,056,126	96.9	62.2
Organic	4,886,675	58.8	37.8
Garden waste	482,571	5.8	3.7
Other organic waste	113,167	1.4	0.9
Food waste	4,290,937	51.6	33.2
Kitchen waste[1]	2,196,516	26.4	17.0
Food scraps[2]	1,309,520	15.7	10.1
Packaged food (net)	784,901	9.4	6.1
Total[3]	**12,942,801**	**155.6**	**100.0**
Total from private households[4]	**10,505,832**	**126.3**	**81.2**
Food waste from private households	**3,485,746**	**41.9**	**33.2**

[1] Kitchen waste = food waste before consumption, for example fruit peels.

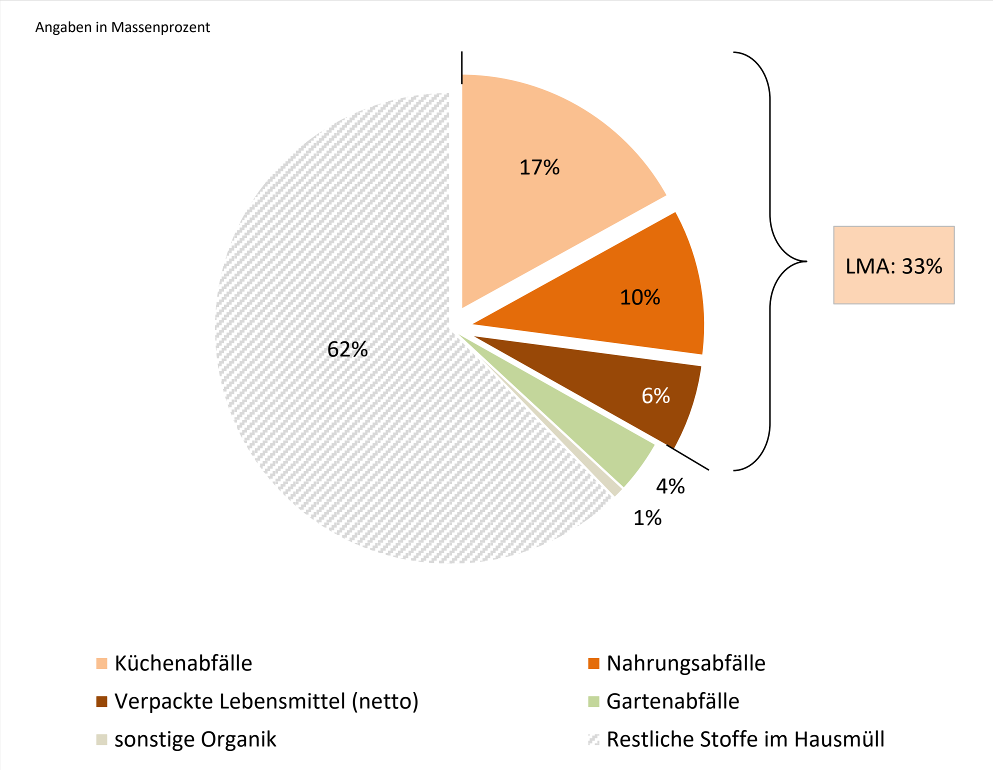
[2] Food scraps = food waste after consumption, for example leftovers.

[3] From the OERE statistics from the federal states in the reporting year 2019 (StBA 2021), rounded values.

[4] Calculation of the annual amounts for 2019 based on the same extrapolation methodology used in the Nationwide Household Waste Analysis.

Sources: StBA 2021; own research WI, ARGUS, INFA, USTUTT

Figure 3: Composition of household waste and the food waste it contains in Germany in the reporting year 2019



Source: Kern et al. (2022)

6.1.1.3.2 Influence of settlement structure on the composition of household waste and food waste

Table 9 and Figure 4 show the influence of settlement structure on the amount of household waste and the food waste it contains per inhabitant. In the settlement areas with high population density (urban, > 750 inhabitants per square kilometre), there are higher amounts of organic waste and also other fractions of residual household waste. The higher amounts of organic material per inhabitant are primarily due to kitchen waste and food scraps. The strata “rural” and “densely populated rural area” mainly only differ with respect to the amounts of kitchen waste and food scraps. In the “densely populated rural area” stratum, there is a little less kitchen waste and food scraps in residual household waste, which is presumably due to the higher use of biowaste bins in this settlement structure.

In order to assess the extent to which households in urban settlement structures actually throw away more food, it is necessary to consider the separately collected amounts of biowaste. This is explained in more detail in Chapter 6.1.2.3.2.

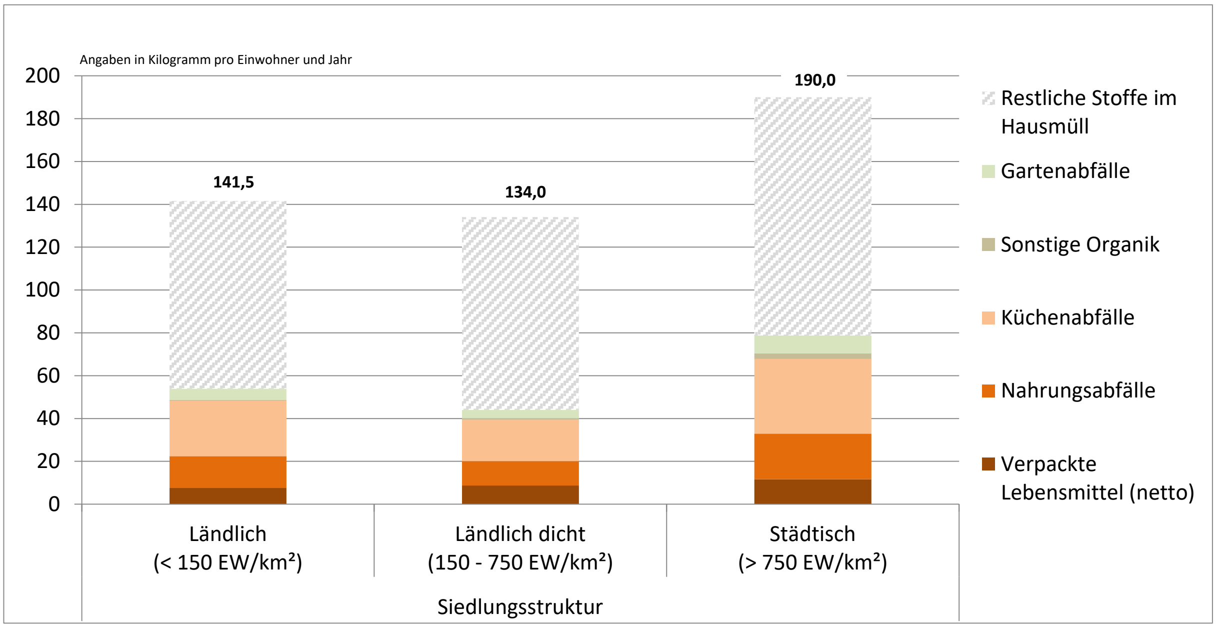
Table 9: Specific amounts of household waste in relation to settlement structure in the reporting year 2019

Material group	Germany	Rural	Densely populated rural area	Urban
	kg/(i*a)			
Residual material in household waste	96.9	87.6	90.0	111.2
Organic	58.8	53.9	44.1	78.8
Garden waste	5.8	5.2	3.9	8.4
Other organic waste	1.4	0.5	0.8	2.6
Food waste	51.6	48.2	39.4	67.8
Kitchen waste	26.4	25.8	19.3	34.9
Food scraps	15.7	14.8	11.4	21.3
Packaged food (net)	9.4	7.6	8.7	11.6
Total[1]	**155.6**	**141.5**	**134.0**	**190.0**

[1] From the OERE statistics from the federal states in the reporting year 2019 (StBA 2021).

Sources: StBA 2021; own research, WI, ARGUS, INFA, USTUTT

Figure 4: Specific amounts of household waste in relation to settlement structure in the reporting year 2019



Source: Kern et al. (2022)

6.1.1.3.3 Influence of separately collected biowaste on the composition of household waste and food waste

Table 10 and Figure 5 show the influence of separately collected biowaste on the amounts of household waste and the food waste it contains per inhabitant. In the strata with the lowest amounts of biowaste collected separately (< 25 kg/(i*a)), there are higher amounts of both organic waste and also other fractions of waste. The higher amounts of organic material per inhabitant can be primarily attributed to kitchen waste and to a lesser extent food scraps. This is presumably due to the higher use of biowaste bins in this stratum.

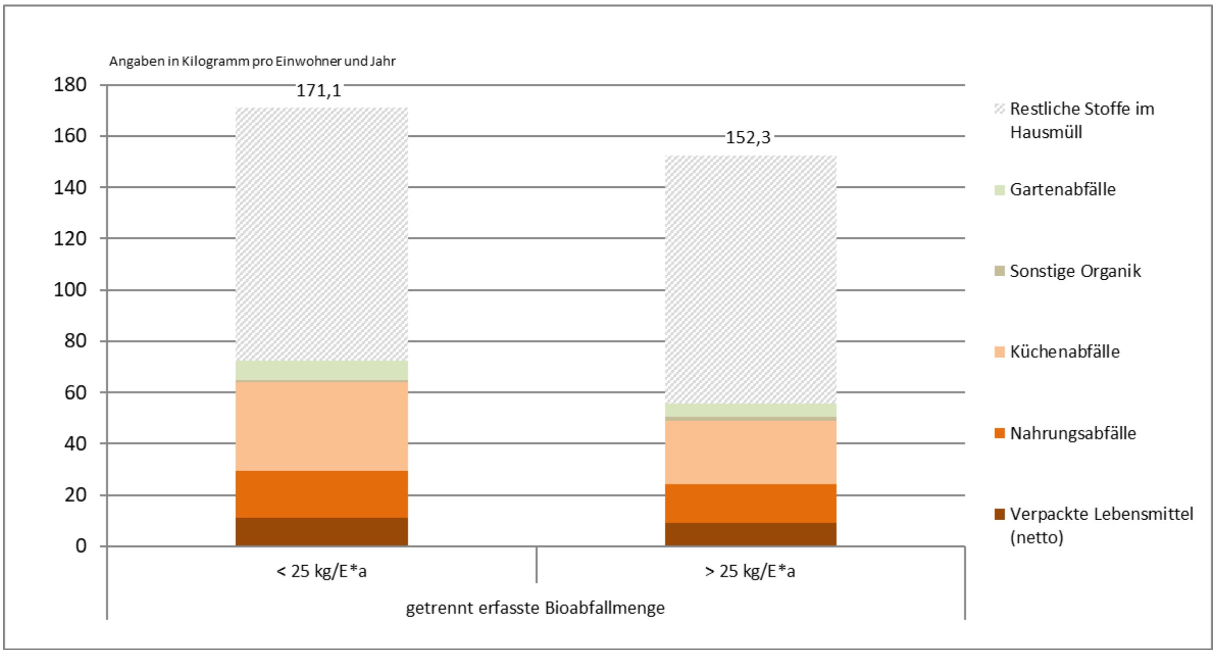
Table 10: Specific amounts of household waste in relation to the separate collection of biowaste in the reporting year 2019

Material group	Germany	< 25 kg/(i*a)	≥ 25 kg/(i*a)
Residual material in household waste	96.9	98.8	96.5
Organic	58.8	72.3	55.8
Garden waste	5.8	7.5	5.4
Other organic waste	1.4	0.8	1.5
Food waste	51.6	64.0	48.9
Kitchen waste	26.4	34.8	24.6
Food scraps	15.7	18.3	15.2
Packaged food (net)	9.4	10.9	9.1
Total[1]	**155.6**	**171.1**	**152.3**

[1] From the OERE statistics from the federal states in the reporting year 2019 (StBA 2021).

Sources: StBA 2021; own research, WI, ARGUS, INFA, USTUTT

Figure 5: Specific amounts of household waste in relation to the separate collection of biowaste in the reporting year 2019



Source: Kern et al. (2022)

6.1.1.3.4 Influence of a fee system on the composition of household waste and food waste

Table 11 and Figure 6 show the influence of a fee system on the amount of household waste and the food waste it contains per inhabitant. There are higher amounts of waste per inhabitant for all material groups in the stratum "scheduled collection". For organic waste, the biggest differences were in kitchen waste and food scraps. The consistently higher amounts per inhabitant in all groups could indicate a lack of incentives. In contrast, fee-based technological systems help to incentivise the reduction of waste in residual waste bins.

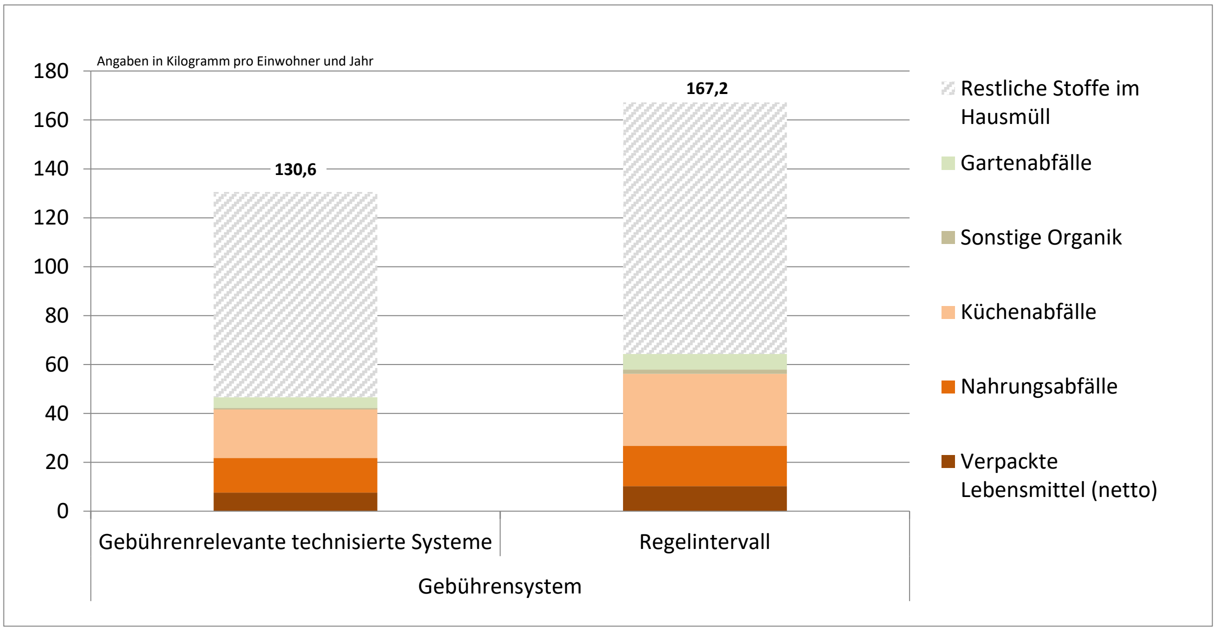
Table 11: Specific amounts of household waste in relation to fee-based system in the reporting year 2019

Material group	Germany	Scheduled collection:	Fee-based technological systems
		kg/(i*a)	
Residual material in household waste	96.9	102.8	83.9
Organic	58.8	64.3	46.7
Garden waste	5.8	6.4	4.5
Other organic waste	1.4	1.7	0.6
Food waste	51.6	56.2	41.6
Kitchen waste	26.4	29.4	19.9
Food scraps	15.7	16.5	14.1
Packaged food (net)	9.4	10.3	7.6
Total[1]	**155.6**	**167.2**	**130.6**

[1] From the OERE statistics from the federal states in the reporting year 2019 (StBA 2021).

Sources: StBA 2021; own research, WI, ARGUS, INFA, USTUTT

Figure 6: Specific amounts of household waste in relation to a fee-based system in the reporting year 2019



Source: Kern et al. (2022)

6.1.1.3.5 Influence of building structure on the composition of household waste and food waste

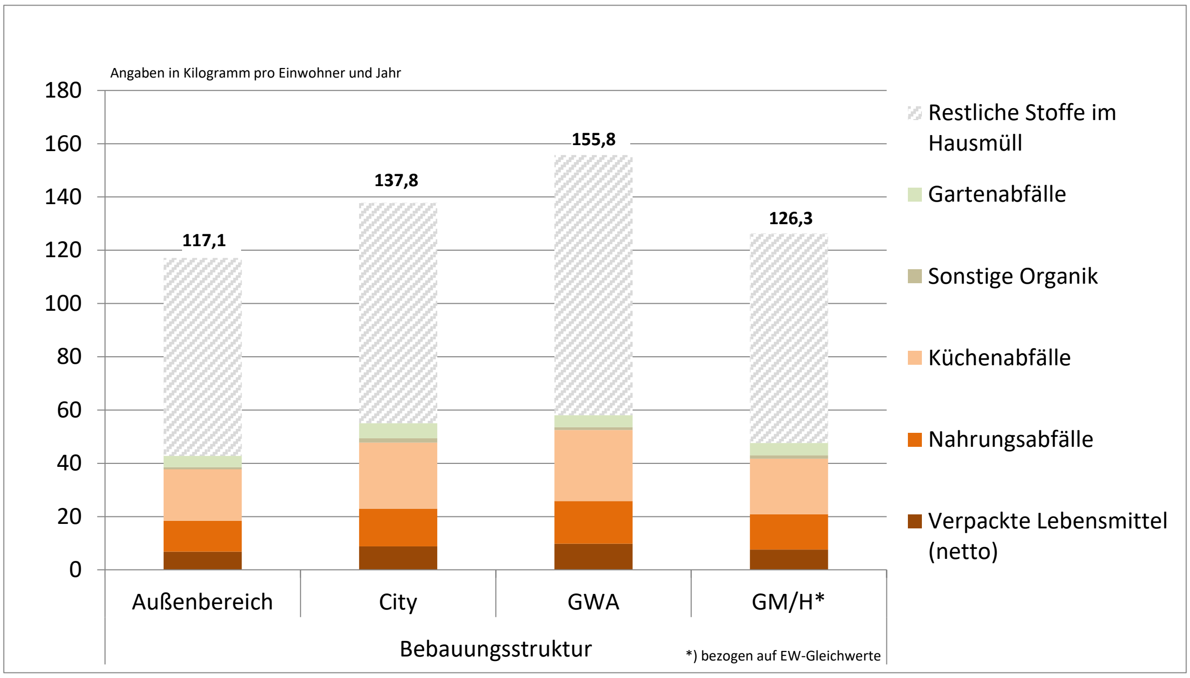
Table 12 and Figure 7 show the influence of building structure within the örE on the amount of household waste and the food waste it contains per inhabitant. The amount per inhabitant increases for all material groups (with the exception of garden waste) as the building density increases. The amount of food waste increases from the stratum "Outskirts" (rural/suburban buildings) to the urban strata "City" and "LHE". The biggest difference is for the material groups kitchen waste and food scraps. The increase in household waste and also food waste in strata with a denser building structure is probably due to lower incentives to reduce costs in these strata.

Table 12: Specific amounts of household waste in relation to building structure in the reporting year 2019

Material group	Germany[1]	Outskirts[2]	City[2]	LHE[2]	CW/H[3]
	kg/(i*a)				kg/(i*a)
Residual material in household waste	96.9	74.2	82.7	97.7	78.7
Organic	58.8	42.8	55.1	58.1	47.6
Garden waste	5.8	4.3	5.7	4.5	4.7
Other organic waste	1.4	0.8	1.6	1.0	1.2
Food waste	51.6	37.7	47.8	52.5	41.7
Kitchen waste	26.4	19.3	24.8	26.7	20.9
Food scraps	15.7	11.6	14.1	16.0	13.2
Packaged food (net)	9.4	6.8	8.8	9.8	7.6
Total[4]	**155.6**	**117.1**	**137.8**	**155.8**	**126.3**

[1] Based on the total inhabitants in Germany.
[2] Based on the total inhabitants in each stratum.
[3] CW/H (commercial waste collected together with household waste in residual waste bins) based on inhabitant equivalents.
[4] From the OERE statistics from the federal states in the reporting year 2019 (StBA 2021).
Sources: StBA 2021; own research, WI, ARGUS, INFA, USTUTT

Figure 7: Specific amounts of household waste in relation to building structure in the reporting year 2019



Source: Kern et al. (2022)

A final estimate of the extent to which households in urban strata really throw away more food than those in the stratum “Outskirts” can only be carried out after comparing the data with the amounts of biowaste collected via biowaste bins. This is explained in more detail in Chapter 6.1.2.3.4.

6.1.2 Biowaste including commercial waste (20 03 01 04)

6.1.2.1 Collection of data and the data set taken from waste sorting analyses

The waste coefficient for the eight-digit waste code “20 03 01 04 – waste from biowaste bins” was determined using data from secondary analyses. The findings from biowaste bin analyses carried out by the consortium for 26 örE in Germany flowed into this process. The analyses were carried out in ten urban districts (independent cities) and 16 rural districts with a total population of around 5.056 million inhabitants (federal and state statistical offices 2020). Based on the total population of Germany in 2019 of 83.167 million inhabitants, the 26 sampling areas represented approx. 6.1 % of the German population (StBA 2022).

These areas had an average amount of biowaste of approximately 78.1 kg/i*a (calculated according to the waste balances of the federal states for 2019), which is higher than the average amount for the whole of Germany of 56 kg/i*a (calculated on the basis of data from StBA 2022)[25]. The average amount of waste weighted by population size was a little higher again at 82.5 kg/i*a (calculated according to the waste balances of the federal states for 2019). The differences can mainly be explained by the level of access to a biowaste bin, which is presumably higher in these analyses than the average level for the whole of Germany.

In addition, the consortium calculated the level of access to a biowaste bin in the sampling areas based on available data or – if such information was lacking – on estimates. The weighted average was around 70 %. The results were barely any different with regard to the actual number of inhabitants with access to a biowaste bin.

In accordance with the requirements of Delegated Decision (EU) 2019/1597 for the first reporting period, the results were taken from the year 2017 or later.

The methodologies and depth of the analyses carried out by two members of the consortium were evaluated and the data was then prepared and structured in accordance with the guidelines for statistical processing (see Chapter 6.1.2.2.2 and 6.1.2.2.3).

For this purpose, the methodologies and depth of the analyses were compared and evaluated. Minimum requirements for biowaste bin analyses were defined based on an existing list of criteria (Intecus 2016[26]). These included geographical location, geographical distribution, waste management conditions, residential and building structure and vegetation period. Preference was given to biowaste bin analyses in which samples had been taken in the respective area during both low vegetation and rich vegetation periods. This ensured a representative stratification of the total population of Germany.[27]

The results of the analyses were reviewed at the lowest level of the sampling units – above all to ensure they complied with the definition of food waste according to the requirements in

[25] Waste from biowaste bins (RY 2019) 4.674 million t (p. 33), population 83.167 million inhabitants as of 31/12/2019 (p. 40).

[26] This list of criteria was published for the first time as the Saxon Sorting Guidelines 1998. This catalogue was created to unify the waste sorting analyses of solid municipal waste. The aim is to generate comparable data on the amount and composition of municipal waste that can be kept up to date and merged.

[27] The samples were taken in accordance with the Saxon Sorting Guidelines and the methodological guidelines issued by the BKG. In general, the urban/rural districts carried out a sampling campaign in both a rich vegetation and low vegetation period. As this study was evaluating secondary data, all of the available analyses were included at first as random samples. The analyses were then tested to determine whether they covered all of the strata necessary for the subsequent extrapolation to a federal level.

Delegated Decision (EU) 2019/1597 – and the material groups were revised if necessary. If it was not possible to quantify the data set after it was restructured at the level of the individual samples, the consortium made qualified estimates.

The structure of the available data from INFA and WI was prepared and unified so that the biowaste data could be statistically evaluated in the same way as the household waste and also to ensure that the results were compatible and representative.

6.1.2.2 Methodological approach to derive the waste coefficients

6.1.2.2.1 Collection of data

The data used to determine the waste coefficients for biowaste are presented below.

To determine the material composition of the biowaste that was needed to calculate the proportion of food waste, 26 waste analyses each involving two sampling campaigns and one analysis with one campaign from the period 2017 to 2021 were included and evaluated in this study. The initial data for the evaluation and extrapolation process were taken from the weekly amounts of biowaste per inhabitant from the örE broken down by stratum. These were taken from the waste balances submitted by the federal states (2019). The amounts of waste for reporting year 2019 were used because the amounts of waste for reporting year 2020 were not yet available at the time the waste coefficients were calculated. The amounts of biowaste are measured every year by the örE and reported to the StBA via the statistical offices of the federal states. All of the results for the biowaste analyses are from sampling carried out by the consortium.

The amount of food waste in separately collected biowaste was determined exclusively by evaluating the data available from secondary studies that had been carried out in accordance with the different waste sorting regulations in the various federal states. The quality of the data from the secondary studies was audited before it was integrated into the evaluations. The secondary studies covered all of the intended strata and it was thus possible to take all of the relevant influences on the amount and composition of the biowaste into account. This ensured that the study satisfied the requirements for representative data. Annex D shows the distribution of the samples (from each sampling campaign) across the strata.[28]

The peripheral data[29] necessary for the statistical analysis and extrapolating the amount of biowaste overall and the amounts of food waste were taken from secondary studies and from official statistics for 2019. The number of sampling campaigns and the definitions for the strata were adapted to the requirements for separately collected biowaste. The örE strata for building and settlement structures were the same as for household waste. The “fee system” parameter was omitted because it was not expected to have any influence on biowaste [30]. The stratum “separate collection of biowaste” was replaced by the stratum “level of access to a biowaste bin” (high level of access[31], low level of access[32], no access[33]).

[28] The sampling process was not planned on the basis of the distribution of the samples to the strata or the number of samples per strata. This diagram merely shows that the number of samples in each strata was sufficiently large.

[29] The peripheral data used for the extrapolation process included data on the strata (influencing variables) and the population data, at all levels of the strata broken down by total population and sample.

[30] The consortium believes that the incentive system focuses on household waste. Fees could be saved by disposing of more residual waste in the biowaste bin. Therefore, no direct influence could be identified.

[31] örE with a voluntary biowaste bin = “low level of access” (criterion < 80 kg/i*a of separately collected biowaste in the biowaste bin).

[32] örE with access to and an obligation to use a biowaste bin = “high level of access” (criterion ≥ 80 kg/i*a of separately collected biowaste in the biowaste bin).

[33] örE without a biowaste bin = “no access” (criterion 0.0 kg/i*a of separately collected biowaste in the biowaste bin).

Using adjusted peripheral data (numbers of inhabitants, allocation to a particular stratum, definitions of the material groups, etc.) from the reference year 2019, the same stratified multi-stage methodology used in the Nationwide Household Waste Analysis was repeated.

It was not necessary to comprehensively plan the sampling process as is usually necessary when carrying out representative studies because there were a sufficient number of biowaste analyses available that were well distributed across Germany. For biowaste, this can therefore be considered a representative study. This is also true because many of the biowaste analyses were carried out in the same areas as those randomly selected for the Nationwide Household Waste Analysis.

The extrapolation calculation for the sampling parameters at a federal level begins with the composition of household waste within the strata at an örE level. This data was taken from secondary studies and extrapolated based on the peripheral data (number of inhabitants and strata) adjusted for the reporting year 2019.

The result is the extrapolated amount and composition of biowaste primarily from private households. The difference to the amounts of waste from the waste balances for the federal states (2019) corresponds approximately to the amount of commercial waste.

The amounts and composition of the biowaste were calculated using the same multi-stage stratified extrapolation method as in the Nationwide Household Waste Analysis. The amounts of waste in the different strata (different aspects of the analysis based on various influencing factors) at the örE level were extrapolated to the federal level. The extrapolation process was carried out for each specific stratum according to the number of inhabitants served by the biowaste disposal system. Four strata were formed at an örE level: large housing estates (LHE), condensed urban structures (City), suburban structures and rural structures (the suburban and rural structures were combined into one stratum (Outskirts)). A total of six strata were formed at a federal level (three strata for settlement structure and two strata for level of access to a biowaste bin).

Due to the number of örE samples (26 samples) used by the consortium, it can be assumed that the data has sufficient statistical power (test strength) for defining the waste coefficients precisely enough for this study. Therefore, the target parameters can be assumed to have a precision in the single-digit percentage range.

A detailed description of the methodology used to plan the sampling campaigns (sampling units) and evaluate and extrapolate the findings can be found in Chapter 5 of the Nationwide Household Waste Analysis on pages 44 to 83 (Dornbusch et al. 2020). This methodology was also used for biowaste.

6.1.2.2.2 Ensuring consistency in the secondary data

The secondary data for biowaste was unified in the same way as the secondary data for household waste (see Chapter 6.1.1.2.2).

6.1.2.2.3 Data management

The data for biowaste was managed in the same way as the data for household waste (see Chapter 6.1.1.2.3).

6.1.2.2.4 Statistical analysis/extrapolation

The extrapolations and estimates were calculated using the same methods described in the Nationwide Household Waste Analysis. The calculations were made simpler by the fact that the extrapolation process was not based on secondary analyses carried out at the sampling level but rather at an örE level. A pre-defined algorithm was used for the extrapolation calculation. Evaluation and extrapolation files were developed for this purpose. The results of the extrapolation process are presented in clearly structured tables and graphics in Chapter 6.1.1.2.5. The multi-stage stratified ratio estimator method was selected as an appropriate extrapolation method for calculating the composition of the biowaste, which was also used for household waste (see Chapter 6.1.1.2.5).

The results of the 26 secondary studies at an örE level for each campaign and vegetation period together with the inhabitants per stratum in 2019 were adapted for the reporting year 2020. The evaluation process was generally carried out in the same way as the evaluation for household waste (see 6.1.1.2.4 and Figure 2). The following section will therefore only describe the deviations to this evaluation process.

The inhabitants in the strata matrix in Table 13 were used as the basis for the extrapolation process for biowaste. All of the inhabitants in the strata were taken into account here (not just the inhabitants with access to a biowaste bin). In the strata with a lower settlement density (see Table 13 and Table 14, rural settlement structure (< 150 i/km^2) and strata numbers 1 and 2), only the building structures “Outskirts” and “City” were reported. The latter includes the stratum LHE[34] in this case.

The annual data for each federal strata was then compared with the corresponding amounts of biowaste in the waste balances from the federal states for the reporting year 2019. The annual amounts for each federal strata were adjusted using fixed correction factors so that the average proportion of commercial waste in each strata was 5 % of the total amount [35]. The proportions of packaging in the material groups for packaged food were already applied during the preparation of the secondary data and were thus not relevant at this stage.

[34] In rural areas, there are generally no notable LHEs. However, LHEs may account for some of the building structures in a few cases. This was then allocated to the stratum “City”.

[35] The extrapolated amounts of waste in the biowaste bins do not contain any commercial waste because this was excluded from the analyses. To enable a comparison with the statistics provided by the örE on the amounts of waste collected in biowaste bins (including commercial waste), fixed correction factors were applied to the data. These were again based on empirical values from the consortium.

Table 13: Compilation of the data from the public waste disposal authorities on the proportion of biowaste in each of the strata in the reporting year 2019

Settlement structure	Level of access to a biowaste bin	No. of örE	Proportion in this strata in %	Inhabitants	Proportion of inhabitants in %
Rural (<150 i/km²)	High	56	14	8,507,598	10
	Low	71	18	10,085,29	12
	Not used	15	4	2,328,551	3
Densely populated rural area (150-750 i/km²)	High	83	21	19,302,38	23
	Low	65	17	12,275,16	15
	Not used	5	1	1,253,656	2
Urban/metropolitan (>750 i/km²)	High	15	4	2,398,282	3
	Low	77	20	26,672,38	32
	Not used	3	1	343,401	0
Total		**390**	**100**	**83,166,71**	**100**

Sources: Waste balances of the federal states 2019; own research, ARGUS

Table 14: Strata matrix for the nine federal strata and the three örE strata – number of inhabitants in the overall population in reporting year 2019

Strata no. Federal level	Number of inhabitants in the overall population (by federal and örE strata)			
	Total	Outskirts	City	LHE
1	8,507,598	6,659,826	1,469,739	378,034
2	10,085,290	7,474,015	2,030,269	581,006
3	2,328,551	1,521,313	603,244	203,994
4	19,302,389	13,972,435	3,895,456	1,434,497
5	12,275,161	8,259,927	2,935,897	1,079,337
6	1,253,656	841,261	292,707	119,688
7	2,398,282	1,351,952	777,037	269,293
8	26,672,383	11,286,169	11,920,274	3,465,940
9	343,401	158,769	152,569	32,063
Total	**83,166,711**	**51,525,667**	**24,077,193**	**7,563,851**

Values have been rounded.

Sources: Waste balances of the federal states 2019; own research, ARGUS

6.1.2.2.5 Multi-stage stratified ratio estimator

The multi-stage stratified ratio estimator method for biowaste was the same as the method for household waste (see Chapter 6.1.1.2.5)

6.1.2.2.6 Quality management

The quality management process for biowaste was carried out in the same way as for household waste (see Chapter 6.1.1.2.6)

6.1.2.3 Presentation and evaluation of the results

The extrapolated results for the federal territory based on the sampling areas will be presented below. Table 15 and Figure 8 show the results at the federal level extrapolated from the individual results of the sampling areas, while taking into account the relative percentages of each of the strata in the overall population. The principles behind the calculation method are described in detail in Chapter 6.1.1.2.5.

Irrespective of the annual amounts to which the waste coefficients are applied, the waste coefficients remain unchanged because they were determined on the basis of material composition and the proportions in the waste from private households and commercial waste were assumed to have the same composition.

For the purposes of this study, the differentiated results for the material groups from the sampling areas (samples from the örE) were aggregated into seven materials groups at three different levels "total biowaste", "organic" and "food waste". This was for the purpose of highlighting the relevance of food waste in separately collected biowaste.

6.1.2.3.1 Composition of biowaste and the food waste it contains

Table 15 shows the composition of biowaste and the food waste it contains and the amount of biowaste per inhabitant of 65 kg/(i*a). The amounts of separately collected biowaste from private households in Germany were extrapolated from the masses allocated to each of the strata. This resulted in an annual amount of biowaste from private households of approximately 5.417 million t. The separately collected amounts of biowaste in Germany based on the waste balances from the federal states for the reporting year 2019 was approximately 5.702 million t, which corresponds to 68.6 kg/(i*a). This contains amounts of commercial waste that were also recorded within the logistical process for measuring biowaste and included in this study. The difference of around 5 % between the total amounts from the waste balances from the federal states and the extrapolated annual amount based on the results of the analyses reflects the amount of commercial waste in the separately collected biowaste in Germany. It was assumed that the amounts of commercial waste had the same composition as the extrapolated data for the composition of biowaste from private households. This proportion of commercial waste (and its composition) in the biowaste corresponds in its order of magnitude to empirical values taken from numerous individual analyses carried out by the consortium.

As expected, native organic waste was the largest material group in the separately collected biowaste with approx. 54.9 kg/(i*a) in 2019. Alongside the recyclable wastes suitable for separate collections (garden waste), this includes food in the form of kitchen waste, food scraps and food in packaged form or in partially empty packaging, less the mass of the packaging (=net).

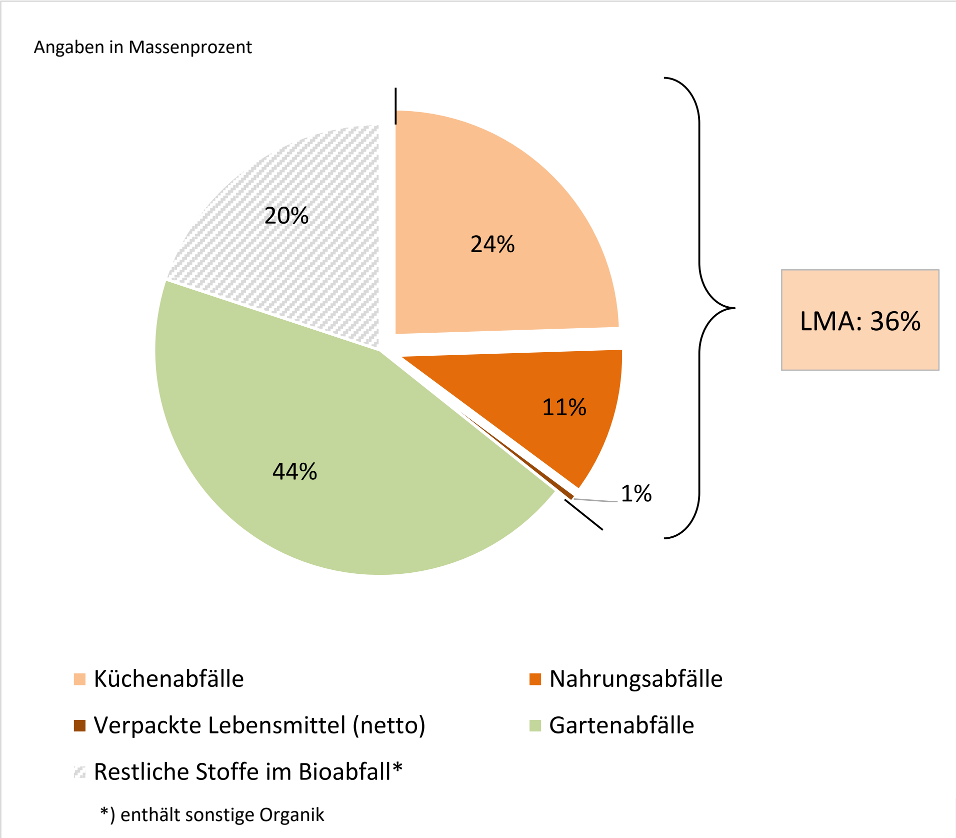
The proportion of food waste or the waste coefficient for biowaste is 36 %. The total food waste from the separately collected biowaste was 2.036 million t, which corresponds to 24.5 kg/(i*a).

Table 15: Composition of biowaste and the food waste it contains in Germany in the reporting year 2019

Material group	Annual amount t/a	Annual amount per inhabitant kg/(i*a)	Composition (mean value) mass %
Residual material in biowaste	1,135,074	13.6	19.9
Organic	4,566,878	54.9	80.1
Garden waste	2,531,299	30.4	44.4
Food waste	2,035,579	24.5	35.7
Kitchen waste	1,396,957	16.8	24.5
Food scraps	607,679	7.3	10.7
Packaged food (net)	30,943	0.4	0.5
Total[1]	**5,701,952**	**68.6**	**100.0**
Biowaste from private households[2]	**5,416,854**	**65.1**	**95.0**
Food waste from private households	**1,933,800**	**23.3**	**35.7**

[1] From the waste balances of the federal states for the reporting year 2019, rounded values.
[2] Calculation of the annual amounts for 2019 based on the same extrapolation methodology used in the Nationwide Household Waste Analysis.
Sources: Waste balances of the federal states 2019; own research, WI, ARGUS, INFA, USTUTT

Figure 8: Composition of biowaste and the food waste it contains in Germany in the reporting year 2019



Source: Kern et al. (2022)

6.1.2.3.2 Influence of settlement structure on the composition of biowaste and food waste

Table 16 and Figure 9 show the influence of settlement structure on the amount of separately collected biowaste per inhabitant and the food waste it contains. The settlement structure "densely populated rural area" (150 to 750 inhabitants per square kilometre) had the highest amounts of biowaste per inhabitant for the levels "organic" of 76.3 kg/(i*a) and "food waste" of 37.6 kg/(i*a). This is probably due to the higher level of access to biowaste bins in the households in this strata. If we examine the amount of food waste in household waste in the stratum "densely populated rural area", it is clear that there is considerably less food waste in household waste. The total amount of food waste in household waste and biowaste was 67.0 kg/(i*a) in the stratum "rural", 77.0 kg/(i*a) in the stratum "densely populated rural area" and 81.7 kg/(i*a) in the stratum "urban". This means that the smallest amounts of food waste in household waste and biowaste are found in the rural settlement structure. Therefore, the lowest amount of food waste tends to be thrown away in rural areas.

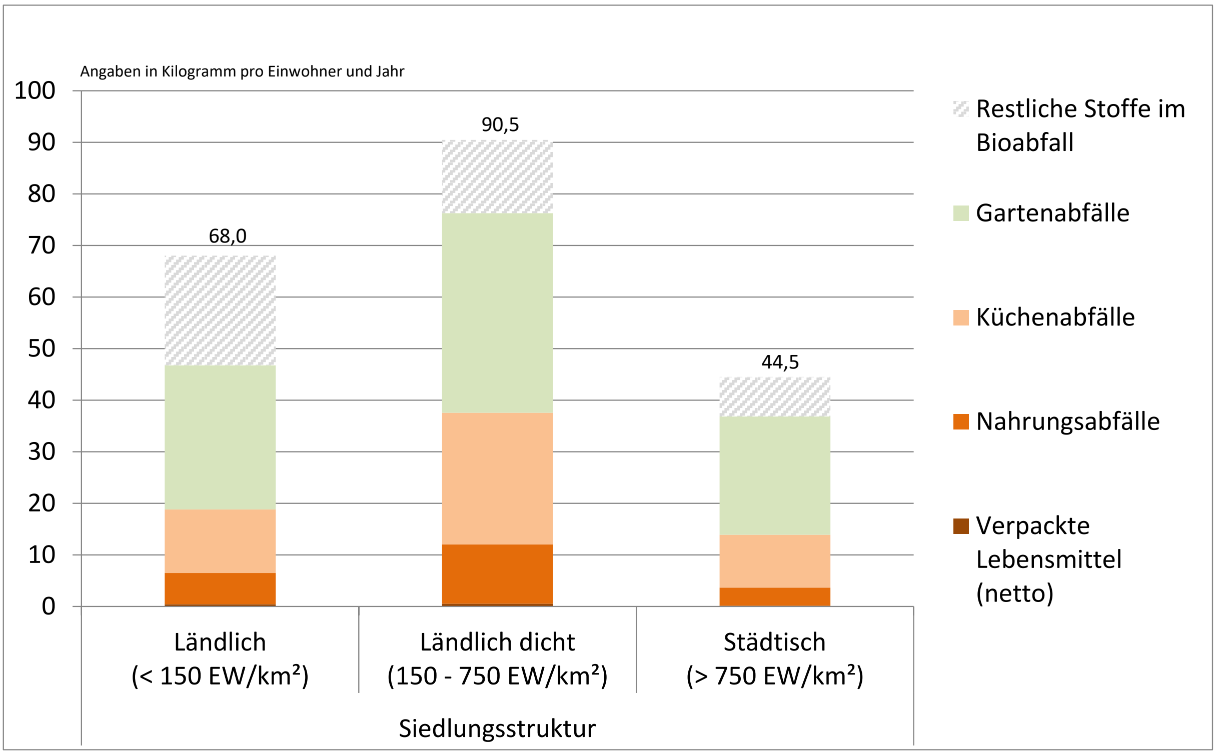
Table 16: Specific amounts of biowaste in relation to settlement structure in the reporting year 2019

Material group	Germany	Rural	Densely populated rural area	Urban
	kg/(i*a)			
Residual material in biowaste	13.6	21.3	14.2	7.7
Organic	54.9	46.8	76.3	36.9
Garden waste	30.4	28.0	38.7	23.0
Food waste	24.5	18.8	37.6	13.9
Kitchen waste	16.8	12.3	25.5	10.2
Food scraps	7.3	6.1	11.5	3.5
Packaged food (net)	0.4	0.4	0.5	0.2
Total[1]	**68.6**	**68.0**	**90.5**	**44.5**

[1] From the waste balances of the federal states for the reporting year 2019.

Sources: Waste balances of the federal states 2019; own research, WI, ARGUS, INFA, USTUTT

Figure 9: Specific amounts of biowaste in relation to settlement structure in the reporting year 2019



Source: Kern et al. (2022)

6.1.2.3.3 Influence of the level of access to a biowaste bin on the composition of biowaste and food waste

Table 17 and Figure 10 show the influence of the level of access to a biowaste bin on the amount of separately collected biowaste per inhabitant and the food waste it contains. A comparison of the strata shows that there is a strong correlation in the values as expected. While the food waste in the stratum with the highest level of access to a biowaste bin is 2.6 times higher, the amount of garden waste is four times higher (factor of 4). This means that as access to a biowaste bin increases, primarily the amount of garden waste increases. It was not possible to draw any conclusions about differences in the food waste disposal behaviour between the strata.

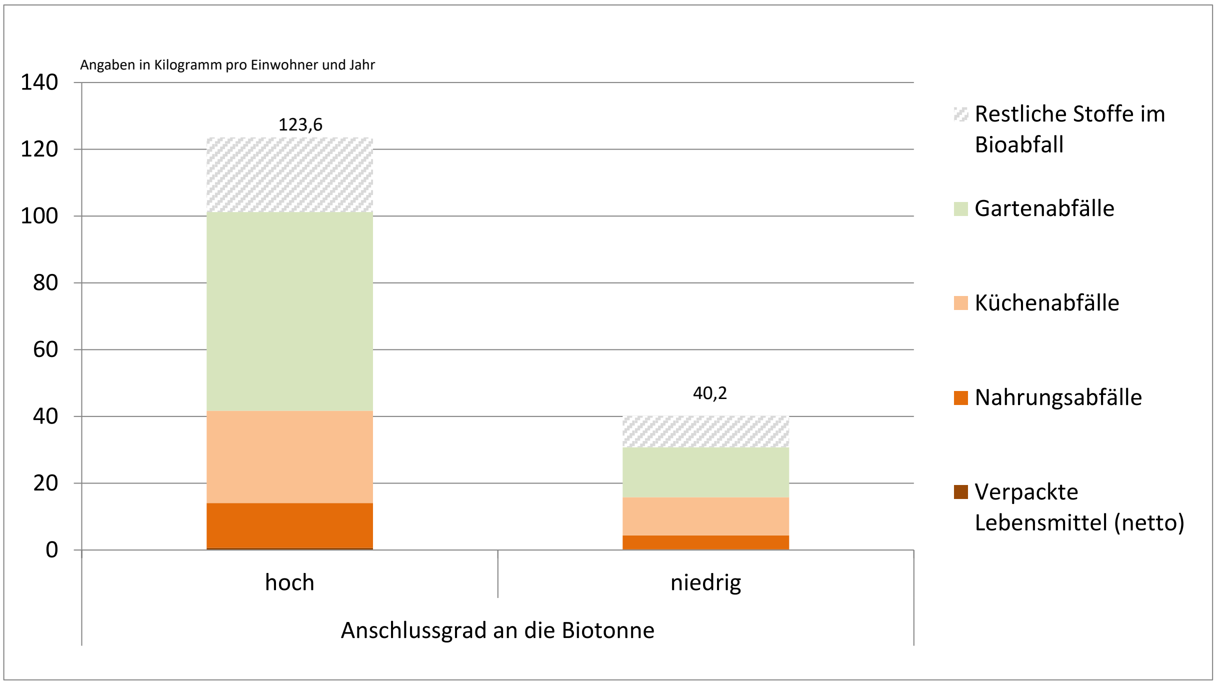
Table 17: Specific amounts of biowaste in relation to the level of access to a biowaste bin in the reporting year 2019

Material group	Germany	Level of access to a biowaste bin	
		High	Low
	kg/(i*a)		
Residual material in biowaste	13.6	22.4	9.4
Organic	54.9	101.2	30.8
Garden waste	30.4	59.5	15.0
Food waste	24.5	41.7	15.8
Kitchen waste	16.8	27.7	11.5
Food scraps	7.3	13.4	4.1
Packaged food (net)	0.4	0.6	0.2
Total[1]	**68.6**	**123.6**	**40.2**

[1] From the waste balances of the federal states for the reporting year 2019.

Sources: Waste balances of the federal states 2019; own research, WI, ARGUS, INFA, USTUTT

Figure 10: Specific amounts of biowaste in relation to the level of access to a biowaste bin in the reporting year 2019



Source: Kern et al. (2022)

6.1.2.3.4 Influence of building structure on the composition of biowaste and food waste

Table 18 and Figure 11 show the influence of the building structure on the amount of separately collected biowaste per inhabitant and the food waste it contains. In the stratum “Outskirts” (primarily single-family and two-family houses with gardens within suburban and rural structures), considerably larger amounts of organic waste and residual materials per inhabitant were collected in the biowaste bin than in the urban strata “City” and “LHE”. The difference in the amount of food waste per inhabitant was approximately 7.6 kg/(i*a) or 29 %.

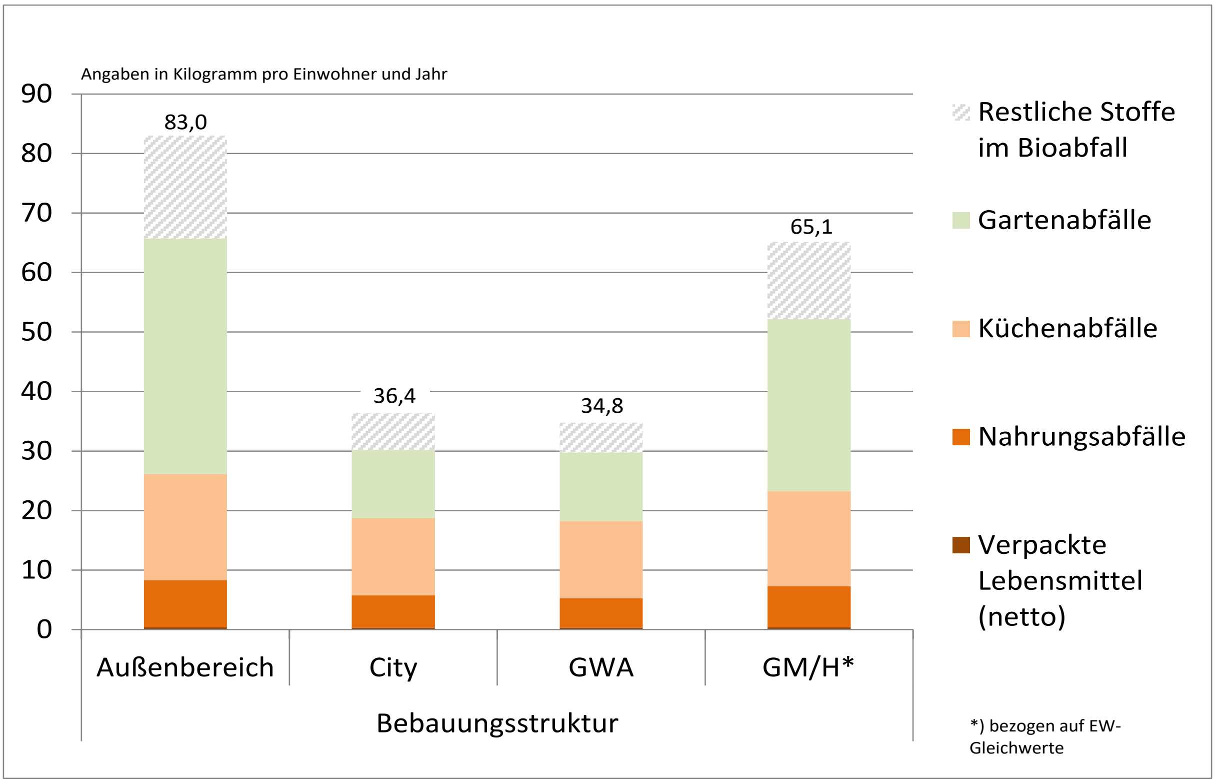
If we examine the amount of food waste in household waste in the stratum “Outskirts”, it is clear that there is considerably less food waste in household waste. The total amount of food waste in household waste and biowaste was 63.8 kg/(i*a) in the stratum “Outskirts”, 66.5 kg/(i*a) in the stratum “City” and 70.7 kg/(i*a) in the stratum “LHE”. This means that the smallest amounts of food waste in household waste and biowaste are found in the stratum “Outskirts”. In the strata for building structure, the lowest amount of food thus tends to be thrown away in less densely built-up areas.

Table 18: Specific amounts of biowaste in relation to building structure in the reporting year 2019

Material group	Germany[1]	Outskirts[2]	City[2]	LHE[2]	CW/H[3]
	kg/(i*a)				kg/(i*a)
Residual material in biowaste[4]	13.6	17.3	6.2	5.0	13.0
Organic	54.9	65.7	30.2	29.8	52.2
Garden waste	30.4	39.6	11.5	11.5	28.9
Food waste	24.5	26.1	18.7	18.2	23.3
Kitchen waste	16.8	17.8	13.0	13.0	16.0
Food scraps	7.3	7.9	5.4	5.0	6.9
Packaged food (net)	0.4	0.4	0.3	0.3	0.4
Total[5]	**68.6**	**83.0**	**36.4**	**34.8**	**65.1**

[1] Based on the total inhabitants in Germany.
[2] Based on the total inhabitants in each stratum.
[3] Based on inhabitant equivalents.
[4] Contains other organic waste.
[5] From the waste balances of the federal states for the reporting year 2019.
Sources: Waste balances of the federal states 2019; own research, WI, ARGUS, INFA, USTUTT

Figure 11: Specific amounts of biowaste in relation to building structure in the reporting year 2019



Source: Kern et al. (2022)

6.1.3 Commercial waste similar to household waste

The following chapter presents the process for determining the waste coefficient for commercial waste similar to household waste (waste code 20 03 01 02). This eight-digit waste code is not part of the European List of Waste but is only used for statistical purposes. It is allocated to the six-digit waste code "mixed municipal waste" (waste code 20 03 01).

6.1.3.1 Collection of data and the data set

The data set on the composition of commercial waste similar to household waste that is delivered or collected separately from household waste (waste code 20 03 01 02) is very incomplete. Any detailed analyses were carried out a long time ago and reflect the waste composition during a time period that was subject to different waste management conditions. Due to the lack of current data, the consortium decided to use the Rhineland Palatinate (RLP) commercial waste register (WI 1993) (compiled by WI; state-wide study into commercial waste). The proportions of food waste were calculated at this time. A transformative process that takes into account developments in waste management since then is needed in order to be able to use this study to make estimations on the current proportions of food waste in commercial waste similar to household waste. It was thus inevitable that there would be a high margin of error when evaluating the results, although this was mitigated by the fact that the amounts of food waste in commercial waste similar to household waste only account for a small fraction of the total amount of food waste. The estimation was made by the consortium and audited to make sure it was plausible.

The data was also compared with the study "Aufkommen, Verbleib und Ressourcenrelevanz von Gewerbeabfällen" (The amount, fate and resource relevance of commercial waste) (Dehne et al. 2011) that was published in 2011 and commissioned by the UBA. This study was carried out as a meta study and summarised all published information on the composition of commercial waste up to 2011. The authors explain that the data is primarily based on the results from numerous commercial waste sorting analyses published by the consortium as well as other publications to a lesser degree (Kern & Sprick 2001). The data is thus also based to some extent on the data from the RLP commercial waste register used here in this study. Additional unpublished data from Dehne et al. (2011) was also consulted. The meta study reported an average proportion by mass of commercial waste accounted for by overall organic waste of 10 %. The study did not give any details on the proportion of food waste.

6.1.3.2 Methodological approach to derive the waste coefficients

The composition of the commercial waste in the selected sampling areas for the RLP was essentially determined based on secondary analyses. The commercial waste was sorted at the disposal facilities in the federal state for this purpose. The fact that every waste sorting analysis was allocated to the respective supplier by name means that the study also gave a transparent picture of the amount of waste and its composition in relation to the economic sector (WI 1993).

The results were based on an estimate of the proportions by volume of every sorted delivery. The study differentiated between 150 materials groups. A material group was only included if it accounted for a proportion by volume of 5 %. The sorting analyses were carried out at 34 landfill sites, transfer facilities and sorting plants from December 1992 to July 1993. Data on the material-specific bulk weight of the waste was also collected during the around 5,000 sorting analyses (WI 1993).

6.1.3.3 Presentation and evaluation of the results

Table 19 shows that native organic waste accounted for 4.9 % by volume and 5.0 % by mass of the commercial waste. Based on the total amount of commercial waste stated in RLP 1992 of approximately 1.04 million t, this corresponded to approximately 168,000 m^3 and approximately 52,000 t of native organic waste (WI 1993).

Due to the fact that waste separation and recycling structures were still in the early stages of development at the time, the so-called “commercial waste” in this study comprised a huge mix of different waste delivered from a broad range of sources and economic sectors (WI 1993). This waste stream comprising 1.04 million t of waste is about comparable today with the amount of waste in “municipal waste from other sources”, which in the waste balance from RLP 2020 (Ministry for Climate Protection, Environment, Energy and Mobility RLP 2021) was reported at 114,185 t. This corresponds to a decrease of more than 90 % by mass.

Against the background of developments in the waste management sector, it can be assumed that almost all recyclable materials are today processed via a different route and are no longer reported under this waste code. This is particularly true for waste streams that contained a huge mass of waste at the time, especially the fractions “sludges and minerals”, but also “textiles”, “compound materials” and “paper/cardboard”.

Another aspect of these commercial waste sorting analyses were the deliveries described as “mono-batches”. A delivery is described as a mono-batch if a single fraction accounts for either > 50 % by volume or > 70 % in another category. Around 43 % of the total amount of commercial waste was accounted for by mono-batches > 50 % by volume, while native organic waste accounted for approximately 20 % by volume.

The data was first modified by deducting the waste streams identified as mono-batches based on their proportion of the total fraction and their degree of purity. This adjusted composition resulted in a slightly higher percentage by mass for native organic waste of 6.4 % (WI 1993).

Table 19: Composition of commercial waste in the State of Rhineland Palatinate from 1992 to 1993

Waste fraction	Proportion			Amount of waste[1]		Mono-batches with a single fraction > 50 % by volume				Amount/composition less the mono-batches		
						Proportion of total	Degree of purity	Proportion of mono-batches[1]		Mixed commercial waste[1]		
	Volume %:	t/m³	Mass %	m³/a	t/a	Volume %:	Volume %:	m³/a	t/a	m³/a	t/a	Mass %
Organic	4.9	0.31	5.0	168,000	52,000	20.4	72.6	25,000	8,000	143,000	44,000	6.4
Wood	11.2	0.22	8.2	386,000	85,000	24.7	72.5	69,000	15,000	317,000	70,000	10.2
Paper/cardboard	13.0	0.13	5.7	436,000	59,000	32.6	68.4	97,000	13,000	339,000	46,000	6.7
Composite material	10.2	0.30	5.8	200,000	60,000	54.6	78.7	86,000	26,000	114,000	34,000	5.0
Metal	2.3	0.51	3.8	78,000	40,000	-	-	-	-	78,000	40,000	5.8
Plastic	15.7	0.17	8.9	547,000	92,000	24.4	72.9	97,000	16,000	450,000	76,000	11.1
Textiles	2.0	0.15	1.0	67,000	10,000	55.9	82.3	31,000	5,000	36,000	5,000	0.7
Minerals	9.8	1.00	32.6	338,000	338,000	73.1	84.2	208,000	208,000	130,000	130,000	19.0
Glass	1.3	0.63	2.7	44,000	28,000	-	-	-	-	44,000	28,000	4.1
Sludges	1.9	1.05	6.8	68,000	71,000	94.1	92.2	59,000	62,000	9,000	9,000	1.3
Other	27.8	0.37	19.5	941,000	202,000	-	-	-	-	941,000	202,000	29.5
Total	**100**	**0.31**	**100**	**3.3 m.**	**1.04 m.**	**43**		**672,000**	**353,000**	**2.6 m.**	**684,000**	**94**

[1] Values have been rounded.

Source: Own research, WI 1993

The material group "organic" was then subdivided into 18 material groups. Only the material groups "biowaste"[36] with a proportion of 24.8 % by volume and "food"[37] with a proportion of 9.3 % by volume were relevant for food waste (Table 20). When measured by mass, this corresponded to a proportion of food waste of 33.6 % of the organic fraction. Based on the adjusted total amount of commercial waste of around 684,000 t, this resulted in a proportion of food waste of 2.2 % by mass.

The fact that this value was too low and did not sufficiently reflect reality was mainly due to two aspects:

- During the sorting process, only those waste substances that accounted for at least 5 % by volume of the total volume of waste were recorded. However, a large amount of native organic waste exists as a suspension so the actual proportion would thus be higher.
- The sharp reduction especially in waste streams that contained a large mass and also a presumed sharp reduction in recyclable dry wastes such as paper/cardboard, wood, textiles, etc. would lead to a relative increase in the percentage proportion in commercial waste today.

Noting the unsatisfactory data, which could not be audited for plausibility, an approximated waste coefficient of 4 % by mass was applied for commercial waste similar to household waste as the most important subgroup of the total amount of commercial waste considered here.

Table 20: Composition of the organic material group in commercial waste in the State of Rhineland Palatinate in 1992

Composition of the organic fraction							
Amount less the mono-batches				**Total[1]**	**Organic[1]**		
				t/a	**m³/a**	**t/a**	**Mass %**
				684,000	143,000	44,000	6.4
	Proportion of food waste in the organic fraction						
	Volume %:	**t/m³**	**Mass %**				
Biowaste[2]	24.8	0.318	25.2		35,000	11,100	1.6
Food[3]	9.3	0.284	8.4		13,000	3,700	0.5
Total food waste					**48,000**	**14,800**	**2.2**

[1] Values have been rounded.
[2] Biowaste in WI 1993 was the total amount of native organic waste (including garden waste).
[3] Food waste in WI 1993 referred to biowaste generated in the kitchen, primarily leftover food.
Source: Own research, WI 1993

This approach was supported by the study from Dehne et al. (2011), which gave an average figure for the proportion of overall organic waste in commercial waste similar to household waste of 10 % by mass. Based on the data from Dehne et al. (2011), the waste coefficient assumed here of 4 % by mass would correspond to 40 % by mass of the overall organic waste

[36] Biowaste in WI 1993 described the total amount of native organic waste (including garden waste).

[37] Food waste in WI 1993 referred to biowaste generated in the kitchen, primarily leftover food.

accounted for by food waste. When applied to the data source being evaluated here, the proportion of the overall organic waste accounted for by food waste was 33.6 % by mass. Based on evaluations of the waste balance from the StBA, around 3.271 million t of commercial waste similar to household waste were reported in the reporting year 2019 (StBA 2022).[38] This corresponds to 39.3 kg/(i*a). Owning to a lack of data, it is not possible to differentiate the waste based on its source.

Using the approximated waste coefficient mentioned above of 4 % food waste, the amount of food waste in commercial waste similar to household waste was approximately 131,000 t/a (Table 21). Based on the number of inhabitants, this corresponds to around 1.6 kg/(i*a).

Table 21: Estimate of the composition of commercial waste similar to household waste and the food waste it contains in Germany in the reporting year 2019 based on expert opinion

Material group	Annual amount t/a	Annual amount per inhabitant kg/(i*a)	Composition mass %
Residual material in commercial waste similar to household waste	2,943,900	35.4	90
Organic	327,100	3.9	10
Food waste	130,840	1.6	4
Other organic waste	196,260	2.4	6
Total commercial waste similar to household waste [1]	**3,271,000**	**39.3**	**100**
Food waste in commercial waste similar to household waste	**130,840**	**1.6**	**4**

[1] Calculation of annual amounts based on the waste balance from the StBA 2019, values have been rounded.

Sources: StBA 2022; own research, WI, ARGUS, INFA, USTUTT

6.1.4 Results for the waste coefficients for mixed municipal waste

Table 22 shows the determined amounts and compositions of the types of mixed municipal waste for the reporting year 2019 in condensed form. A total of 21,909,338 tonnes of waste were recorded for waste codes 20 03 01 01, 20 03 01 04 and 20 03 01 02 in the reporting year 2019. This corresponds to 263 kg/(i*a) of waste per inhabitant for these waste codes. A total of 6,323,691 tonnes of food waste was recorded in these waste codes in the reporting year 2019. This corresponds to 76 kg/(i*a) of waste per inhabitant for these waste codes in the reporting year 2019.

The average weighted waste coefficient for mixed municipal waste is 29 %. The waste coefficients correspond to the values stated in Table 22 (composition in mass %) but have been rounded. The calculations resulted in a waste coefficient of 33 % for household waste, 36 % for biowaste and approximately 4 % for commercial waste similar to household waste. At the time of the evaluation, there was no information available on the composition of this waste stream for

[38] The amounts of waste for reporting year 2019 were used because the amounts of waste for reporting year 2020 were not yet available at the time the waste coefficients were calculated.

the waste code "20 03 01 00 – non-differentiable mixed municipal waste". Therefore, the average weighted proportion of food waste of 29 % was adopted for this eight-digit code.

Table 22: Waste coefficients for mixed municipal waste (waste code 20 03 01) in the reporting year 2019

Waste streams	Annual amount t/a	Annual amount per inhabitant kg/(i*a)	Composition (mean value) mass %
Household waste (20 03 01 01)[1]	12,942,801	155.6	100.0
Organic	4,886,675	58.8	37.8
Food waste	4,290,937	51.6	**33**
Kitchen waste	2,196,516	26.4	17.0
Food scraps	1,309,520	15.7	10.1
Packaged food (net)	784,901	9.4	6.1
Biowaste (20 03 01 04)[2]	5,701,952	68.6	100.0
Organic	4,566,878	54.9	80.1
Food waste	2,035,579	24.5	**36**
Kitchen waste	1,396,957	16.8	24.5
Food scraps	607,679	7.3	10.7
Packaged food (net)	30,943	0.4	0.5
Commercial waste similar to household waste (20 03 01 02)[3]	3,271,000	39.3	100.0
Organic	327,100	3.9	10.0
Food waste[4]	130,840	1.6	**4**
Non-differentiable mixed municipal waste (20 03 01 00)[5]	-	-	**29**

1 From the OERE statistics for the federal states in the reporting year 2019 (StBA 2021), rounded values.
2 From the waste balances of the federal states for the reporting year 2019, rounded values.
3 From the waste balance of the StBA for the reporting year 2019 (StBA 2022), rounded values.
4 The waste coefficient is estimated based on expert opinion.
5 At the time of the evaluation, there was no information available about the composition of this waste code.
Sources: Waste balances of the federal states 2019; StBA 2021; StBA 2022; own research, WI, ARGUS, INFA, USTUTT

The waste coefficients stated above were determined on the basis of, amongst other things, data from the reporting year 2019. For EU reporting for the reporting year 2020, these waste coefficients were applied to the data prepared for this report for 2020, which was calculated using the methodology described in Chapter 5, to determine the amount of food waste in the total amount of waste.

6.2 Other waste codes

This chapter describes the research carried out for determining the waste coefficients for the other waste codes stated in Annex II of Delegated Decision (EU) 2019/1597 (except for 20 03 01

– mixed municipal waste). The waste coefficients for these other waste codes were determined using a different methodology to that used for waste code 20 03 01. At the time of this evaluation, the consortium did not have access to any original waste sorting analyses for these waste codes. For this reason, a well-founded plan was developed for an evaluation and then an online survey was designed and implemented. The amounts of waste for reporting year 2019 were used to determine the waste coefficients because the amounts of waste for reporting year 2020 were not yet available at this time. Before application of the waste coefficients, the other waste codes accounted for 4,515,311 t of waste in reporting year 2020. This was approximately 17 % of potential food waste before application of the waste coefficients (total amount 26,944,977 t[39]).

6.2.1 Objective and subject matter

Waste coefficients for the proportion of food waste had to be determined for the 34 waste codes from Annex II to the Delegated Decision (EU) 2019/1597 (except20 03 01 “mixed municipal waste”) that are shown in Table 23.

Table 23: Overview of other waste codes from Annex II of Delegated Decision (EU) 2019/1597

Waste code	Description
02 01 02	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing: Animal-tissue waste
02 01 03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing: Plant-tissue waste
02 02 01	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Sludges from washing and cleaning
02 02 02	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Animal-tissue waste
02 02 03	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Materials unsuitable for consumption or processing
02 02 04	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Sludges from on-site effluent treatment
02 02 99	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Wastes not otherwise specified
02 03 01	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Sludges from washing, cleaning, peeling, centrifuging and separation
02 03 02	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Wastes from preserving agents
02 03 03	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Wastes from solvent extraction

[39] Including home composting in stage 5 of the food supply chain and the modifications.

Waste code	Description
02 03 04	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: materials unsuitable for consumption or processing: Materials unsuitable for consumption or processing
02 03 05	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Sludges from on-site effluent treatment
02 03 99	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Wastes not otherwise specified
02 04 01	Wastes from sugar processing: Soil from cleaning and washing beet
02 04 02	Wastes from sugar processing: Off-specification calcium carbonate
02 04 03	Wastes from sugar processing: Sludges from on-site effluent treatment
02 04 99	Wastes from sugar processing: Wastes not otherwise specified
02 05 01	Wastes from the dairy products industry: Materials unsuitable for consumption or processing
02 05 02	Wastes from the dairy products industry: Sludges from on-site effluent treatment
02 05 99	Wastes from the dairy products industry: Wastes not otherwise specified
02 06 01	Wastes from the baking and confectionery industry: Materials unsuitable for consumption or processing
02 06 02	Wastes from the baking and confectionery industry: Wastes from preserving agents
02 06 03	Wastes from the baking and confectionery industry: Sludges from on-site effluent treatment
02 06 99	Wastes from the baking and confectionery industry: Wastes not otherwise specified
02 07 01	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Wastes from washing, cleaning and mechanical reduction of raw materials
02 07 02	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Wastes from spirits distillation
02 07 03	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Wastes from chemical treatment
02 07 04	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Materials unsuitable for consumption or processing
02 07 05	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Sludges from on-site effluent treatment
02 07 99	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Wastes not otherwise specified
16 03 06	Off-specification batches and unused products: Organic wastes other than those mentioned in 16 03 05

Waste code	Description
20 01 08	Municipal wastes – separately collected fractions: Biodegradable kitchen and canteen waste
20 01 25	Municipal wastes – separately collected fractions: Edible oil and fat
20 03 02	Municipal wastes – other municipal wastes: Waste from markets

Source: Own illustration, StBA

6.2.2 Methodological approach

The consortium did not have access to any original waste sorting analyses for the waste codes listed in Chapter 6.2.1 from Annex II of Delegated Decision (EU) 2019/1597. For this reason and to develop a well-founded plan for the evaluation process, the consortium initially researched and evaluated all available national and international literature and the latest studies on food waste. It was able to call on existing data, its own studies and a large body of literature on the subject. Against this background, the best available data for determining the waste coefficients according to the methodological requirements in Delegated Decision (EU) 2019/1597 from the EU Commission was used. Other articles and publications on the subject of "food waste and waste sorting analyses" in Germany that were relevant to this project were also examined. In the process, the consortium considered all sources and information in order to guarantee the generation of the most reliable baseline data for the fulfilment of the future reporting obligation. The following steps were examined to see if they were viable processes for determining the waste coefficients:

1. Carrying out surveys of associations and companies in the waste disposal sector with the aid of an online questionnaire.
2. Examining and preparing existing waste coefficients and data.
3. Preparing and updating statistical reference values for 2019: The amounts of cultivated food from the statistical yearbook for agriculture, the amounts of produced food from production statistics for the food processing industry, the retail space taken up by German food retailers.
4. Collecting waste coefficients from relevant literature (if available) for the other waste codes from Annex II of Delegated Decision (EU) 2019/1597.
5. Querying the results available from the dialogue forums for the first stages 1 to 3 of the food supply chain (primary production, processing and manufacturing, retail and other distribution of food).

It was determined during this planning stage that steps 2 to 5 could not be used for determining the waste coefficients. Overall, there is little information and only a few studies available for determining waste coefficients for the other waste codes (outside of mixed municipal waste). However, these studies did not relate to waste codes and could not be used. The consortium thus rated step 1 as the only feasible possibility for determining waste coefficients for the other waste codes.

6.2.3 Online survey: Preparation – checking the waste coefficients for quantitative relevance

In preparation for the online survey, the first step was to check whether there were actually amounts of waste for these waste codes large enough to be relevant. The consortium based this decision on the total amounts of waste in the AE, BS, DepBau and GV statistics for the reporting year 2019 (see creation of the data set in Chapter 5.1.1), because the waste statistics for the reporting year 2020 were not available at this point in time. Those waste codes for which the amounts of waste were less than 1,000 t according to the national, official waste statistics for reporting year 2019 were omitted from the online survey because of the resources and time it would have taken to analyse them. Table 24 shows the eight waste codes with total generated waste of around 1,065 t in reporting year 2019.

Table 24: Other waste codes with amounts of waste less than 1,000 t in the reporting year 2019

Waste code	Description
02 03 02	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Wastes from preserving agents
02 03 03	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Wastes from solvent extraction
02 04 01	Wastes from sugar processing: Soil from cleaning and washing beet
02 04 02	Wastes from sugar processing: Off-specification calcium carbonate
02 04 03	Wastes from sugar processing: Sludges from on-site effluent treatment
02 06 02	Wastes from the baking and confectionery industry: Wastes from preserving agents
02 06 99	Wastes from the baking and confectionery industry: Wastes not otherwise specified
02 07 03	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Wastes from chemical treatment

Source: Own illustration, StBA

Due to a lack of information on the composition of the waste in these eight waste codes, the consortium decided to take a conservative approach and thus selected a waste coefficient of 100 % for each. Annex II of Delegated Decision (EU) 2019/1597 states which waste codes usually also contain food waste. To avoid underestimating amounts of food waste, these waste codes were not excluded from the reporting. Therefore, this resulted in a slight overestimation of the amounts of food waste in the waste codes in stages 1 to 4 of the food supply chain.

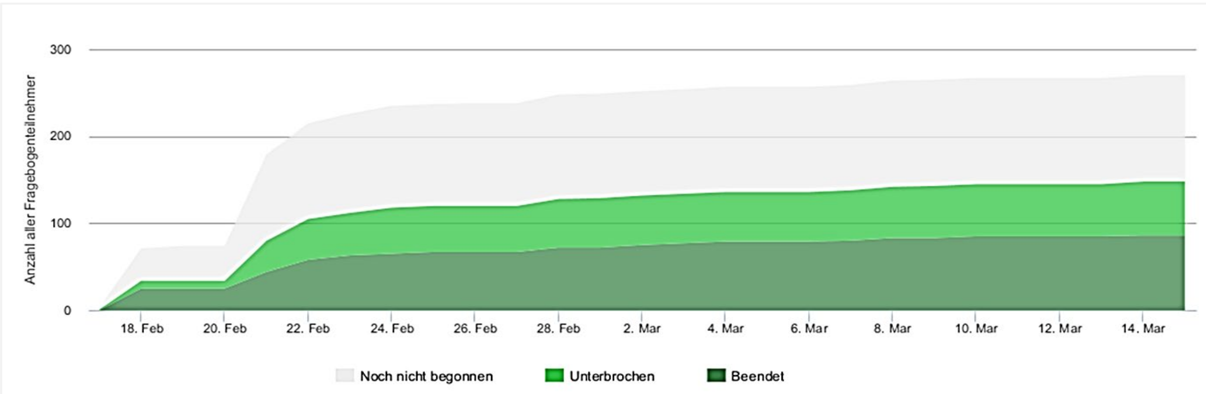
For the remaining waste codes listed in Annex II of Delegated Decision (EU) 2019/1597 (with the exception of 20 03 01), the consortium carried out an online survey without any legal obligation for those surveyed to provide information.

6.2.4 Online survey: Procedure

In order to derive the waste coefficients for the waste codes in Annex II of Delegated Decision (EU) 2019/1597, the consortium member USTUTT conducted the first nationwide voluntary survey of the waste disposal industry. An online questionnaire was developed for this survey and published on the website of the host "Unipark". The online questionnaire was designed with the close cooperation of those responsible at the StBA, UBA, BMUV and USTUTT. In the questionnaire, the operators of waste disposal facilities were surveyed on the amounts of waste and the proportion of food waste in certain waste codes in the reporting year 2019. The published questionnaire is included with this report as Annex E. This voluntary online survey also covered reporting year 2019 so that it was consistent with the process used for determining the waste coefficients.

USTUTT sent out the questionnaire via email to a total of 748 recipients on February 18, 2022. The deadline for responses was March 14, 2022. The respondents were companies in the German waste management sector or operators of waste disposal facilities in Germany – e.g. waste incineration plants, biowaste fermentation plants, composting plants and mechanical-biological waste treatment plants. Figure 12 shows the number of respondents to the online survey. The questionnaire was opened 270 times in different web browsers. The questionnaire was fully completed a total of 86 times (see Table 25).

Figure 12: Number of respondents to the online survey of the German waste disposal industry in the reporting year 2019



Source: Kern et al. (2022)

Table 25 shows the total number of participants in the survey, including the questionnaires returned via email. The overall response rate to the survey was around 13.5 % or 101 completed questionnaires, of which 49 (6.6 %) contained usable data[40]. Although it was an anonymous survey, 69 of the 101 responses contained voluntary contact details. In comparison to previous surveys of the food processing sector by Schmidt et al. (2019), the response rate for this survey was about four times higher.

[40] In the other 52 responses submitted by the operators of waste disposal facilities, the operators responded that they did not have any information available on the composition of the waste.

Table 25: Participation in the online survey on the other waste codes in the reporting year 2019

	Number	Percent
Recipient (email addresses of the operators of the waste disposal facilities)	748	100
Participation in the online questionnaire	148	19.8
Online questionnaire completed	86	11.5
Online questionnaire interrupted	62	8.3
Responses via email	15	2.0
Net participation (online questionnaire completed + responses via email)	101	13.5
Usable information on food waste (as of March 8, 2022)	**49**	**6.6**

Source: Own research, WI, ARGUS, INFA, USTUTT

6.2.5 Online survey: Feedback

In view of the low amount of feedback providing information on each waste code, the existing gaps in the data and the sporadic data available to the respondents, the online survey carried out by USTUTT cannot meet the requirements of a representative sample. However, it is important to note that this study marked the first time that the German waste management sector had been surveyed about the amount of food waste. The collected information was the only available data set for determining waste coefficients for the waste codes named in Chapter 6.1 for the purpose of fulfilling the first food waste reporting obligation to the EU Commission for the reporting year 2020 by June 30, 2022. A repeat of this survey of the waste disposal industry could update, expand and possibly improve the quality of the existing data over the coming years.

The online survey carried out by USTUTT produced a maximum of one response for a total of 13 different waste codes. Therefore, it was not possible to use the results of the online questionnaire for these waste codes. Due to a lack of any further information, a conservative approach was also taken here in order to ensure that the amounts of food waste were not underestimated. Therefore, the waste coefficients for these waste codes were set at 100 %. This resulted in a slight overestimation of the amounts of food waste for these waste codes (total amount of waste before application of the waste coefficient for reporting year 2020: around 373,411 t) in stages 1 to 4 of the food supply chain. Table 26 shows these 13 waste codes.

Table 26: Other waste codes with a maximum of one response in the online survey in the reporting year 2019

Waste code	Description
02 02 01	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Sludges from washing and cleaning
02 02 99	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Wastes not otherwise specified
02 03 01	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Sludges from washing, cleaning, peeling, centrifuging and separation
02 03 05	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Sludges from on-site effluent treatment
02 03 99	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Wastes not otherwise specified
02 04 99	Wastes from sugar processing: Wastes not otherwise specified
02 05 99	Wastes from the dairy products industry: Wastes not otherwise specified
02 06 03	Wastes from the baking and confectionery industry: Sludges from on-site effluent treatment
02 07 01	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Wastes from washing, cleaning and mechanical reduction of raw materials
02 07 02	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Wastes from spirits distillation
02 07 05	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Sludges from on-site effluent treatment
02 07 99	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Wastes not otherwise specified
16 03 06	Off-specification batches and unused products: Organic wastes other than those mentioned in 16 03 05

Source: Own illustration, StBA

The online survey by USTUTT produced at least two responses for 13 other waste codes that were used to derive the waste coefficients. Table 27 shows these waste codes (total amount of waste before application of the waste coefficients for reporting year 2020: around 2,970,313 t).

Table 27: Other waste codes with at least two responses in the online survey in the reporting year 2019

Waste code	Description
02 01 02	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing: Animal-tissue waste
02 01 03	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing: Plant-tissue waste
02 02 02	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Animal-tissue waste
02 02 03	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Materials unsuitable for consumption or processing
02 02 04	Wastes from the preparation and processing of meat, fish and other foods of animal origin: Sludges from on-site effluent treatment
02 03 04	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: materials unsuitable for consumption or processing: Materials unsuitable for consumption or processing
02 05 01	Wastes from the dairy products industry: Materials unsuitable for consumption or processing
02 05 02	Wastes from the dairy products industry: Sludges from on-site effluent treatment
02 06 01	Wastes from the baking and confectionery industry: Materials unsuitable for consumption or processing
02 07 04	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Materials unsuitable for consumption or processing
20 01 08	Municipal wastes – separately collected fractions: Biodegradable kitchen and canteen waste
20 01 25	Municipal wastes – separately collected fractions: Edible oil and fat
20 03 02	Municipal wastes – other municipal wastes: Waste from markets

Source: Own illustration, StBA

6.2.6 Determination the waste coefficients: Methodology

USTUTT evaluated the results of the online survey and first determined average waste coefficients for the relevant 13 waste codes (see 6.2.5). A plausibility check was then carried out to once again examine the stability and volatility of the waste coefficients determined from the online survey. It can be assumed that the information from the online survey is subject to significant variations due to the method used to collect the data. In order to take these uncertainties into account, USTUTT calculated confidence intervals for the estimated values taken from the online survey and used the upper limit as the estimate for the waste coefficient. Accordingly, the consortium assumed a binomial distribution and selected the upper limit (see Table 28) of the 95 % Clopper-Pearson confidence interval (CPCI) (α=5 %) as the waste coefficient for the reporting. Taking the upper confidence limit reduced – with a relatively high probability – any underestimation of food waste to a minimum. This calculation methodology was used as the basis for the reporting to the EU Commission on June 30, 2022.

The subsequent optimisation of the processes and the quality of the data after the reporting meant the CPCI could be used for estimating the proportions of waste at the level of the waste disposal facilities. It also showed, however, that the original CPCI used by the consortium was not methodologically suitable for aggregating the results from the waste disposal facilities. The assumption of a binomial distribution is not compatible with the previous calculation carried out for the waste coefficients. For this reason, the waste coefficients were recalculated and corrected during the course of the project.

Assuming a normal distribution for a waste coefficient for different sizes of waste disposal facility, the interval limits for the student's t-distribution were calculated instead of the CPCI. To ensure that the proportions of food waste were not underestimated, the consortium also used the upper limit of the 95 % confidence interval of the t-distribution (α=5 %) for this method. It should be noted that it was not possible to subsequently verify or falsify the assumed distribution using the available data.

Due to the low response rates, the consortium supplemented the waste coefficients determined via the upper limit of the confidence interval for the t-distribution with estimates based on expert opinion. Considering all of the information and data available from the online survey, the consortium believes that it has achieved the best possible approximation of the actual values.

The following assumptions were made when calculating the upper limits of the confidence intervals of the t-distribution:

- A normal distribution can be assumed for the calculation of the waste coefficients.
- The calculation of the t-distribution confidence interval is also permissible for a low number of responses ($n \geq 5$).

For waste codes with less than five responses in the online survey from USTUTT, the consortium critically examined the calculated upper limits for the t-distribution confidence intervals and used estimates based on expert opinion to verify or substitute them where necessary (if the variation in the amounts from the facilities was too large and could result in large distortions). A plausibility test was carried out on each of the waste codes being considered using all of the available information, i.e. data from the online survey, material properties of the waste, materials in the respective waste codes (if known). This ensured that the waste coefficients were determined using a uniformly consistent process comprising evaluations of the questionnaires and estimates based on expert opinion.

The justification for the waste coefficients determined using this method is given for each of the 13 relevant waste codes from Chapter 6.2.5 (see Table 27) below (total amount of waste before application of the waste coefficients for reporting year 2020: around 2,970,313 t).

6.2.7 Determination the waste coefficients: Results

The justifications for the waste coefficients determined for each of the 13 relevant waste codes are presented in the following chapter.

Estimates based on expert opinion

- "02 01 02 – Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing: Animal-tissue waste"

The two responses for waste code 02 01 02 (Agriculture: Animal-tissue waste) from the surveyed operators of the waste disposal facilities gave amounts close to zero. These two responses are currently the best available dataset. Based on the estimates of the respondents, it can be assumed that the proportion of food waste in waste code 02 01 02 is virtually zero.

After querying the two respondents, the consortium was informed that the waste in this waste code consisted of horse manure (contact person 1) and oak processionary moth (contact person 2). This information confirmed the assessment that the waste in this waste code is largely not made up of food waste. In light of this information, the consortium believes that a waste coefficient of 0 % is plausible or represents the best possible approximation at this time.

► "02 01 03 – Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing: Plant-tissue waste"

The upper limit of the 95 % confidence interval of the t-distribution for waste code 02 01 03 (Agriculture: Plant-tissue waste) is 32.6 % (n=13). The consortium believes that the most conservative estimate for the waste coefficient of 33 % should be made for waste code 02 01 03, which corresponds to the upper limit of the 95 % confidence interval.

The "List regarding the concretion of possible materials which can be credited as waste and residues for the GHG-quote pursuant to § 37 a para. 4 of the BImSchG" breaks down the different materials that can be found in this waste code (BLE 2015). This list was created on 02/01/2015 by the Federal Office for Agriculture and Food (BLE) and is available online.

According to this list, waste code 02 01 03 contains the following materials:

- Flax shives and hemp shives
- Coconut fibre
- Vegetable waste from horticulture
- Vegetable waste from water maintenance
- Vegetable waste from agriculture
- Vegetable waste from aquaculture and fisheries
- Vegetable waste from biological waste air purification
- Reed
- Cereal dust and husks

A large majority of the listed materials are not explicitly food waste, which is why the consortium considered that a waste coefficient of 33 % was a plausible approximation.

► "02 02 02 – Wastes from the preparation and processing of meat, fish and other foods of animal origin: Animal-tissue waste"

The two responses to the online survey from USTUTT for waste code 02 02 02 (Meat processing: Animal-tissue waste) from the surveyed operators of the waste disposal facilities gave amounts close to zero. These two responses are currently the only available data on the proportion of food waste in this waste code. Based on the estimates of the respondents, it can be assumed that the proportion of food wastes in waste code 02 02 02 is virtually zero.

After querying the two operators of the waste disposal authorities, the consortium was informed that the waste in this waste code consisted of animal fur (contact person 1) and protein hydrolysates (contact person 2). This information confirmed the assessment that the waste in this waste code is largely not made up of food waste. In light of this information, the consortium believes that a waste coefficient of 0 % is plausible or represents the best possible approximation at this time.

- "02 02 03 – Wastes from the preparation and processing of meat, fish and other foods of animal origin: Materials unsuitable for consumption or processing"

The upper limit of the 95 % confidence interval of the t-distribution for waste code 02 02 03 (Meat processing: materials unsuitable for consumption or processing) is 43 % (n=6). The most conservative estimate for the waste coefficient of 43 % should therefore be made for waste code 02 02 03, which corresponds to the upper limit of the 95 % confidence interval.

Further information on the composition of the waste in this waste code and the materials it contains is not currently available. In light of this information, the consortium believes that a waste coefficient of 43 % is plausible or represents the best possible approximation at this time.

- "02 02 04 – Wastes from the preparation and processing of meat, fish and other foods of animal origin: Sludges (on-site effluent treatment)"

Six responses were received for waste code 02 02 04 (Meat processing: sludges from on-site effluent treatment) in the online survey from USTUTT. The upper limit of the 95 % confidence interval is 16 % (n=6). It is possible that the operators of waste disposal facilities who responded do not define this waste stream as food waste because the waste code has the word "sludges" in the description. Due to there being no legal definition for whether food waste is contained in sludges, there is some room for interpretation in this area. It is thus possible that the responses to the survey could give a highly distorted picture due to the lack of a uniform definition and the low number of responses.

In view of the available information, the consortium recommends making the most conservative estimate for the waste coefficient. The online survey from USTUTT revealed that sludges can contain up to 54 % food waste. USTUTT contacted the operator of a waste disposal facility who provided this data by telephone on November 30, 2022 to query the reliability of this value and was able to confirm it. Due to the underlying uncertainty and the absence of any other information on this waste code, the consortium recommends the most conservative estimate for the waste coefficient of 54 %.

- "02 03 04 – Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Materials unsuitable for consumption or processing"

The upper limit of the 95 % confidence interval of the t-distribution for waste code 02 03 04 (Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation: Materials unsuitable for consumption or processing) is 71.3 % (n=15). The most conservative estimate for the waste coefficient of 71 % should be made for waste code 02 03 04, which corresponds to the upper limit of the 95 % confidence interval.

Further information on the composition of the waste in this waste code and the materials it contains is not currently available. In light of this information, the consortium believes that a waste coefficient of 71 % is plausible or represents the best possible approximation at this time.

- "02 05 01 – Wastes from the dairy products industry: Materials unsuitable for consumption or processing"

The two responses from the surveyed operators of the waste disposal facilities for waste code 02 05 01 (Dairy processing: Materials unsuitable for consumption or processing) gave amounts of about 12 % and 3 %). It is possible that the respondents did not consider this waste stream to be food waste because the waste code is named “Materials unsuitable for consumption or processing”. It is possible here that the legal definition for food waste was not applied consistently by the respondents in the survey.

The consortium believes that food waste can certainly be generated during the production of milk that is classified as materials unsuitable for consumption or processing. The most conservative estimate for the waste coefficient should thus be made for waste code 02 05 01. Taking into account the material property of this waste (milk) and its classification (“Materials unsuitable for consumption or processing”), a conservative estimate for the waste coefficient can be made as was the case with a comparably classified waste code, e.g. waste code 02 03 04 (Fruit: Materials unsuitable for consumption or processing). The most conservative estimate would mean that the waste coefficient for waste code 02 05 01 was set at 71 %.

The “List regarding the concretion of possible materials which can be credited as waste and residues for the GHG-quote pursuant to § 37 a para. 4 of the BImSchG” breaks down the different materials that can be found in this waste code (BLE 2015).

According to this list, waste code 02 05 01 contains the following materials:

- Whey.

Information on other materials in this waste code is not available. Based on this data, it can be assumed that the waste in waste code 02 05 01 primarily consists of whey and is thus food waste. In light of this information, the consortium believes that a waste coefficient of 100 % is a plausible approximation.

► “02 05 02 – Wastes from the dairy products industry: Sludges (on-site effluent treatment)”

The two responses from the surveyed operators of the waste disposal facilities for waste code 02 05 02 (Dairy processing: sludges from on-site effluent treatment) gave amounts of about 0 % and 0.7 %). However, it is possible that the respondents did not define this waste stream as food waste because the waste code is named “Sludges from on-site effluent treatment”. Due to there being no legal definition for whether food waste is contained in sludges, there is some room for interpretation in this area. It is thus possible that the responses to the survey could give a highly distorted picture due to the lack of a uniform definition and the low number of responses.

In view of the available information, the consortium recommends making the most conservative estimate for the waste coefficient. The online survey from USTUTT revealed that sludges can contain up to 54 % food waste (see waste code 02 02 04). The respondents who provided this data were contacted by telephone on November 30, 2022 to query the reliability of this value and were able to confirm it. Taking into account the material property of this waste (milk) and its classification (“sludges”), a conservative estimate for the waste coefficient can be made as was the case with a comparably classified waste code, e.g. waste code 02 02 04 (Meat: Sludges). Due to the underlying uncertainty and the absence of any other information on this waste code, the consortium thus recommends the most conservative estimate for the waste coefficient of 54 %.

► “02 06 01 – Wastes from the baking and confectionery industry: Materials unsuitable for consumption or processing”

The upper limit of the confidence interval of the t-distribution for waste code 02 06 01 (Baking and confectionery processing: Materials unsuitable for consumption or processing) is 100 % (n=6). The most conservative estimate for the waste coefficient of 100 % should be made for waste code 02 06 01, which corresponds to the upper limit of the 95 % confidence interval.

The "List regarding the concretion of possible materials which can be credited as waste and residues for the GHG-quote pursuant to § 37 a para. 4 of the BImSchG" breaks down the different materials that can be found in this waste code (BLE 2015).

According to this list, waste code 02 06 01 contains the following materials:

- Old flour
- Fermentation residues from enzyme production
- Yeast and yeast-like residues
- Dough waste.

A large majority of the listed materials are food waste, which is why the consortium considered that a conservative waste coefficient of 100 % was a plausible approximation.

- ► "02 07 04 – Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa): Materials unsuitable for consumption or processing"

The responses from the surveyed operators of the waste disposal facilities for the waste code 02 07 04 (Beverage processing: Materials unsuitable for consumption or processing) gave amounts of almost zero (0 %, 0.62 % and 1 %). However, it is possible that the respondents did not consider liquid food waste (beverages) as food because the waste code is named "Materials unsuitable for consumption or processing". It is possible here that the legal definition for food waste was not applied consistently by the respondents in the survey.

The consortium believes that food waste can certainly be generated during the production of beverages that is classified as materials unsuitable for consumption or processing. The most conservative estimate for the waste coefficient should thus be made for waste code 02 07 04. Taking into account the material property of this waste (beverages) and its classification ("Materials unsuitable for consumption or processing"), a conservative estimate for the waste coefficient can be made as was the case with a comparably classified waste code, e.g. waste code 02 03 04 (Fruit: Materials unsuitable for consumption or processing). The most conservative estimate would mean that the waste coefficient for waste code 02 07 04 was set at 71 %.

Further information on the composition of the waste in this waste code and the materials it contains is not currently available. In light of this information, the consortium believes that a waste coefficient of 71 % is plausible or represents the best possible approximation at this time.

- ► "20 01 08 – Municipal wastes – separately collected fractions: Biodegradable kitchen and canteen waste"

The upper limit of the 95 % confidence interval of the t-distribution for waste code 20 01 08 (Biodegradable kitchen and canteen waste) is 100 % (n=8). Due to the underlying uncertainty, the most conservative estimate for the waste coefficient of 100 % should be made for waste code 20 01 08, which corresponds to the upper limit of the 95 % confidence interval. In Germany, there is a legal obligation to separately collect kitchen and canteen waste. Against this background, it can be assumed that kitchen and canteen waste largely comprises food waste. In addition, there is also the possibility of incorrectly sorted waste. However, it can be assumed that this would only be in the small single-digit percentage range. In light of this information, the consortium believes that a waste coefficient of 100 % is the most conservative estimate that can be made.

- "20 01 25 – Municipal wastes – separately collected fractions: Edible oil and fat"

The amounts given in the two responses for waste code 20 01 25 (Edible oil and fat) from the surveyed operators of the waste disposal facilities of 0.1 % and 100 % were very far apart. It is very probable that the two respondents in this case based their responses on a different classification or definition of food waste. It is possible here that the legal definition for food waste was not applied consistently by the respondents in the survey.

Moreover, it is possible that the operator defined edible oil (frying fat) as an operating material and not as food. Assuming that edible oil and fat is defined as food and not as an operating material, it can also be expected that separately collected edible food and fat for recycling consists almost 100 % of food waste. A waste coefficient of 100 % can be assumed for the waste code 20 01 25.

Further information on the composition of the waste in this waste code and the materials it contains is not currently available. In light of this information, the consortium believes that a waste coefficient of 100 % is plausible or represents the best possible approximation at this time.

- "20 03 02 – Municipal wastes – other municipal wastes: Waste from markets"

The upper limit of the 95 % confidence interval of the t-distribution for waste code 20 03 02 (Waste from markets) is 100 % (n=5). Therefore, a conservative estimate of a maximum of 100 % can thus be made for the waste coefficient for waste code 20 03 02.

Further information on the composition of the waste in this waste code and the materials it contains is not currently available. In light of this information, the consortium believes that a waste coefficient of 100 % is plausible or represents the best possible approximation at this time.

6.2.8 Rating the quality of the available data and recommendations for closing gaps in the data

It is important to note that the voluntary online survey from USTUTT and the consortium delivers an indicative estimation that can contain distortions due to the chosen methodology and is not reliable from a statistical perspective due to the low number of responses. It is thus not possible to recognise it as a representative study. Furthermore, the information given by the respondents is mostly based on estimates and not on physical measurements. The impact of those who did not respond to the survey is also not known, while the size of the sample is not sufficient for deriving high quality estimates of the proportions of waste (waste coefficients). Nevertheless, the information gathered by the consortium is the only available data set for determining waste coefficients for the waste codes stated in Chapter 6.1 – and thus for the timely fulfilment of the first reporting obligation to the EU Commission for food waste for the reporting year 2020 by June 30, 2022 at the latest.

Estimates made based on expert opinion are made on the basis of specialist expertise within the consortium taking into consideration the responses to the voluntary online survey from USTUTT, the material properties of the waste and the materials contained in the waste codes. Furthermore, the responses to the online survey were also queried with the respondents where possible. The waste coefficients should be understood as a plausible approximation of the actual values, whereby it is not ultimately possible to state how reliable the data is in each case.

The consortium has examined all of the data and evaluated all of the information available at the current time. In view of the available time frame and budget for this current study, the consortium believes that more thorough analyses were not possible.

6.2.9 Results of the waste coefficients for the other waste codes

Table 28 provides a summary of the results from this chapter. In addition, Table 28 gives a comparison between the originally calculated waste coefficients based on the CPCI and the modified waste coefficients optimised for methodological reasons on the basis of expert opinion (supplementing the t-distribution). As described in Chapter 6.2.6, the waste coefficients listed in Table 28 were determined using the upper limit of the 95 % confidence interval.

Table 28: Comparison of the waste coefficients based on the Clopper-Pearson confidence interval (α=5 %) and estimates based on expert opinion

Waste code	Number of responses (n) from the online survey from USTUTT	Original waste coefficient based on the Clopper-Pearson confidence interval in %	Modified waste coefficient based on expert opinion (supplementing the t-distribution) in %
02 01 02	2	0	**0**
02 01 03	13	42	**33**
02 02 02	2	0	**0**
02 02 03	6	64	**43**
02 02 04	6	52	**54**
02 03 04	15	65	**71**
02 05 01	2	89	**100**
02 05 02	2	84	**54**
02 06 01	6	94	**100**
02 07 04	3	71	**71**
20 01 08	8	97	**100**
20 01 25	2	97	**100**
20 03 02	5	87	**100**

Source: Own research, WI, ARGUS, INFA, USTUTT

The recalculated amounts of food waste (based on expert opinion supplementing the t-distribution) using the modified waste coefficients (see the right-hand column in Table 28) decreased in comparison to the originally calculated amount of food waste (based on the CPCI) by around 3,435 t. This means that the total amount of food waste in Germany (approximately 10.9 million t) decreased by around 0.03 % due to this modification – compared to the data reported to Eurostat on June 30, 2022.

7 Home composting in stage 5 of the food supply chain

7.1 Collection of data and the data set

In this chapter, the consortium gives an estimate of the amount of food waste recycled by households through home composting (stage 5 of the food supply chain). Due to the fact that the available data was only reliable to a limited extent, it was only possible to make a rough estimate.

There was no data on the impact of home composting available in the official statistics at the time of the reporting. A research project is currently being carried out for the UBA[41] to determine the amount of waste recycled in home composting as part of a representative survey. Due to the tight timescale for reporting the amount of food waste for the reporting year 2020 by June 30, 2022 and the fact that the UBA research project was not yet completed at the time of the reporting for the reporting year 2020, it was not possible to take the findings from the UBA research project into account.

The methodology used by the consortium to estimate the amount of food waste recycled through home composting was based on two existing external studies that contained information on home composting.

On the one hand, the consortium examined a study by the "Gesellschaft für Konsumforschung" (GfK SE – Society for Consumer Research) on the amount of food waste from households. This first study was carried out on data collected in the period from July 2016 to June 2017 (Hübsch 2021). It was then updated for the reference period 2020. This updated study was subsequently taken into account.

The GfK SE study was designed as a study in which private households kept diaries. The households were selected so as to ensure a representative random sample. The total length of the study was twelve months. The test subjects participating in the study were each asked to record the amount of food waste generated in their household for 14 days.

Shopping statistics from the GfK SE household panel were used to validate the amounts of food waste derived from the evaluation of the dairies.

Alongside the GfK SE study, the consortium also examined a study published by the TI with the short name "Baseline 2015" for estimating the amount of food waste recycled through home composting (Schmidt et al. 2019).

7.2 Methodological approach

The results of the two studies were evaluated in combination with respect to the amounts of food waste from private households. The consortium did not carry out its own surveys or calculations.

7.3 Presentation and evaluation of the results

Based on the results from the diaries and a subsequent extrapolation to 40.8 million private households, the GfK SE calculated an annual amount of food waste of 3.9 million t. After taking into account the coverage factor[42] from the comparison with the data from the GfK SE shopping

[41] ARGUS GmbH, WI GmbH, INFA GmbH: ReFoPlan 2021 "Determining a data set for calculating the influence of home composting on biowaste recycling". FKZ 3721 33 302 0. Currently in progress.

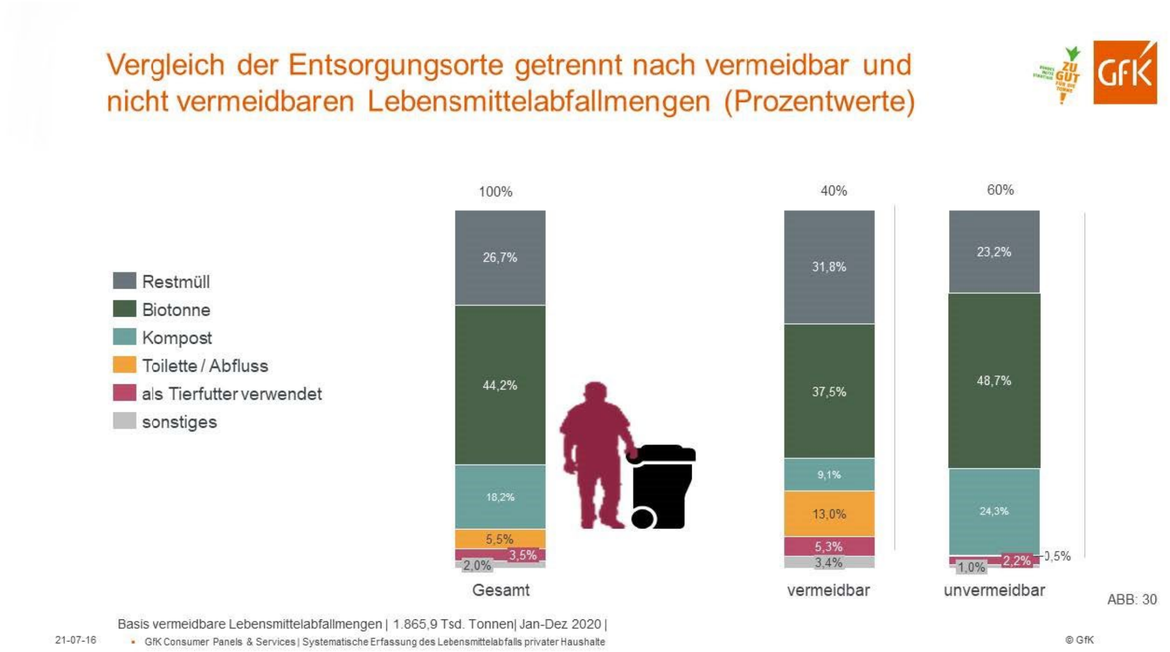
[42] See Hübsch (2021) for more detailed explanation and a list of the coverage factors.

panel, the amount of food waste from private households was 4.6 million t, which corresponds to an average amount of food waste in private households in Germany of 56 kg/(i*a).

The diary study from GfK SE has the methodological advantage that it not only analyses the amount of waste but also the ways in which the food waste is disposed of in private households. The study recorded the food that was disposed of via the drains or reused as animal feed and also food that was recycled by the household itself. The results of the diary study are presented in Figure 13, which was directly taken from the GfK SE study. The distribution with respect to the total amount of waste is relevant for this study.

However, the fact that the GfK SE study was carried out in the form of a diary study also has a disadvantage. It can be assumed that the actual figures were underestimated because as a rule test subjects will tend to behave in a more socially desirable manner (in this case: generate less waste) simply because they are participating in a study (Schmidt et al. 2017).

Figure 13: Disposal channels for food waste in private households



Source: Hübsch (2021)

The study found that 18.2 % of food waste was recycled through home composting (classification: “composting”). This value was used for the subsequent calculations.

According to the GfK SE study for the reporting period 2020 (Hübsch 2021), the amount of food waste recycled though home composting can be estimated as approximately 0.837 million t/a (corresponds to 10.1 kg/(i*a)). The “Baseline 2015” study found approximately 1.117 million t/a of recycled food waste (which corresponds to 13.6 kg/(i*a)).

Another study published by the UBA in 2015 called “Compulsory implementation of separate collection of biowaste” (Krause et al. 2015) provided additional information that could be used to check the plausibility of the results. This reported that 13.6 kg/(i*a) of kitchen waste was recycled through home composting. The fraction of kitchen waste was differentiated from garden waste and can largely be classified as food waste. Against this background, the result (13.6 kg/(i*a)) from the “Baseline 2015” study seemed plausible because it was similar to the value calculated in the study “Compulsory implementation of separate collection of biowaste”

(13.6 kg/(i*a)) (Krause et al. 2015). Another argument in favour of this result is the fact that it can be assumed in diary studies (such as the GfK SE study) that test subjects will tend to underestimate the amount of generated and disposed of waste.

According to the Baseline study (Schmidt et al. 2019), private households generated approximately 6.14 million t of food waste (reference year 2015), of which about 5.05 million t was recorded by the municipal waste collection systems. Food waste disposed of via drains was not included in this amount.

Based on the German population as of December 31, 2015 of approximately 82.2 million inhabitants, this corresponded to a total amount of waste generated in private households of approximately 74.7 kg/(i*a). Using the percentage distribution by disposal channel in the GfK SE study, around 18.2 % of this total would be accounted for by home composting, which corresponds to approximately 13.6 kg/(i*a).

Following an evaluation of both studies, the food waste recycled through home composting was thus estimated at between 0.837 million t/a and 1.117 million t/a (Table 29).

The consortium decided not to derive a waste coefficient for home composting at this point because it would have required specific data on the total amount of organic waste recycled by private households themselves and also the amount of food waste within it. Please refer to the results of the ongoing research project on home composting referenced above in which reliable data is currently being collected.

Table 29: Comparison of the amounts of food waste generated in households and the proportions recycled through home composting in the two studies

	Society for Consumer Research 2020	Baseline 2015
Total amount of household food waste	4,600,000 t/a[1]	6,140,000 t/a[1]
Proportion recycled through home composting	18.2 %	18.2 % (assumption)
Food waste home composting	837,000 t/a[1]	1,117,000 t/a[1]
Population of Germany	83.16 million (as of 31/12/2020)	82.18 million (as of 31/12/2015)
Total amount of household food waste	55.3 kg/i*a	74.7 kg/i*a
Food waste home composting	10.1 kg/i*a	13.6 kg/i*a

[1] Values have been rounded.

Sources: Hübsch (2021); Schmidt et. al (2019)

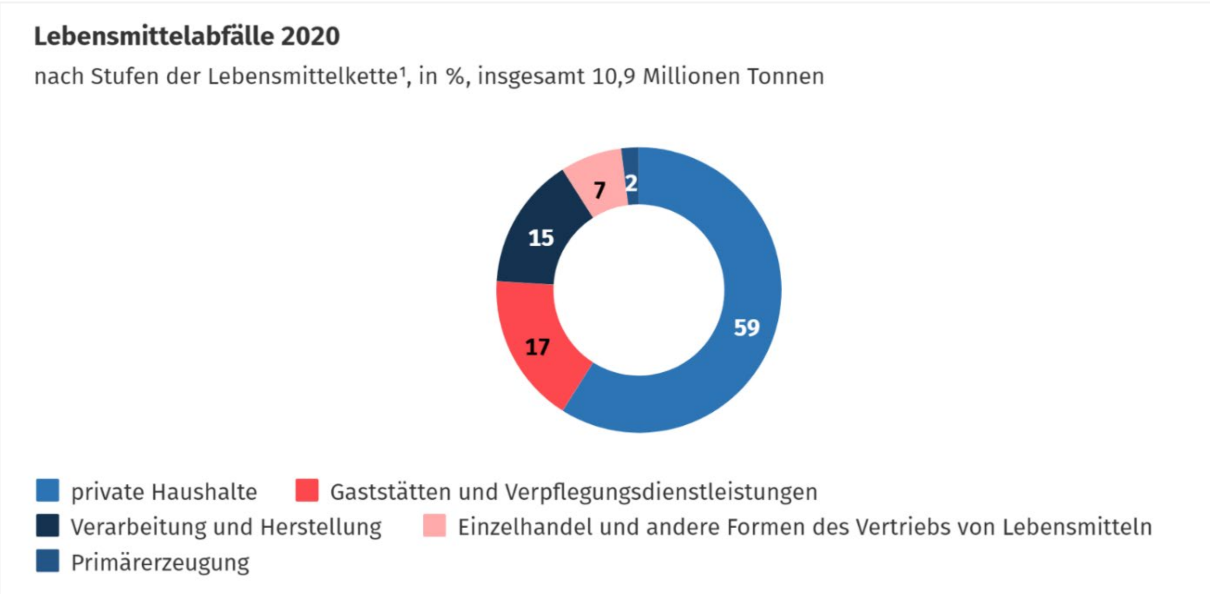
8 Results

8.1 Food waste in Germany

Figure 14 and Table 30 show the food waste in Germany in the reporting year 2020 at each stage of the food supply chain. On the one hand, these include the figures reported to Eurostat on June 30, 2022 and, on the other hand, the table contains the corrected values that were calculated on the basis of expert opinion (supplementing the t-distribution). Furthermore, the StBA corrected a programming error as part of the optimisation process that meant that individual data in stage 1 of the food supply chain were not updated. This resulted in slight deviations to the results reported to Eurostat on June 30, 2022. The StBA and the consortium presented the project results in a final specialist meeting in March 2023 and confirmed the results with the UBA, BMUV, BMEL, the research advisory group and other stakeholders.

The total amount of food waste in Germany in the reporting year 2020 was around 10.9 million t (fresh mass). Primary production accounts for 2 % of the total amount of waste (0.2 million t), while processing and manufacturing accounts for 15 % (1.6 million t). 7 % of the food waste was generated in retail and in other forms of food distribution (0.8 million t). 17 % (1.9 million t) of the waste was generated in restaurants and food services. The largest proportion of food waste was generated in private households (59 % or 6.5 million t). This means that around 78 kg of food is thrown away per capita in households each year (including home composting of food waste).

Figure 14: Food waste in Germany in the reporting year 2020



[1] According to Delegated Decision (EU) 2019/1597. Rounding deviations are possible.
Source: StBA (2023c)

Table 30: Food waste in Germany in the reporting year 2020

Stage of the food supply chain	Food waste in 1000 t (as reported to Eurostat on 30/06/2022)	Food waste in % (as reported to Eurostat on 30/06/2022)	Food waste in 1000 t[2] (quality assured)	Food waste in %[3] (quality assured)
Primary production	190[1]	2	178	2
Processing and manufacturing	1,613	15	1,594	15
Retail and other food distribution	762	7	774	7
Restaurants and food services	1,861	17	1,877	17
Households	6,496	59	6,496	59
Total	**10,922**	**100**	**10,919**	**100**

[1] As part of the optimisation process, the StBA checked the quality of the food waste calculation, especially with a view to future reporting years. During this process, the StBA resolved a programming error that meant that individual data in stage 1 of the food supply chain (primary production) were not updated. The correction in the programme led to an increase in the amount of food waste in primary production from 190,203 t to 199,953 t after application of the unrevised waste coefficient.
[2] These are corrected values that were calculated on the basis of expert opinion (supplementing the t-distribution). These deviate from the results reported to Eurostat on June 30, 2022.
[3] The corrections have no impact on the proportions of food waste in the stages of the food supply chain. Therefore, the percentage distribution remains unchanged in comparison to column two.
Source: StBA 2023a

8.2 European comparison

The average amount of food waste generated in Germany of 131 kg per inhabitant in the reporting year 2020 was at around the average level for the whole of the EU[43]. A little more than half (53 %) of the food waste in the EU (Germany: 59 %) was from households according to Eurostat. The highest average amounts of food waste per inhabitant were in Cyprus (397 kg) and Denmark (221 kg). The measured amounts of food waste were significantly lower in some countries, especially in the eastern EU states. The lowest recorded amounts of waste per head were in Croatia (71 kg) and Slovenia (68 kg). France (133 kg) and Austria (136 kg) reported similar values to Germany (Eurostat 2023, as of March 2023).

[43] Link to the EU overview tables for the food waste results for the reporting year 2020: https://ec.europa.eu/eurostat/databrowser/view/env_wasfw/default/table

9 Optimising the reporting

9.1 Potential for optimising the data set

9.1.1 Waste outside of the waste management system

Food waste monitoring for the EU reporting focusses exclusively on the waste measured in the waste management system. Therefore, the gaps identified so far in the data for the monitoring of food waste for EU reporting with respect to those waste streams outside of the waste management system will be explained below.

According to Delegated Decision (EU) 2019/1597, the European List of Waste can provide guidance for the measurement of food waste.

Agricultural material referred to in Article 2(1)(f) of Directive 2008/98/EC and animal by-products referred to in Article 2(2)(b) of Directive 2008/98/EC are excluded from the scope of that Directive and should therefore not be measured as food waste. While materials that are destined for use as feed materials referred to in Article 2(2)(e) of Directive 2008/98/EC are excluded from the scope of that Directive and should therefore not be measured as food waste, information on food originally intended for human consumption and then directed to animal feed (including former foodstuffs as defined in point 3 of Part A of the Annex to Commission Regulation (EU) No 68/2013 (6) is important for understanding material flows related to food and may be useful in planning a targeted food waste prevention policy. For this reason, member states should have the possibility to report this information uniformly on a voluntary basis.

9.1.1.1 Food waste disposed of via a drain or toilet

According to Implementing Decision (EU) 2019/2000, food waste that is disposed of as or in wastewater can be reported voluntarily. The StBA decided not to report voluntarily on this type of waste.

According to Delegated Decision (EU) 2019/1597, there is currently no method for measuring this type of waste that will guarantee a sufficient level of confidence and comparability of the collected data. If reports on the methodology used by the other EU member states are published, it would be advisable to check whether and how this food waste is determined. These reports are not yet available.

It would be possible to estimate the amounts of food waste that are disposed of via drains or toilets in private households based on the kind of data in the GfK SE study (Hübsch 2021). However, the GfK SE study would have to be carried out regularly. The GfK SE study reported an amount of food waste in Germany of 4.6 million t for the reporting year 2020, while the EU reporting for Germany estimated a total amount of food waste of 6.5 t from private households for the same year. If the GfK SE study were to be used for determining amounts of food waste, it could thus be assumed that the results would underestimate the actual amounts.

It should be noted that kitchen waste grinders are permitted in some European countries (e.g. Great Britain, Denmark, Ireland, Italy, Sweden, Norway, Spain) but prohibited in others (e.g. Austria). Many municipalities in Germany explicitly prohibit the disposal of kitchen waste, even in ground or shredded form, via drains or toilets in their drainage and wastewater regulations.

9.1.1.2 Amounts of waste that are no longer intended for human consumption but are converted by animal feed companies for sale as animal feed, and food waste used to feed privately owned pets

Food from the retail trade, unless it can be otherwise recycled, is sometimes processed into animal feed (Heinrich et al. 2022). Further information on this food was not available to the StBA and thus it did not choose to report on it voluntarily.

In order to determine the amounts of food that are no longer intended for human consumption and which are converted by animal feed companies for sale as animal feed, an additional survey of primary production (stage 1 of the food supply chain), industry (stage 2) and the retail trade (stage 3) would be necessary. It is possible that future publications of the TI report will report amounts of waste in stages 1 and 2 of the food supply chain. The current publication covers stage 3 of the food supply chain (Heinrich et al. 2022) and does not contain any data on these stages.

There is also no information available to the StBA in the official statistics on the amounts of food waste that were originally intended for human consumption but were fed by people to their own pets or animals. The StBA decided not to report voluntarily on this type of waste.

The amounts of food waste that are fed to pets or animals in private households could be estimated based on the data in the GfK SE study because this study also collects data on disposal channels. However, the GfK SE study would have to be carried out regularly. As already explained, if the GfK SE study were to be used for determining the amounts of food waste, it could thus be assumed that the results would underestimate the actual amounts.

9.1.1.3 Home composting

At the time the results for the reporting year 2020 were determined, amounts of waste used for home composting were not included in the waste management system. The EU Commission intends to introduce a reporting obligation for this type of waste for some EU countries such as Germany.

In the reporting for the reporting year 2020, it was possible to close this gap in the data for stage 5 of the food supply chain (private households) with respect to the waste used for home composting (see Chapter 7). The required data was calculated using the information on the average amount of food waste recycled through home composting of 13.6 kg per inhabitant from the “Baseline 2015” study (Schmidt et al. 2019). The methodology used in the “Baseline 2015” study is based on the extrapolation of voluntary household surveys carried out by a private market research institute and is thus not based on official statistics. It is currently unclear whether the data in the “Baseline 2015” study can still be used for the next reporting year. This depends on the legal guidelines issued by the EU Commission for future reporting years.

If it is not possible to continue using data from the “Baseline 2015” study, it would be possible to determine the amount of food waste recycled through home composting using one of the following options.

The first option would be to use data collected by the UBA. A ReFoPlan project commissioned by the UBA called “Determining a data set for calculating the influence of home composting on biowaste recycling” is currently being completed (FKZ 3721 33 302 0). It is possible that this project will also determine the proportions of food waste used for home composting (waste coefficient). This would mean that a waste coefficient for home composting could be determined and applied to the amounts of waste determined in the UBA project. This research project is, however, a one-off study and it would be necessary to update the measured figures in subsequent years. Furthermore, it is unclear when the study will be concluded and published.

The second option would be to apply the waste coefficient potentially determined in the UBA project to the amount of biowaste separated and recycled at source (home composting) that must be reported to the EU in accordance with Implementing Decision (EU) 2019/1004.

The third option would be to reuse the data from the GfK SE study. This assumes that it is carried out regularly. As already explained, if the GfK SE study were to be used for determining the amounts of food waste, it could thus be assumed that the results would underestimate the actual amounts.

9.1.1.4 Other waste outside of the waste management system

The EU food waste reporting for Germany in the reporting year 2020 only considered waste recorded as part of the waste management system. Therefore, the data may not be complete in this regard. There are full surveys of the officially approved waste disposal facilities that can be used to determine the total amount of waste that could contain food waste. As almost all waste disposal facilities require approval, it is possible to assume that these surveys are comprehensive. There are some deficits in determining data in relation to the direct recycling of "waste", i.e. if waste goes directly from the producers to the recycler and does not pass through a disposal system in the waste industry but exists somewhere in the grey zone between waste and product.

There is also other waste outside of the waste management system. For example, there was no information on the amounts of waste due to post-harvest losses and transport losses in Germany for stage 1 of the food supply chain. If this waste is disposed of within the waste management system, it will also appear in the official waste statistics. Furthermore, pre-harvest losses also occur in stage 1 of the food supply chain. However, this waste is not defined as food waste according to the EU and should not be reported as food waste in the EU reporting. It is possible that data on food waste that does not flow into the waste management system will be collected by the dialogue forums. However, the dialogue forums are designed as temporary projects and they would probably not be able to provide this data for every reporting year.

Athai et al. (2023) studied food waste and food losses via the data collected in a voluntary company survey as part of the dialogue forums "primary production" and "processing".[44] They identified the material flows "marketed flows", "alternative use within the food supply chain" and "alternative use outside of the food supply chain (food losses)" that occur alongside the commercial waste disposal system at the beginning of the food supply chain (stages 1 and 2) (Athai et al. 2023).

It is important to note that the measurements carried out in the dialogue forums on food waste, unlike those for the EU reporting, were exclusively based on data from individual participating companies. This data was not extrapolated for the entire sector. It is thus not possible to make representative statements on the corresponding sector for the EU reporting.

[44] The complete Thünen Working Paper can be found via the following link: https://www.thuenen.de/media/publikationen/thuenen-workingpaper/Thuenen_Working_Paper_209.pdf

9.1.2 Potential loss of moisture before measuring the waste

Another gap in the data is the amount of moisture that is potentially lost before the waste is measured. The data set for the food waste calculations is mainly based on the AE statistics. In Germany, the amounts recorded in these statistics are measured by weighing the waste immediately when it arrives at the waste treatment plants. Therefore, the measurements are carried out directly after the waste is collected, i.e. before any treatment such as drying. In particular, biowaste such as fruit and vegetables has a higher water content when it is fresh. The water in this waste is lost to evaporation as a result of sunlight or heat. This evaporation process can also occur before the waste is collected depending on how long the waste is stored in the household or bin and depending on the weather conditions.

The StBA believes that loss of moisture is theoretically possible before the waste is measured. However, the StBA and the consortium concluded that any specific estimate of the level of any moisture loss before measurement of the waste could not be reliably quantified. The StBA is not aware of any research or studies into this subject and it would be an extensive and time consuming process. In view of the limited time frame, the lack of reliable data and the difficulty in determining moisture loss, this issue was not taken into account when collecting the data. Further studies will be necessary to quantify any potential loss of moisture.

As it is probable that a quantified measurement of moisture loss will also not be possible in all subsequent reporting years, the data for all years will suffer from the same systematic measurement error, although the actual size of the error will deviate depending on the weather conditions. Ultimately, the most important aspect of this reporting is to measure how the amount of food waste changes over time.

9.1.3 Possibility that the same waste is measured multiple times

Discussions with the operators of waste disposal facilities has revealed that some waste that passes through several different waste treatment and disposal facilities could possibly be recorded as an input several times. Therefore, the amounts of waste recorded for each waste code could be higher than they actually are in reality. The amounts of waste per waste code for European reporting purposes is almost exclusively based on the AE statistics.

In theory, waste should be assigned to a new waste code (waste codes beginning with 19)[45] after its treatment in the waste disposal facility and thus it should not be possible for waste to be measured multiple times in certain waste codes. However, the StBA is aware that waste is not in practice always assigned a new waste code after it has been processed in the waste disposal facility.

The StBA believes that it is probable that some waste is recorded as an input multiple times. However, it is not possible to quantify the extent of this problem. In the reporting year 2020, around 28 million t of waste was recorded as an input in food waste codes and about 1.2 million t was recorded as an output. In theory, the output of 1.2 million t could subsequently appear in another facility. The StBA is not able to follow a waste stream across several processing stages. It thus remains unclear which waste code is used by the subsequent facility to report the waste. If the subsequent facility does not use a new waste code, the waste will be reported under the same waste code. As a result, the same waste can be recorded as an input multiple times. Furthermore, the delivering and receiving facility could correctly use one of the waste codes beginning with 19, which would avoid the waste being measured multiple times.

[45] Waste in the waste codes beginning with 19 was not included in the food waste monitoring for the EU reporting.

It is also possible that waste could be measured multiple times if the first disposal facility classifies it with a waste code beginning with 19 as an output and the subsequent facility classifies it using a different waste code (e.g. beginning with 02 or 20). However, the StBA believes that this is rather unlikely because the subsequent facility must register the source of the waste (e.g. meat processing).

It is thus not possible to quantify the extent to which waste is measured multiple times. In the most extreme case, it is possible that the entire 1.2 million t of output waste is also classified under food waste codes as input in the subsequent facility.

Further questions asked of the waste disposal facilities by the StBA have not yet produced any answers to explain why they would not properly reclassify their waste after it had been processed. According to the StBA, one possible cause could be that facilities sometimes only have approval for certain types of waste. Although the statistics do not contain any data to confirm this is the case, the waste disposal facility operators mostly only use the waste codes for which they have the necessary approval. The StBA believes that possible reasons for not acquiring the correct approval are the costs and effort involved in the approval process. Another possible cause of the faulty classifications could be the ignorance of the waste disposal facility with respect to the correct classification of the waste. In addition, the eight-digit waste codes are not used in all waste disposal facilities, whereby the corresponding waste is not always correctly classified. In the view of the StBA, waste that is temporarily stored (transitory items) can be excluded from the possibility of being measured multiple times.

In order to find a solution to this problem, it is first necessary to identify the actual cause. Further discussions with operators of waste disposal facilities will be necessary in this regard. As it is probable that the multiple measurement of waste will also not be quantified in all subsequent reporting years, the data for all years will suffer from the same systematic measurement error, although the size of the error could deviate depending on the reporting year. It is possible that this error will cancel out if the most important aspect of reporting is not the absolute amount of food waste but the change in the amount of food waste over time.

9.1.4 Reliability of the allocations to economic sectors

Amongst other things, the StBA uses the AEU statistics for allocating the amounts of waste per waste code to economic sectors (and thus to stages 1 to 4 of the food supply chain). The AEU statistics are exclusively collected from large companies every four years. The cut-off thresholds for the number of employees vary according to economic sector (e.g. at least 50 employees subject to social security contributions in agriculture and at least 500 employees subject to social security contributions in service companies) (StBA 2020). The reason for this is that the law states that the survey may only be sent to a maximum of 20,000 companies. Therefore, there is no survey of smaller companies (with less than 50 employees subject to social security contributions). This is a methodological compromise in order to, on the one hand, collect data on the origins of the waste and, on the other hand, keep the burden on those obligated to report to a minimum.

The latest AEU statistics (reporting year 2018) at the time of the reporting covered around 0.8 % of the companies and 31 % of the employees in Germany. The percentage of employees covered by the survey in manufacturing industries (more than 71 % on average) is considerably higher than in the services sector (18 % on average) (StBA 2020).

According to the AEU quality report, this survey was not representative for every economic sector and is thus not suitable for a reliable extrapolation process. At the same time, the AEU statistics fulfil the purpose of classifying waste at an aggregated level (the stages of the food supply chain stipulated by the EU). The AEU statistics are thus suitable for fulfilling the requirements for EU reporting.

The amounts of food waste were published exclusively in aggregated form (stage of the food supply chain) for this reason.

To collect representative data for each economic sector, the AEU survey would have to cover considerably more companies in the future. This would require a legal amendment in the form of an increase in the permitted number of recipients of the survey. This is counterbalanced by increasing annual costs for the survey and, to an equal extent, the permanent additional burden on surveyed companies. Appropriate, comprehensive compensatory measures would therefore have to be put into place, e.g. relieving companies of the burden of other reporting obligations.

9.2 Potential for optimising the waste coefficients

9.2.1 Potential for optimising the waste coefficients for household waste and biowaste

The six-digit waste code "mixed municipal waste" (20 03 01) contains the following four eight-digit waste codes: "household waste" (20 03 01 01), "commercial waste similar to household waste" (20 03 01 02), "non-differentiable mixed municipal waste" (20 03 01 00) and "biowaste" (20 03 01 04). The consortium took the weighted average for the three waste codes 20 03 01 01, 20 03 01 02 and 20 03 01 04 as the waste coefficient for the six-digit waste code 20 03 01.

Delegated Decision (EU) 2019/1597 stipulates an in-depth measurement of food waste every four years. Therefore, all of the waste coefficients – including the ones for biowaste and household waste – must be determined regularly, i.e. at least every four years. The methodology in the Nationwide Household Waste Analysis (Dornbusch et al. 2020) has been used up to now for calculating the waste coefficients for biowaste and household waste.

The consortium believes that to ensure the waste coefficients are kept up to date for the years in which in-depth measurement is necessary, the method used to determine the waste coefficients for household waste and biowaste for the initial reporting can be used for future reports. For this purpose, the compositions of waste taken from secondary studies would have to be standardised for the respective reporting year and extrapolated to the federal level using updated peripheral data (stratification characteristics and population data). The data will have to be sourced from waste balance data reported by the public waste disposal authorities, waste analyses on household waste and biowaste from the örE for the past five years and the peripheral data for the waste analyses, strata, seasonal influences and population data.

In order to consider the variables that influence the amount of waste, the design of the sorting campaigns have to take seasonal influences into account (multiple analyses in each örE at different times of the year) and strata must be selected to consider spatial/factual influences (regions in Germany, settlement and building structures, separate collection systems, fee systems, etc.). When selecting studies on waste, the consortium believes that it is important to ensure that all of the required influencing variables (strata and campaigns) are covered by the waste analyses.

This requires a balanced plan for the study that guarantees there are a sufficient number of current waste sorting analyses available, influencing variables can be adequately taken into account and both the representativeness of the study and also the requirements for the precision of the data are ensured. Additional analyses may need to be promptly initiated to this end. It will be necessary to update the waste coefficient at the latest for the reporting year 2024. Therefore, new waste sorting analyses must be commissioned in good time.

The StBA understands that the örE also sometimes commission waste sorting analyses. However, it is possible that they are carried out by various different consulting firms, which will not or are not permitted to publish the individual data. In addition, this collection of arbitrarily commissioned waste sorting analyses may not be representative. The advantage of a nationwide waste sorting analysis is that it is possible to ensure the representativeness of the data by carefully selecting the samples in accordance with the stratification characteristics stated above. The waste sorting analyses could also serve other purposes alongside the monitoring of food waste for EU reporting purposes, e.g. reporting on packaging and observing the waste separation behaviour of the population.

If the waste sorting analyses are to be used outside of a uniform nationwide concept, the consortium believes that the rules regarding access to the data would need to be examined as well as the quality of the waste analyses included in the study. Waste sorting analyses are carried out in Germany in accordance with the waste sorting guidelines, which are not uniformly defined at a federal level. Furthermore, these waste sorting analyses may have different objectives with respect to material groups and fractions and to stratification that would need to be unified before they could be jointly evaluated.

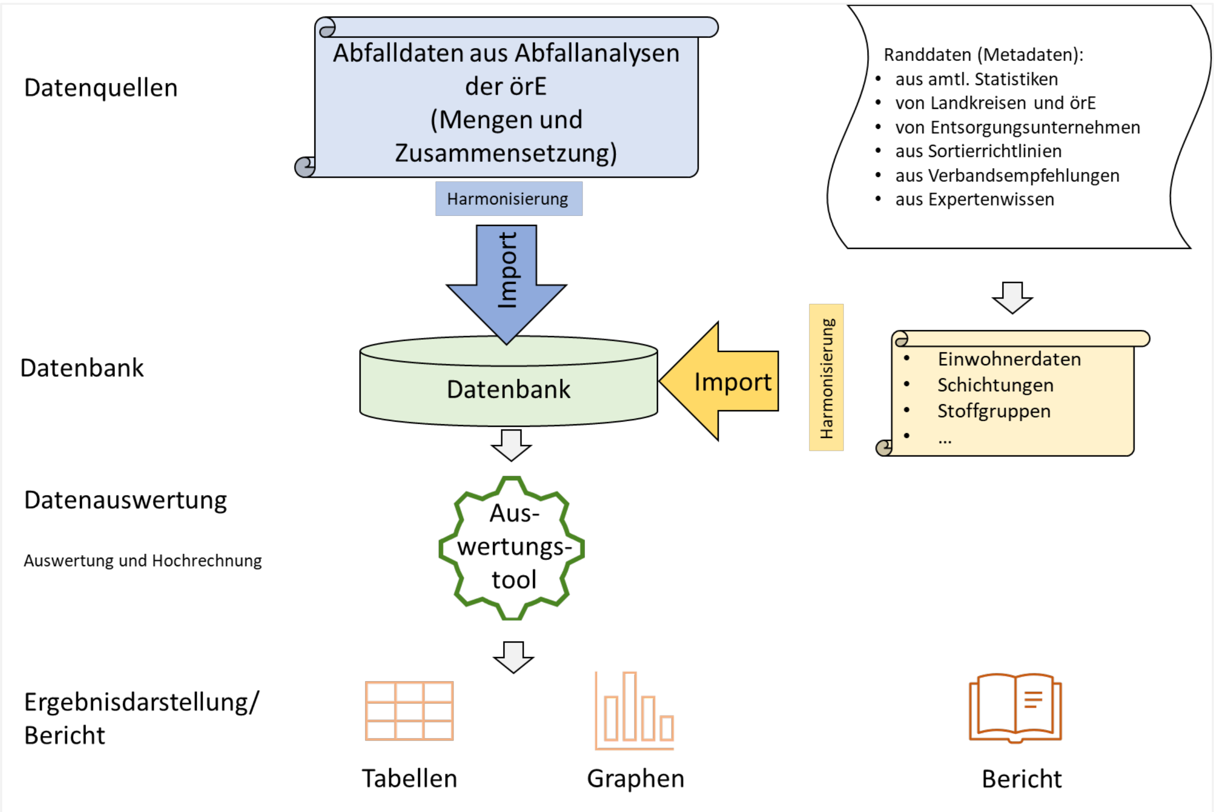
In the view of the consortium, the representative waste sorting analyses at the örE level would have to be unified with respect to material group, fraction and stratification, and the results then imported into the waste database established for this research project. In parallel, the peripheral data for the reporting year, which is necessary for the evaluation and extrapolation process, would have to be researched, evaluated and finally also imported into the database.

The evaluation and extrapolation process would then be carried out using an evaluation tool that accesses the quality assured weekly amounts of waste per inhabitant in each of the strata in the database. Based on the plan for the analyses, the data from the database would have to be prepared using the evaluation and extrapolation tool in such a way that tables of results and diagrams could be generated in one final step. The tables and diagrams produced in this manner could then be used directly in the reporting format.

In essence, this method comprises plans for the representative sampling process, which include quality assured and consistent waste sorting analyses at an örE level, a central data repository in the form of a waste database, an evaluation and extrapolation tool for making multi-stage, stratified relational estimates and, ultimately, the production of tables of results and diagrams for the reporting.

Figure 15 shows a schematic diagram of the calculation for the waste coefficients based on the methodology proposed for future reporting by the consortium.

Figure 15: Schematic diagram of the calculation for the waste coefficients for household waste and biowaste for future reporting



Source: Kern et al. (2022)

Another challenge when determining a waste coefficient for the six-digit waste code 20 03 01 was that there were no or no current waste sorting analyses for the eight-digit waste codes 20 03 01 02 and 20 03 01 00. The following section will therefore explain how these two waste codes were taken into account by the consortium and where there is potential to optimise the data.

9.2.2 Potential for optimising the waste coefficient for 20 03 01 00 – non-differentiable mixed municipal waste

The six-digit waste code "mixed municipal waste" (20 03 01) covers, amongst other things, the eight-digit waste code "non-differentiable mixed municipal waste" (20 03 01 00). It was not possible to define a waste coefficient for this waste code alone. Therefore, the weighted waste coefficient for waste code 20 03 01 was used for this waste code. The waste coefficient for the six-digit waste code 20 03 01 was defined as the weighted average of the waste coefficients for codes 20 03 01 01, 20 03 01 02 and 20 03 01 04.

As there was no information available at the time of the study about which materials were contained in "non-differentiable mixed municipal waste", it is not currently possible to make any specific recommendation for determining a waste coefficient for this waste code. It is unclear whether the benefits of a waste sorting analysis will justify the costs involved.

In order to define a reliable and up-to-date waste coefficient for this waste code, it will be necessary to either carry out new waste sorting analyses or to use a different methodology for the survey (see Chapter 9.2.4).

9.2.3 Potential for optimising the waste coefficient for 20 03 01 02 - commercial waste similar to household waste that is delivered or collected separately from household waste

The six-digit waste code "mixed municipal waste" (20 03 01) covers, amongst other things, the eight-digit waste code "commercial waste similar to household waste that is delivered or collected separately from household waste" (20 03 01 02). The waste coefficient for this code was determined by the consortium based on waste sorting analyses.

According to the consortium, the data set on the composition of commercial waste similar to household waste that is delivered or collected separately from household waste is very incomplete. Any detailed analyses were carried out a long time ago and reflect the waste composition during a time period that was subject to different waste management conditions. Due to the lack of current data, the consortium decided to use the RLP commercial waste register from 1993 (completed by WI; state-wide study into commercial waste in Rhineland-Palatinate). Data on the proportions of food waste were collected in the study. A transformative process that takes into account developments in waste management since then is needed in order to be able to use this study to make estimations on the current proportions of food waste in commercial waste similar to household waste. More specifically, the proportion of food waste in the organic fraction was calculated from the RLP commercial waste register from 1993, while the proportion of the total amount of waste accounted for by the organic fraction in this waste code was taken from a newer source (Dehne 2011). Due to the reform of the Commercial Waste Ordinance that came into force on August 1, 2017, the actuality of the organic proportion of waste taken from the 2011 source is unclear.

In the view of the consortium, it was thus inevitable that there would be a high margin of error when evaluating the results, although this is mitigated by the fact that the total amount of food waste in commercial waste similar to household waste only accounts for a small proportion of the total amount of food waste. The estimation was made by the consortium and audited to make sure it was plausible.

As it has not yet been clarified what materials this waste code actually contains, the consortium does not currently believe that it is possible to make a specific recommendation on how to derive the waste coefficient. Therefore, it is unclear whether the benefits of a waste sorting analysis will justify the costs involved.

In order to define a reliable and up-to-date waste coefficient for this waste code, it is the opinion of the consortium that it will be necessary to either carry out new waste sorting analyses or to use a different methodology for the survey (see Chapter 9.2.4).

9.2.4 Potential for optimising the waste coefficients for the other waste codes

As described in Chapter 6.2.8, the consortium believes that the voluntary online survey from USTUTT delivers an indicative estimate for the other waste codes (all waste codes except 20 03 01) but that it is neither representative nor statistically reliable. Depending on the waste code, the consortium finds that between 80 and 200 samples are required to achieve a level of precision of ± 10 %. In addition, these samples must be randomly selected. The online survey from USTUTT was sent to all of the waste disposal authorities for which the consortium had contact details. The responses provided on a voluntary basis were considered as random samples.

In order to create a more stable data set and draw conclusions on its volatility, the consortium recommends that future studies should also include physical measurements (waste sorting analyses or waste screening campaigns). This would be carried out ideally at the source of the waste, i.e. the producer of the waste, or at the waste disposal facility, i.e. the recycler. Waste sorting analyses are usually associated with a relatively high amount of investment in terms of finance and human resources. By surveying relevant players, the scope is very large and the financial cost relatively small. According to the consortium, it is conceivable that waste sorting analyses only need to be carried out on certain waste codes and sectors as long as the expected gain in knowledge will lead to a significant improvement in the data.

In general, the consortium recommends carrying out further surveys, research and analyses for future reporting for defining waste coefficients for the other waste codes. In the process, it will be particularly important to improve the data by carrying out physical surveys and using a larger sample size. A framework concept first has to be developed and defined so that it will be possible to make valid statements regarding the sample size for waste sorting analyses in stages 1 to 4 of the food supply chain. Overall, it is especially important to take a systematic approach to planning the sampling process and the analysis methods.

9.3 General recommendations for the reporting

According to the consortium, monitoring and reporting food waste should enable us to make the best possible statements on the development of the amounts of waste over time. Developing and updating a comprehensive data set is therefore key to long-term reporting. Complete and transparent monitoring will thus only be possible in cooperation with all relevant players. Against this background, the consortium recommends that not only should the food waste at a waste code level that is part of the obligatory reporting be measured and reported but also other material streams and food streams that will support the documentation of trends in food waste over time. European member states can voluntarily report on these kinds of food waste to the EU and thus document progress in a transparent way. Therefore, the consortium recommends using all available data sources for future reporting, while giving preference to more thoroughly validated data in each case. Physical data, such as waste statistics, supplemented by physical information on the composition of waste, represents the most reliable data set in this context. To produce the most complete reporting in this regard, the consortium believes that the obligatory information on the amounts of food waste should be supplemented in the reporting with voluntary information.

In the opinion of the consortium, the reporting of food waste from households provides a good example. Physical data on household waste is available in the national, official waste statistics and is regularly updated. This data should continue to be used for future reporting. However, it does not cover all waste streams, such as food waste that is used for home composting. This supplementary information could be sourced from the GfK SE study and used to make a plausible estimate of the total physical material streams for food waste (Hübsch 2021). However, the GfK SE study would have to be carried out regularly.

According to the consortium, the recommended methodology for the future monitoring of food waste for EU reporting is thus based on the following data sources:

- Reporting on the basis of national, official statistics relating to the waste codes stated in Delegated Decision (EU) 2019/1597.
- Determining the waste coefficients by:
  - Evaluating physical measurements (e.g. waste sorting analyses) for estimating the amounts of food waste in the official waste statistics.
  - Potentially carrying out supplementary, voluntary, non-official surveys of the waste disposal industry.
  - Potentially carrying out supplementary, voluntary, non-official surveys of companies (waste producers).
- Evaluating studies (e.g. the GfK SE study) for estimating food waste in other disposal channels (i.e. home composting).

10 Recommendations for reducing food waste

The EU is committed to meeting the UN goal of halving per capita food waste at the retail and consumer level by 2030 and reducing food losses along the food production and supply chains (United Nations 2015). In response to the setting of these policy goals and the need to find solutions, multiple studies have been published over the last few years that investigate the amounts of food waste and measures or action to reduce it.

It is important to emphasise that it was not possible to derive measures to reduce food waste directly from the data presented in this report – the first report to the EU on food waste in Germany for the reporting year 2020. The methodology described in Chapters 1 to 7 that uses the disposal of waste to measure the total amounts of waste in Germany overall, as well as for each stage of the food supply chain, in accordance with EU requirements. It is not possible to use such data as a basis to derive and monitor measures or action to reduce food waste at each stage of the food supply chain.

In contrast to the EU reporting, the measurements carried out as part of the dialogue forums do not provide information on an entire stage of the food supply chain. Instead, they focus on the food waste generated by individual companies who are voluntarily participating in the forums. Depending on the dialogue forum in question, the information can be used to make specific statements about e.g. the effectiveness of individual measures to reduce food waste and the different waste streams that exist alongside officially approved waste disposal systems. The data generated in the dialogue forums can thus be used e.g. as the basis for the establishment of effective reduction measures and the best possible utilisation of excess food (BMEL, BMUV, UBA 2023).

The following sections provide a summary of solutions and measures to reduce food waste found in national and international literature. This summary is not based on the results of the data collection process for this first EU report for the reporting year 2020. The following chapter was exclusively compiled by the consortium. In it, the consortium has formulated recommendations for action for every stage of the food supply chain based on the current state of scientific knowledge and research and highlighted, where relevant, any future need for action and research with respect to the reduction of food waste.

10.1 Literature research

10.1.1 Best practice UK: Successful reduction in food waste along the entire value added chain

Verma et al. (2020) found that a lot more food is discarded globally than generally thought because the amount of food waste stated in some of the most widely cited scientific publications is grossly underestimated. Flanagan et al. (2019) also emphasised that more governments and companies urgently need to define reduction targets in line with sustainable development goals in order to measure food waste and above all take bold action to reduce it. The initiatives to reduce food waste in Great Britain could be used as a role model at the policy level. Great Britain had managed to reduce the amount of food waste from households by around 1.44 million t by 2018 in comparison to 2007. Accordingly, food waste from households fell from 132 kg/(i*a) to around 100 kg/(i*a) (Parry et al. 2020). The starting point for this positive development was the foundation of the "Waste and Resources Action Programme" (WRAP) in 2000 to support the development of a sustainable waste management system and increase recycling in the United Kingdom. WRAP launched the campaign "Love Food Hate Waste" in 2007 as a continuation of the recycling initiatives and to raise awareness for the issue of food waste. The aim was to empower consumers to reduce their food waste by providing them with awareness-raising information (Falcon et al. 2008). The campaign was one of the first of its kind worldwide and not only raised the awareness of the general public but also of other actors in industry, politics and science. In the years following this campaign, Great Britain and some other countries launched numerous initiatives to reduce food waste at all stages of the food supply chain. The Courtauld Commitments are a series of voluntary agreements and have proven to be an effective instrument for bringing about change and making improvements with respect to food waste. The first Courtauld Commitment was launched in 2005 for a period of four years with the aim of developing solutions and technologies to help reduce food waste and packaging waste (WRAP 2020a; 2020b). With support from the "Love Food Hate Waste" campaign, local authorities and charitable organisations in Great Britain were able to reduce food waste by around 670,000 t and packaging waste by 520,000 t during this period. The targets for 2025 are a further reduction in food and drink waste of 20 % and a reduction in greenhouse gas emissions associated with the production and consumption of food and drinks by 20 % (WRAP 2020a; 2020b). No other country can demonstrate such a positive trend in the reduction of food waste. Nevertheless, WRAP believes that more action must be taken to ensure that the majority of people and organisations are committed to making the necessary changes to achieve the policy goals. In contrast to the United Kingdom, Germany has not yet achieved any statistically relevant reduction in food waste. In 2012, household food waste in Germany stood at around 82 kg (i*a) and remained at almost the same level until 2019 (Leverenz 2021). It is important to note, however, that British households still throw away considerably more food than German consumers, despite the fact that they have reduced the amount of waste by about 24 % since 2007. In light of this fact, the question arises as to whether awareness-raising campaigns and initiatives in Germany would have the same positive impact as in Great Britain. It could prove more difficult to reduce food waste in German households than in Great Britain because the amounts of waste are already at a comparatively low level. Therefore, the impact consumer-related measures would have in Germany still needs to be investigated and evaluated, especially with respect to the realisation of the policy goals.

10.1.2 Prioritising action based on its effectiveness

According to the model developed by Campoy-Muñoz et al. (2017), avoidable food waste causes considerable economic losses in Germany of around 30 billion euros per year. In order to improve the economic and environmental efficiency of measures to reduce food waste, the relevant literature recommends prioritising waste prevention strategies (Goossens et al. 2019). Investment in the form of both time and money is required to achieve economic and environmental benefits through the reduction of food waste. It is thus especially important for companies that the benefits of the measures to reduce food waste exceed the associated cost (Parry et al. 2020). Huppes & Ishikawa (2005) presented an analytical approach that uses the principle of economic efficiency as a tool to evaluate sustainability and demonstrates that there is an empirical relationship between the environmental cost and environmental impact of economic activities. Companies can obtain appropriate information in this regard using a combination of life cycle analyses and life cycle cost assessments (Gabriel & Braune 2005). This method is also used in environmental research at a macroeconomic level to assess the economic impact of food waste for whole countries. Another approach is to prioritise the reduction strategies based on the concept of optimising sustainable measures. This model was presented by Cristóbal et al. (2018) and used the Pareto optimisation principle to determine waste prevention measures with the highest environmental impact. An important component of their model is the Pareto principle that combines different scenarios involving waste reduction measures to maximise the environmental benefits for an individual budget. Cristóbal et al.

(2018) came to the conclusion that decision-makers should prioritise strategies and reduction targets that primarily focus on environmental impact rather than on reducing the mass of the food waste. In addition, Cristóbal et al. (2018) formulated several general recommendations. The authors believe that the selected measures should always be prioritised because they will deliver quick wins and avoid a high environmental impact at a low cost (e.g. consumer education campaigns, waste tracking, digital measurement systems, standardised data labelling, smaller plates, trayless dining, improved inventory and cold chain management, manufacturing line optimisation, standardised donation regulations and animal feed). Parry et al. (2020) highlighted another important aspect and found that the size of the company plays an important role in the development of strategies. For example, larger food companies can undoubtedly have a considerable influence but smaller companies need other kinds of support, which must be made accessible to them in a suitable way. Smaller companies could, for example, document their food waste using self-reporting methods but are often restricted by the lack of specialists who can carry out the measurements and waste analyses. Papargyropoulou et al. (2016) presented a different and very practice-oriented concept of economic efficiency that emphasises the relationship between the economic value of the food waste and the amount of waste. The authors developed efficiency indicators by comparing the price of selected food products to how much they contributed to food waste. The method proposed by Papargyropoulou et al. (2016) could help companies to evaluate their food management processes and prioritise strategies for reducing food waste.

10.1.3 Recommendations for action from the Joint Research Centre of the European Commission

The EU Platform on Food Losses and Food Waste that was established in 2016 aims to support all actors in defining measures for preventing food waste, sharing best practices and evaluating the progress made over time. The Joint Research Centre (JRC) of the European Commission has published recommendations for evaluating action for preventing food waste and for assessing the effectiveness and efficiency of such action (Caldeira et al. 2019). The recommendations are based on a comprehensive analysis and evaluation of existing action in Europe. The most important recommendations from the JRC will be briefly summarised in this chapter. The recommendations are mainly determined from the results of a survey of the members of the EU Platform on Food Losses and Food Waste. The JCR analyses data sets on a total of 91 actions submitted by different actors (NGOs, local authorities, companies, etc.) and eight additional actions collected through a review of relevant literature. The actions were subdivided into the following groups:

- **Redistribution** of food for human consumption: Actions aimed at redistributing surplus food fit for human consumption (see Table 31),
- **Consumer behaviour change**: Actions promoting a behavioural shift amongst consumers to achieve a reduction in food waste generation (see Table 32) and
- **Improvement of efficiency in the supply chain**: Actions leading to an increase in efficiency in the food supply chain, by acting either on the processes, the products or the packaging to promote food waste reduction (see Table 33).

According to the JRC, the objective of a preventative action should be defined by following the so-called “SMART” principle (**S**pecific, **M**easurable, **A**chievable, **R**elevant, **T**ime-bound) and whenever possible, it should focus on the action’s impact on food waste generation (i.e. it should make it possible to measure tangible change that has occurred following the intervention, such as achieving a reduction in food waste generated in households). The JRC explicitly recommends the use of performance indicators (key performance indicators – **KPI**s) to evaluate the preventative action. The following tables contain a list of proposed KPIs to measure the effectiveness and efficiency of actions to prevent food waste based on the type of action (see Table 31, Table 32 and Table 33).

Table 31: Suggestions for KPIs to measure effectiveness and efficiency of actions of the type "food redistribution" – from the Report of the Joint Research Centre of the European Commission 2019

Criteria	Dimension	Suggested KPIs	Monitoring approach
Effectiveness		Amount of food redistributed/reused Number of food insecure individuals reached	1. Set an objective (examples) • Increase by 20 % amount of surplus food redistributed by 2025 against the baseline of 2020 • Increase by 20 % the number of food insecure individuals reached by 2025 against the baseline of 2020 • Increase by 20 % the number of donors by 2025 against the baseline of 2020 • Increase by 20 % the amount of surplus vegetables redistributed by 2025 against the baseline of 2020 2. Monitor the KPIs through time to track progress towards the objective
Efficiency	Food waste	Total amount of food waste prevented / cost of the action	1. Calculate total food waste prevented by the action 2. Estimate related economic benefits and environmental savings 3. Measure the KPIs related to the social and outreach activities 4. Divide the different KPIs defined for each dimension by the cost of the action
	Economic	Net economic benefits / cost of the action	
	Environmental	Net environmental benefits / cost of the action	
	Social	Net environmental savings / cost of the action Number of food insecure individuals reached / cost of the action Number of jobs created / cost of the action Nutritional value of the food donated / cost of the action	
	Outreach	Number of donors / cost of the action Coverage in national media / cost of the action	

Source: Caldeira et al. 2019

Table 32: Suggestions for KPIs to measure effectiveness and efficiency of actions of the type "consumer behaviour change" – from the Report of the Joint Research Centre of the European Commission 2019

Group of actions	Criteria	Dimension	Suggested KPIs	Monitoring approach
A Actions measuring FW reduction obtained	Effectiveness		Households: per capita food waste generated in one year (a) Food services: food waste generated per number of meals served (b)	1. Set an objective e.g. 20 % reduction in food waste per meal/per capita in one year, by 2025 compared with the reference year (e.g. 2020). For this type of action, impact objectives can be defined. 2. Monitor the KPIs through time to track progress towards the objective
	Efficiency	Food waste	Total amount of food waste prevented / cost of the action	1. Calculate total food waste prevented by the action 2. Estimate related economic benefits and environmental savings 3. Divide the different KPIs defined for each dimension by the cost of the action
		Economic	Net economic benefits / cost of the action	
		Environmental	Net environmental benefits / cost of the action	
B Actions measuring increase in awareness/behavioural change obtained	Effectiveness		% of people aware of the campaign % of people reporting a change in behaviour due to the action	1. Set an objective e.g. 50 % of people interviewed should be aware of the campaign by 2025. For this type of action, only outcome objectives can be defined. 2. Monitor the KPIs through time to track progress towards the objective
	Efficiency	Outreach Awareness Behaviour change	Total number of people reached by the campaign / cost of the action Total number of people aware of the campaign / cost of the action Total number of people changing behaviour / cost of the action	1. Calculate the total number of people aware of the campaign/changing behaviour since the start (based on the results of the survey and the total population exposed to the campaign). 2. Monitor the KPIs through time to track progress towards the objective

Source: Caldeira et al. 2019

Table 33: Suggestions for KPIs to measure effectiveness and efficiency of actions of the type "supply chain efficiency" – from the Report of the Joint Research Centre of the European Commission 2019

Group of actions	Criteria	Dimension	Suggested KPIs	Monitoring approach
A Technical measures – Process optimisation, innovation, etc.	Effectiveness		Primary production/manufacturing: food waste generated per kg produced (a) Retail: food waste generated per kg sold (b) Food services: food waste generated per meal served (c)	1. Set an objective e.g. 20 % food waste reduction per meal by 2025 compared with 2020. For this type of action, impact objectives can be defined. 2. Monitor the KPIs through time to track progress towards the objective
	Efficiency	Food waste	Total amount of food waste prevented / cost of the action	1. Calculate total food waste prevented by the action 2. Estimate related economic benefits and environmental savings 3. Divide the different KPIs defined for each dimension by the cost of the action
		Economic	Net economic benefits / cost of the action	
		Environmental	Net environmental benefits / cost of the action	
B Informative measures – Advice, training, etc.	Effectiveness		Number of businesses entering the programme Number of businesses tracking FW Number of businesses reporting a FW reduction	1. Set an objective e.g. engage 800 restaurants by 2025. For this type of action, only outcome objectives can be defined. 2. Monitor the KPIs through time to track progress towards the objective
	Efficiency	Outreach	Total number of businesses entering the programme / cost of the action Total number of businesses tracking FW / cost of the action Total number of businesses reporting a FW reduction / cost of the action	1. Calculate the total number of businesses entering the programme / tracking FW / reporting FW since the start. 2. Monitor the KPIs through time to track progress towards the objective

Source: Caldeira et al. 2019

10.1.4 Food waste at the consumer level: Factors and the intention-behaviour gap

To find solutions to reduce food waste, it is necessary to identify and understand possible tools and any associated factors. Food waste at the consumer level is generated in the handling, storage and preparation of food or as leftover food on the plate or buffet. Accordingly, Hübsch & Adlwarth (2017) recommend raising more awareness amongst consumers for the correct ways to handle, store and prepare food. Visschers et al. (2016) demonstrated that various factors appear to be relevant for food waste in households. The most important factors seem to be more associated with personal attitudes rather than with subjective standards[46], e.g. not throwing food away for ethical reasons (Visschers et al. 2016). There also appears to be some conflict between consumer attitudes to throwing away food and the health risks of eating leftover food (Evans 2011). Accordingly, a person's motivation to avoid wasting food does not necessary translate into appropriate behaviour, which is known in specialist literature as the intention-behaviour gap (Sheeran & Webb 2016). Consumer surveys have demonstrated that respondents tend to follow social norms, i.e. not wasting food (Stancu et al., 2016; Stefan et al. 2013). Self-assessment methods can also bias respondents towards significantly underestimating their actual amount of food waste (Abeliotis et al. 2014; Delley & Brunner 2018). Therefore, awareness campaigns such as the initiative "too good for the bin" must overcome a person's bias and any discrepancies between intention and behaviour before they will lead to a change in behaviour amongst consumers. According to Moussaoui & Desrichard (2016), other difficulties lie in the huge gap between small individual actions and highly ambitious goals such as "halving global food waste". However, certain social influence approaches have been able to effectively encourage behavioural change through communication channels such as social networks or public commitments. The same applies to face-to-face interventions, although they do require higher investment in terms of finance and human resources (Abrahamse and Steg, 2013).

10.1.5 Initiatives to reduce food waste in households

Studies have found that awareness-raising information distributed in the form of brochures does not have any direct influence on the disposal behaviour of consumers (Shaw et al. 2018; Smith et al. 2014). Awareness-raising campaigns often fail to take the specific characteristics of the target group into account when designing the information material or action (Schmidt 2016). This can lead to the recipient feeling overawed or becoming less motivated to absorb the information, especially if most of it is not relevant to them. Therefore, Schmidt (2016) recommended that these initiatives should personalise their information, e.g. by distributing the information via channels such as social media or electronic newsletters targeted at particular groups (Young et al. 2017). To do this, it is important to gain a better understanding of a person's self-perception, which can be achieved, for example, using representative consumer surveys. This method was recently used in Germany by the institute forsa (Gesellschaft für Sozialforschung und statistische Analysen mbH). forsa surveyed 1,230 randomly selected people who were more than 14 years old. In this consumer survey, 7 % of the respondents indicated that they throw food away multiple times per week. Every fifth respondent threw food away once a week (19 %), several times per month (19 %) or once a month (18 %). Younger respondents threw food away significantly more frequently than older respondents. Nine out of ten people (91 %) stated that they had recently received information on this subject via the media. Of those respondents who had recently heard something about food waste in Germany via the media, 18 % indicated that they now throw away significantly less food since they had learnt about this subject (forsa 2019). However, this personal perception of throwing away less

[46] Subjective standards in this context are associated with a perceived social pressure to behave in a certain way (Ajzen 1985).

food does seem to suffer from bias because the studies on food waste in Germany demonstrate that the amount of household food waste has not decreased since 2012 (Schmidt et al. 2019).

In contrast, a dissertation written at USTUTT gave a positive assessment of the impact of action and interventions at a consumer level, i.e. in households, restaurants and food services. The results demonstrated that the policy goals for avoiding food waste could be achieved and even exceeded at a consumer level. The observed changes in behaviour in the pilot households not only resulted in better planning and preparation of meals but also led to improved shopping habits and food storage practices. In hotels, it was simple and small changes to daily processes in the kitchen, such as only refilling the buffet when needed and using smaller serving dishes for the presentation of the food, that proved the most successful (Leverenz 2021).

10.1.6 Action to reduce food waste in restaurants and food services

In a review of existing literature on food waste at the consumer level, Reynolds et al. (2019) examined the effectiveness of strategies to reduce food waste. Most of the interventions found in the literature were case studies and their results were often not representative due to limitations in the design of the study or the individual nature of the applied interventions. The case studies that proved to be most effective and other results from more recent literature will be briefly presented below (Reynolds et al. 2019). Kallbekken and Sælen (2013) used “nudges” at 52 restaurants in a Norwegian hotel chain between June and August 2012 to reduce the waste left on plates. The participating hotel restaurants reduced the amount of food waste by around 20 % by using smaller plates and providing information on their goal of reducing food waste on the buffets. In another intervention, the guests (around 540 participants) at a university canteen were given handwritten notes with information promoting awareness about food waste in the summer semester 2011 (a six-week study). The guests were encouraged not to overfill their plates, which led to a reduction in leftovers of around 15 % by mass (Whitehair et al. 2013). Wansink & van Ittersum (2013) observed the behaviour of guests in four Chinese restaurants in New York and Pennsylvania with all-you-can-eat buffets and noticed that the larger the plate or serving plate, the more people tended to overfill them. Guests with larger plates served themselves 52 % more food than guests who selected smaller plates, ate 45 % more food and wasted 135 % more food (Wansink & van Ittersum 2013). Several field studies in the USA have also shown that people waste more food when they are served on disposable plates rather than porcelain plates (Williamson et al. 2016). In 2010, Thiagarajah & Getty (2013) compared the amount of food waste in a university dining hall before and after the introduction of a trayless serving system over a sampling period of five consecutive weekdays for each test. The result was a reduction in solid food waste of 18.4 % and liquid food waste of 6.8 %. Schwartz et al. (2015) investigated food consumption and food waste in 12 middle schools in an urban, low-income school district in the USA between 2012 and 2014. After introducing improved nutritional policies in the 2012/2013 school year, they found less waste overall on the plates, which indicated that strategies to reduce waste could benefit from healthier nutrition. A German field study on food waste in 11 school canteens was carried out in 2016 by taking random samples over a period of ten days. The results were used to improve food management and menu planning in the schools, which led to reductions in food waste of between 14 % and 48 %. These reductions covered a relatively wide range and can be explained by varying potential for waste reduction and statistical uncertainties related to the design of the study (Waskow et al. 2019). Clowes et al. (2018) analysed data from 42 hotels in 15 countries that had documented amounts of food waste over a period of three years. They found that the hotels had been able to reduce the amount of food waste by around 21 % over a period of twelve months. In addition, Clowes et al. (2019) published a report on 114 restaurants from 12 countries that had managed to reduce food waste by around 26 % after the first year and by around 56 % by the end of the third year.

The most important strategies for reducing food waste in both the hotels and restaurants included action such as training the staff, redesigning the buffet, minimising overproduction, rethinking inventory and purchasing practices and donating surplus food (Clowes et al. 2018; Clowes et al. 2019). Furthermore, Eriksson et al. (2017) recommend that every kitchen should carry out their own measurements to identify specific potential for reducing food waste and develop appropriate action. Heikkilä et al. (2016) have also shown that it is crucially important to try to reduce all aspects of food waste, which means that any action to reduce food waste should also be integrated into corporate philosophy.

10.1.7 Self-reporting: Measurement as a tool to reduce food waste at a consumer level

Self-reporting is often linked to the everyday use of measuring devices in the kitchen, as long as the amounts can be easily weighed and documented by consumers themselves. In general, self-reporting processes help to raise awareness and lead to consumers taking corrective action and changing their behaviour (Zimmerman 2002). Empirical studies in households have already confirmed that significant reductions in food waste can be achieved using self-reporting measures (Comber & Thieme 2013; Leverenz et al. 2019; Thieme et al. 2012). The results presented by Leverenz et al. (2019) have demonstrated, for example, that self-documentation of food waste can raise awareness for the problem and change the behaviour of those participating in the studies. It was possible to reduce the avoidable food waste in the pilot households by around 57 %, which correlates to a monetary saving of about 37 euros per person per year. In addition, the participants changed their shopping habits and reduced their food expenditure by around 341 euros per inhabitant per year on average. The pilot households thus achieved the SDG 12.3 goal, i.e. halving their food waste within a few weeks (Leverenz et al. 2019). In a comparable study, Young et al. (2017) also observed a significant change in food waste in households. Other studies (Shaw et al. 2018; Smith et al. 2014) have shown that external interventions, such as awareness-raising information, do not lead to a reduction in food waste if they are not combined with the self-documentation of food waste. Furthermore, studies have found that measuring food waste is important for evaluating the effectiveness of the action (Heikkilä et al. 2016; Silvennoinen et al. 2015). Therefore, Eriksson et al. (2017) recommended quantifying food waste in every kitchen in detail. Food waste is generated for many different and individual reasons, which means individual action is needed to reduce it. Waste analytics provide an opportunity to gather detailed information as they use the process of weighing discarded food directly at the source of origin (Waskow et al. 2016). The collected data can be used for the further optimization of food management and facilitate the related planning and preparation processes. In the study carried out by Leverenz et al. (2021), self-reporting helped the pilot kitchens reduce their breakfast buffet leftovers by 64 % on average, which resulted in financial savings of more than 9,000 euros per kitchen per year. These findings are consistent with non-scientific case studies and success stories. For instance, Clowes et al. (2018) presented data from 86 catering operations that reduced their amounts of food waste by 44 % on average and their monetary costs by 56 % during a period of three years. The study thus showed that self-reporting led to changes in the work processes at these companies. Systems to track food waste deliver information in real time, which makes it possible to implement measures within a short period of time. If these positive effects were to be transferred to other kitchens, there could be significant savings in food waste made in the hospitality industry (Eriksson et al. 2017).

Technical support for the measurement of food waste exists in the form of different types of digital scales and food waste tracking systems. Based on the positive effects of self-reporting, it is clear that food waste tracking systems deliver relevant information that could result in significant reduction in food waste and monetary savings. Eriksson et al. (2019) found that catering businesses that use digital tracking systems instead of semi-automated or manual tools record more data and achieve somewhat higher reductions in food waste. Systematic monitoring and reporting are thus essential to evaluate measures and interventions. It is reasonable to assume that the use of digital measuring devices can raise the awareness of kitchen staff because they provide the user with immediate information that triggers specific changes in their behaviour. The literature on this subject provides us with a significant amount of knowledge about food waste and demonstrates the benefits of self-reporting interventions. Furthermore, case studies have shown that there is huge potential for reducing food waste in the hospitality sector and confirmed the feasibility of reducing food waste in general. The following section will focus on digital measuring devices themselves.

10.1.8 Digital measuring devices (food waste tracking systems)

Automated systems to measure food waste can help kitchens in the hospitality sector quantify their food waste and are offered by American companies such as Leanpath or European companies such as Winnow Solutions, Kitro, eSmiley, Matomatic and Visma. The basic functionality of these tracking tools is similar and they differ mainly with respect to their consultancy services such as employee training or the customised development of measures. They also offer different optional functions such as visual photo capture and artificial intelligence technology for the automatic identification of the food waste.

Table 34 provides an overview of some of the measuring devices that can be used to record food waste in kitchens in the hospitality sector. Tracking systems such as RESOURCEMANAGER FOOD from USTUTT or the “Küchenmonitor” (kitchen monitor) from the Consumer Advice Centre NRW are free of charge and primarily used to collect data for scientific purposes as part of research and development activities. The commercial systems for tracking food waste have very similar functions and operating modes, although some of them have optional or enhanced features, such as visual photo capture and artificial intelligence technology (see Table 34).

Food management systems such as “Delicious Data” and “Mitakus” also provide forecasting models to better plan and calculate food demand. These software programmes produce sales forecasts based on historical data to support menu and meal planning. Alongside the use of tracking systems and forecasting tools, kitchens in the hospitality sector can also sell their unsold food to environmentally conscious consumers at a discount by using smartphone apps such as “ResQ” or “Too Good To Go” (ResQ Club 2019; Too Good To Go 2019). Another alternative is to cooperate with charitable organisations such as those who distribute food to the needy (FEBA, 2019; Foodsharing, 2019).

Table 34: Food waste tracking systems in restaurants and food services: Advantages and disadvantages of different applications.

Tracking systems	Applications	Advantages	Disadvantages
Delicious Data (forecasting software)	Food services (Germany)	+ Sales forecasting + Improved menu planning + Artificial intelligence	- Algorithms need to be trained - Data mining methods require comprehensive historical data
eSmiley (scale & software)	Food services (Europe)	+ Tailored measurement design + Individual reports & measures + Improved food management	- Semi-automated tool - Data quality depends on user
Kitro (scale, camera & software)	Food services (Switzerland)	+ Fully automated device + Individual reports & measures + Visual photo capture + Artificial intelligence	- Algorithms need to be trained frequently with data from individual measurements
Küchenmonitor (web application)	School canteens (Germany)	+ Free of charge + Individual reports & measures + Tailored tool for school canteens	- Manual data entry - Data quality depends on user
Leanpath (scale, camera & software)	Food services (worldwide)	+ Fully automated device + Visual photo capture + Online portal for users + Individual reports & measures + Artificial intelligence	- Algorithms need to be trained frequently with data from individual measurements
Matomatic (scale & software)	Food services (Sweden)	+ Tailored measurement design + Individual reports & measures + Better food management	- Semi-automated tool - Data quality depends on user
Mitakus (forecasting software)	Food services (Germany)	+ Sales forecasting (food demand) + Improved menu planning + Artificial intelligence	- Algorithms need to be trained - Data mining methods require comprehensive historical data
RESOURCE-MANAGER FOOD (scale & smartphone app)	Food services (Germany)	+ Free of charge + Worldwide deployable through download in Google Play Store + Individual reports & benchmarks	- Semi-automated system - Data quality depends on user
Waste Analytical Tool (scale & web application)	Food services (Germany)	+ Online portal for users + Case studies available online + Individual reports & measures	- Semi-automated system - Data quality depends on user
Winnow Waste Monitor (scale, camera & software)	Food services (worldwide)	+ Fully automated device + Individual reports & measures + Case studies available online + Artificial intelligence	- Algorithms need to be trained frequently with data from individual measurements

Source: Leverenz 2021

10.1.9 "RESOURCE-MANAGER FOOD" smartphone app

USTUTT has developed one of the first smartphone apps in the world for measuring food waste. It enables people in private and commercial kitchens to measure and document their food waste quickly and easily. Users can learn how the measurement process and its documentation work free of charge and are provided with immediate feedback on the amount of food waste they are generating. Giving consumers the opportunity to monitor and evaluate their food waste using a simple app is the first step to bringing the self-reporting approach to a wider audience. An electronic scale connects with the software via Bluetooth® for the weighing process to enable wireless transmission of the data (see Figure 16). This combination of electronic scale and software makes installation in the kitchen with a tablet or smartphone quick and easy. The smartphone app is already available to download as a beta version from the Google Play Store. The collected measurement data is saved to the cloud and users can manage their data using the administration interface. The management options enable businesses, such as hotel chains, to operate the system in multiple kitchens and at different locations at the same time and manage and monitor the measured values centrally via the cloud. The smartphone app will offer users a broad range of options for documenting, reporting and analysing data that can be used for optimising processes. This includes information such as the product weight, date and time, point of origin, reason for disposal, cost of the product, monetary loss, climate impact (CO_2-equivalents), benchmarks and progress reports. The technical advancement and ongoing development of the system are important factors for any subsequent scale up (corporate growth).

Figure 16: RESOURCEMANAGER FOOD: Smartphone app connected to an electronic scale via Bluetooth®

Source: Kern et al. (2022)

10.1.10 Policy instruments: Recommendations from the Wuppertal and Thünen Institutes

The Wuppertal Institute has made some practical recommendations for improving the current legal and economic control instruments for reducing food waste (see Figure 17 and Garske et al. 2020). The recommendations made by Garske et al. (2020) include formulating ambitious, measurable and sanction able reduction targets for food waste within the legal framework for a circular economy and for waste, and integrating specific actions to reduce food waste into the new regulations for the EU's Common Agricultural Policy. Furthermore, they recommend removing barriers to the reduction of food waste, such as legal and private standards, harmonising relevant regulations in the member states, such as date labelling, and providing incentives to promote food donations.

Figure 17: Recommendations for improving existing laws and economic instruments to tackle food waste (Garske et al., 2020)

International verbindliche, umweltpolitische Ziele: Art. 2(1) Pariser Abkommen, Aichi-Ziele B und C des Übereinkommens über die biologische Vielfalt (+ rechtlich nicht verbindliche SDGs, insbesondere SDG 12.3)

Rechtsbereich	Empfehlungen zur Verbesserung des bestehenden Rechts, um die Steuerwirkung bei der Lebensmittelverschwendung zu erhöhen
Abfallrahmenrichtlinie	• Änderung der Abfallhierarchie unter Berücksichtigung der Besonderheiten von Lebensmittelprodukten • Einführung eines quantifizierten, messbaren und umsetzbaren Ziels für die Verringerung von Lebensmittelabfällen (Vgl. KPIs des JRC)
Gemeinsame Agrarpolitik (GAP)	• Reform der GAP-Zahlungen → „öffentliches Geld für öffentliche Güter" • Reduzierung der Marktinterventionen • Aufnahme spezifischer Maßnahmen zur Verringerung der Lebensmittelabfälle in die neuen GAP-Verordnungen • Aufnahme der Lebensmittelabfälle als Indikator in die Fitness-Check-Bewertung der GAP
Gemeinsame Fischereipolitik (GFP)	• Verbesserung der Selektivität in der Fischerei • Einführen einer Verpflichtung zur Verwendung von nicht vermarktbarem Fisch für die Weiterverarbeitung
Verpackungen für Lebensmittelsicherheit Normen, Vermarkungs-standards Kennzeichnung (Labels)	• Einführung kleiner Stückzahlen und Gebindegrößen auf der Grundlage des Produktionsdatums • Falls erforderlich, Verwendung von plastikfreien, wiederverwendbaren oder biologisch abbaubaren Verpackungen, um die Sicherheit und längere Haltbarkeit von Lebensmitteln zu gewährleisten • Abschaffung gesetzlicher und privater Normen und Vermarktungsstandards für Lebensmittel • Erweiterung der Liste der Produkte, die kein Mindesthaltbarkeitsdatum benötigen • Einführung einheitlicher Bestimmungen zur Kennzeichnung / Datumsetikettierung in der EU
Containern Beseitigungsverbote Foodsharing	• Verbot der Verschwendung von genießbaren Lebensmitteln auf Einzelhandelsebene • Unterstützung von Foodsharing-Initiativen und weiteren Initiativen der Zivilgesellschaft oder der wirtschaftlicher Unternehmen
(steuerliche) Anreize für Lebensmittel-spenden	• Hindernisse für Lebensmittelspenden beseitigen und stattdessen Anreize schaffen • Beseitigung rechtlicher Unklarheiten, z.B. hinsichtlich des Status von Initiativen wie der Tafel und anderen Organisationen • Ausschöpfen der Bestimmungen des Europäischen Fonds für die Hilfe für Bedürftige • Förderung der Spende von nicht vermarktbarem Fisch im Rahmen der GFP • Einführung einer Verpflichtung zur Lebensmittelspende auf Einzelhandelsebene • Förderung von Lebensmittelspenden durch Lösung der Frage, wie die Mehrwertsteuer auf gespendete Lebensmittel anzuwenden ist/durch einen Mehrwertsteuersatz nahe Null

Die Empfehlungen können - bis zu einem gewissen Grad - die bestehende Gesetzgebung zur Lebensmittelverschwendung verbessern. Angesichts der typischen Motivations- und Lenkungsprobleme können sie jedoch keinen umfassenden Wandel im Hinblick auf die Klima- und Biodiversitätsziele herbeiführen und die miteinander verknüpften Umweltprobleme angehen.

Wirtschaftliche Instrumente als umfassende Lösung

- Emissionshandelssystem für fossile Brennstoffe und für tierische Produkte in Kombination mit Vorgaben zur Viehbestandsdichte
- Geeignet zur Bewältigung der vielfältigen, miteinander verknüpften Umweltprobleme und zur Erzielung höherer Preise für Lebensmittel (unter Berücksichtigung ihres ökologischen Fußabdrucks / ihrer Ressourcen- und Treibhausgasintensität)

Source: Garske et al. (2020)

The Thünen Institute has also recently issued some recommendations about reducing food waste in restaurants and food services (Kuntscher et al. 2022a; 2022b). They believe that to implement these reduction measures, it is necessary to train and motivate staff and involve them in the developments as well as to integrate a waste monitoring system into the company. Both an environmental and economic evaluation of the reduction strategies is also recommended in order to determine their effectiveness and efficiency. In addition, the Thünen Institute has issued some policy recommendations to support reductions in food waste. These include:

- Monitoring waste in restaurants and food services (e.g. using RESOURCEMANAGER FOOD)
- Training material for restaurants, kitchen and service staff

- Instructions on evaluating reduction strategies
- Guides on communicating with guests
- Auditing supply chains, creating incentives for local producers
- Firmly anchoring the concept of reducing food waste and healthy nutrition into the curricula at schools and vocational colleges
- Promoting the reduction of food waste in public and social media
- Introducing an obligatory climate label on food

10.1.11 "Target-Measure-Act" – Recommendations from the Champions 12.3 coalition

To help make SDG 12.3 become a reality, the global multi-stakeholder summit "No More Food to Waste" proposed establishing a group of executives who would champion the cause of achieving SDG Target 12.3. Champions 12.3 is a coalition of executives from governments, businesses, international organisations, research institutions, associations and civil society dedicated to mobilising action and accelerating progress toward achieving SDG 12.3 (Hanson 2017). The members of the Champions 12.3 coalition call on governments and companies around the world to follow the "Target-Measure-Act" approach, which means:

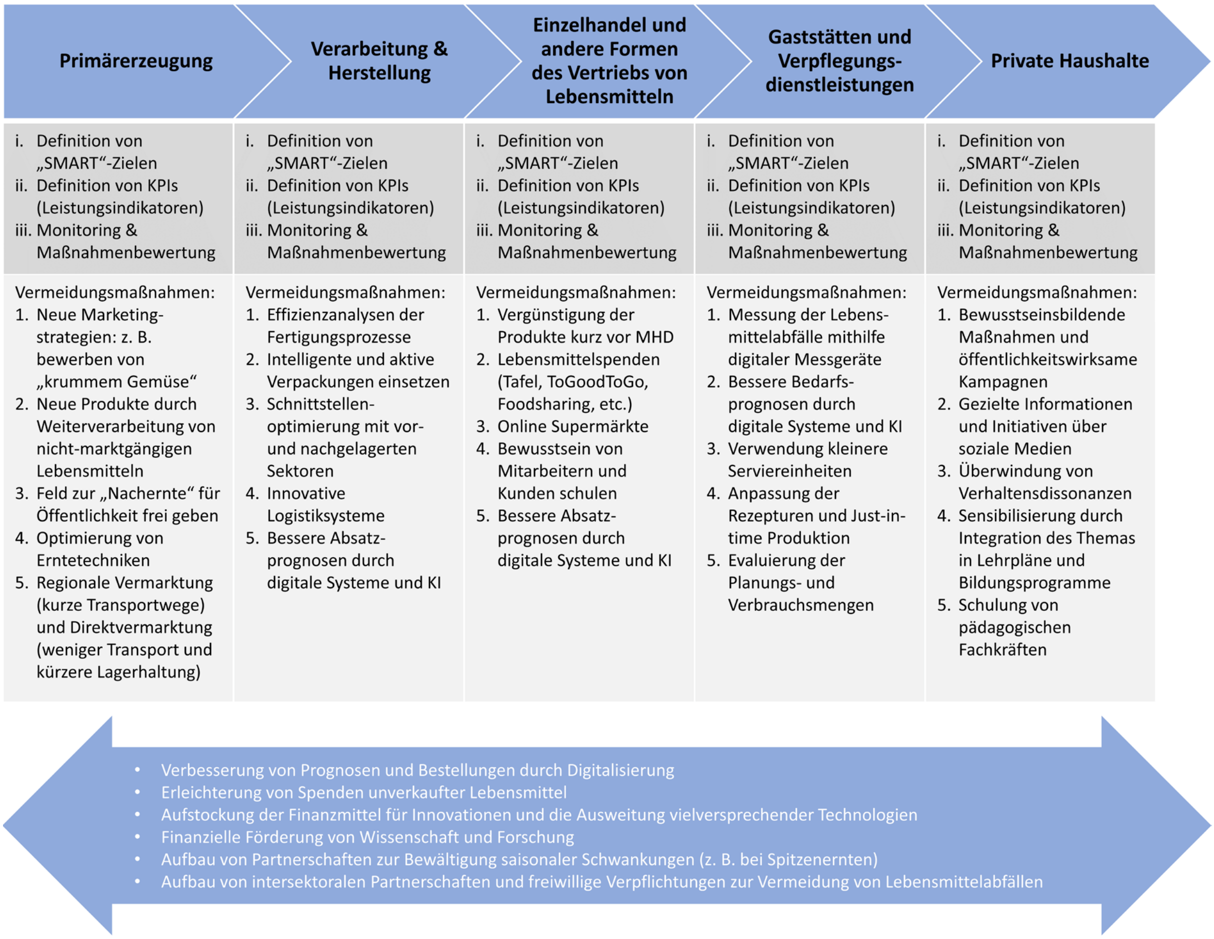
1. Target – Targets set ambition and ambition motivates action: Governments and companies should adopt explicit food waste reduction targets.
2. Measure – Governments and companies should measure their food waste, take action, and document and publish their progress over time.
3. Act – In the end, action is what ultimately matters: Based on information gathered from measurement, governments and companies should develop and implement strategies for reducing their food waste, ranging from on-farm food losses to household food waste and everything in between. National public-private partnerships can be an effective way to take collaborative action, find pragmatic policies and practices, and engage everyone from farmers to consumers in a shared mission.

The recommendations for action issued by the Champion 12.3 coalition have also been picked up and developed in more detail by the JRC of the European Commission at a European level (Caldeira et al. 2019; Hanson & Mitchell 2017). According to the JCR, targets for every stage of the food supply chain ("Target") should be "SMART", measured using performance indicators or KPIs ("Measure") and the resulting action ("Act") monitored and evaluated.

10.2 Summary of the most important approaches and recommendations

This section will briefly summarise the most important recommendations for action for reducing food waste along the entire food supply chain. They are based on the results of the research into the literature on this subject described above (see Chapter 10.1) and the recommendations from the Champions 12.3 coalition and the JRC of the European Commission. Figure 18 describes in key words five promising measures from the literature research for each of the stages of the food supply chain.

Figure 18: Summary of the recommendations for action



Source: Kern et al. (2022)

10.3 Need for further research into action to reduce food waste

According to the Champions 12.3 coalition (“Target-Measure-Act”), measuring and reporting on the amount of food waste is an important basis for deriving and implementing action. However, it is difficult to interpret trends and identify factors that influence the overall situation. Science-based (re-)actions are essential for the monitoring process, which is why Hanson & Mitchell (2017) and Caldeira et al. (2019) stress the need to promote research activities to close any gaps in knowledge and promote innovation.

Furthermore, there is a particular need for future research on the implementation and evaluation of action to reduce food waste and on the evaluation of economic and regulatory instruments (Goossens et al. 2019; Priefer et al. 2016). Stöckli et al. (2018) state that most reduction measures implemented in Europe have been soft instruments such as awareness campaigns, round tables, networks and information platforms. For example, the authors contend that informational interventions are the most popular type of intervention for reducing food waste, although they often do not lead to the desired result. There is a lack of evidence in the literature on the effectiveness of interventions that mainly concentrate on action to reduce food waste at a consumer level. In light of this fact, further studies should be carried out on other types of intervention (Stöckli et al. 2018).

According to a review paper from 2019, initiatives such as cooking classes, fridge cameras, food sharing apps, advertising campaigns and information sharing were all promoted and recommended but with little or no robust evidence provided for their effectiveness (Reynolds et al. 2019). The authors of this study described the situation as worrying because the recommendations were presented as successful approaches. Except for a few studies, however, there is no reproducible quantified evidence to assure their credibility. Reynolds et al. (2019) also declared that a greater number of longitudinal and larger sample size intervention studies are required to strengthen the current state of research. Consequently, a key finding from this review was that there is a significant gap in knowledge, meaning that it is difficult to make evidence-based decisions to effectively prevent or reduce food waste at a consumer level. Goossens et al. (2019) concluded that for many of the proposed reduction measures, economic, environmental, or social assessments are incomplete, and efficiency is only seldom calculated. This gives rise to a certain legal complexity for practitioners and decision-makers when selecting measures based on their efficiency and prioritising them in future interventions (Goossens et al. 2019). The literature referred to in this section provides a chronological overview of the most important scientific publications and reviews dealing with measures to reduce food waste. The research into food waste has increased significantly in the last few years. Most of the findings in this literature are, however, based on the results of case studies with short assessment periods and can only be used to draw generalised conclusions to a limited extent. In particular, there are a lack of findings on avoidance measures because the impact of these measures is rarely investigated over a longer period of time and their effectiveness has not been evaluated at all.

The still ongoing global COVID-19 pandemic has also posed new challenges. For example, it has been necessary to adapt established processes and procedures to the requirements of stricter hygiene concepts. As a result, it is important to test the transferability of already implemented measures and achievements made in food waste reduction against the background of new hygiene concepts and changes in consumer habits. In view of the ongoing dynamic changes in the catering sector, current research faces several challenges and tasks that will need to be tackled in future studies. Further research is need, for example, in order to quantify and evaluate the impact of the global pandemic on food waste across the whole food supply chain.

11 Findings and conclusions

The objective of the research project is to prepare the first report to the EU Commission on food waste for the reporting year 2020. The StBA submitted the results (including the quality control report) to the EU Commission by June 30, 2022 in accordance with EU specifications. In addition, this research project aims to develop suggestions for optimising reporting and identifying tools and actions for further reducing food waste. Moreover, the aim should be to derive reliable data – with the aid of waste coefficients – on the proportion of food waste in the different types of waste that may contain food.

The waste coefficients and the amount of food waste utilised for home composting were determined by a subcontractor within the research project. The subcontractor also identified recommendations for action to reduce food waste. This subcontractor was a consortium consisting of the "Witzenhausen-Institut für Abfall, Umwelt und Energie GmbH (WI)", "ARGUS-Statistik und Informationssysteme in Umwelt und Gesundheit GmbH (ARGUS)", the "Institut für Abfall, Abwasser und Infrastruktur-Management GmbH (INFA)" and the "Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft der Universität Stuttgart (USTUTT)".

The most important findings and conclusions from the research project are summarised below.

Data set

The data set for food waste monitoring is based on national, official statistics where there is a legal obligation to provide information. As this is anchored in law, the data are collected regularly and are of high quality, making the national, official statistics used for food waste monitoring highly reliable and meaningful.

The data set for food waste monitoring is primarily sourced from full annual surveys. This ensures the consistency and reliability of the data and its suitability for time series analysis.

Modifications: Allocating the waste and commercial waste

In order to fulfil the European reporting obligation in the best way possible, the data set was modified to adapt it to the circumstances In Germany.

The first modification was to take the waste codes stated in Delegated Decision (EU) 2019/1597 into account for other stages of the food supply chain. Annex II of Delegated Decision (EU) 2019/1597 names waste codes that may contain food waste and the stages of the food supply chain in which the waste is generated. According to the national, official waste statistics, some of the waste codes listed in Delegated Decision (EU) 2019/1597 also occur in stages of the food supply chain or in economic sectors that are not expressly prescribed by Delegated Decision (EU) 2019/1597. In order to give as complete a picture as possible of the amount of food waste in Germany, these amounts of waste were also considered and assigned to the corresponding stages of the food supply chain. No new waste codes were used for this purpose; instead, the stages of the food supply chain were merely expanded to include waste codes that are already taken into account at other stages and which can contain food waste.

A further modification was to remove the commercial waste from stage 5 of the food supply chain and redistribute it across stages 1 to 4 of the food supply chain. Household waste and, to a small extent, biowaste also always include a proportion of waste of commercial origin, so-called commercial waste, which is collected together with household waste and biowaste from private households. Commercial waste is waste that is generated in small businesses such as engineering offices, tax consultants, lawyers, etc. and is disposed of in the bins provided by the örE (residual waste bin: waste code "20 03 01 01", biowaste bin: waste code "20 03 01 04"). The amount of commercial waste is calculated as the difference between the amounts of waste reported by the örE and the extrapolated amount of household waste from households. In the reporting year 2020, the proportion of commercial waste in the residual waste bin was 19 % and in the biowaste bin 5 %.

Waste coefficients for mixed municipal waste

To fulfil the EU reporting obligation, waste coefficients were used to extrapolate the proportion of food waste in the modified data set (potential amounts of food waste). These coefficients give the proportion (e.g. 45 %) of the total amount of waste accounted for by food waste in each waste code.

Waste from households (stage 5 of the food supply chain) mainly comprises mixed municipal waste with the waste code 20 03 01. This includes household waste (20 03 01 01), commercial waste similar to household waste (20 03 01 02), non-differentiable mixed municipal waste (20 03 01 00) and biowaste (20 03 01 04).

The evaluation and extrapolation methods for household waste and biowaste are the same as the methodological procedure described in the "Bundesweite Hausmüllanalyse" (Nationwide Household Waste Analysis) (Dornbusch et al. 2020) (Chapter 5, p. 44 to 83).

A waste coefficient for mixed municipal waste of 29 % was derived on this basis. The calculations resulted in a waste coefficient of 33 % for household waste, 36 % for biowaste and approximately 4 % for commercial waste similar to household waste. At the time of the evaluation, there was no information available on the composition of the waste code "non-differentiable mixed municipal waste – 20 03 01 00". Therefore, the waste coefficient for mixed municipal waste of 29 % was adopted for this eight-digit waste code. In the reporting year 2020, the waste coefficient for mixed municipal waste was applied to around 22.4 million t of waste that could potentially contain food waste. This corresponded to around 83 % of the total amount of waste (about 26.9 million t[47]) that could potentially contain food waste. The waste coefficients were applied to the data set for reporting year 2020, which was prepared in accordance with the methodology presented in Chapter 5.

Waste coefficients for other waste codes

In order to ensure that the baseline data for fulfilling the future reporting obligation was as reliable as possible, USTUTT carried out a voluntary online survey to determine the waste coefficients for the other relevant waste codes. USTUTT sent out the online survey via email to a total of 748 recipients on February 18, 2022. The deadline for responses was March 14, 2022. The respondents were companies in the German waste management sector or operators of waste disposal facilities in Germany – e.g. waste incineration plants, biowaste fermentation plants, composting plants and mechanical-biological waste treatment plants. The online survey also asked for data on the amounts of waste and waste coefficients for these other waste codes in the reporting year 2019. This included all waste codes specified in Annex II of Delegated Decision (EU) 2019/1597, with the exception of waste code 20 03 01 (mixed municipal waste). Eight of the specified waste codes were not included in the online survey because they were not quantitatively relevant[48] in the reporting year 2019.

The response rate to the survey was 13.5 % or 101 completed questionnaires, of which 49 (6.6 %) contained usable data. The results of the study were evaluated and used to define waste coefficients for the relevant waste codes. The results showed that the surveyed companies in the waste management sector can make an important contribution to defining the waste coefficients

[47] Including home composting in stage 5 of the food supply chain and the modifications.

[48] Those waste codes with less than 1,000 t of waste in the 2019 reporting year were viewed as irrelevant in terms of their amounts.

for a large proportion of the waste codes. The results of the online survey did not provide any usable information for a total of 13 waste codes. In view of the response rate, the existing gaps in the data and the state of the data available to the respondents, the online survey cannot meet the requirements of a representative sample. However, the data collected was the best available information at the time of the research project, since this was the first time the German waste management sector was surveyed about the amount of food waste. In the reporting year 2020, the waste coefficients for the other waste codes were applied to around 4.5 million t of waste that could potentially contain food waste. This corresponded to around 17 % of the total amount of waste (about 26.9 million t[49]) that could potentially contain food waste.

A list of all of the waste coefficients for the reporting year 2020 including the methodology used to calculate them can be found in Annex F.

Home composting

When calculating the amounts of food waste for the reporting year 2020, the amount of food waste recycled though home composting was taken into account. Due to the fact that the data available was reliable to a rather limited extent this could only be done by making a rough estimate of an approximate order of magnitude.

To estimate the food waste utilised in home composting, the results of two studies were taken into account: A study by the GfK SE on the amount of food waste from households (Hübsch 2021) and a study published by the Thünen Institute with the short name “Baseline 2015” (Schmidt et al. 2019).

In particular, the consortium used the figure for the proportion of the total amount of food waste generated in households that is utilised in home composting stated in the GfK SE study. The total amount of food waste that is generated in households was taken from Baseline 2015. Following an evaluation of both studies, the food waste recycled through home composting was thus estimated at 1.117 million t/a or 13.6 kg/i*a.

Result

The total amount of food waste in Germany for the reporting year 2020 was then calculated using the modified data set, the waste coefficients and the amounts used in home composting. The data set for the reporting year 2020 is statistically reliable for the five stages of the food supply chain according to Implementing Decision (EU) 2019/2000.

The following table presents the food waste in Germany in the reporting year 2020 broken down into the different stages of the food supply chain.

[49] Including home composting in stage 5 of the food supply chain and the modifications.

Table 35: Food waste in Germany in the reporting year 2020[1]

Stage of the food supply chain	Food waste in 1000 t	Food waste in %
Primary production	178	2
Processing and manufacturing	1,594	15
Retail and other food distribution	774	7
Restaurants and food services	1,877	17
Households	6,496	59
Total[1]	**10,919**	**100**

[1] These are corrected values that were calculated on the basis of expert assessments made by the consortium. These deviate from the results reported to the EU Commission on June 30, 2022.
Source: StBA 2023a

Recommendations for optimising reporting

The EU food waste reporting for the reporting year 2020 only considers the waste recorded as part of the waste management system. Therefore, the data may not be complete in this regard. Another gap in the data is the amount of moisture that is potentially lost before the waste is measured.

The waste coefficients for biowaste and household waste must be determined regularly, i.e. at least every four years. The methodology in the Nationwide Household Waste Analysis (Dornbusch et al. 2020) has been used up to now for calculating these waste coefficients. The consortium believes that the method used to determine the waste coefficients for household waste and biowaste for the initial report can be used for future reports to ensure that the waste coefficients are kept up to date.

Another gap exists in the data regarding the composition of the other waste codes (waste codes included in the monitoring of food waste except for 20 03 01). There is an urgent need for further research in this area. In general, the consortium recommends carrying out further surveys, research and analyses for future reporting in order to define the waste coefficients for the other waste codes. In the process, it is necessary to improve the data by carrying out physical surveys and using a larger sample size. According to the consortium, a framework concept first has to be developed and defined so that it is possible to make valid statements regarding the sample size for waste sorting analyses in stages 1 to 4 of the food supply chain. Overall, it is especially important to take a systematic approach to planning the sampling process and the analysis methods.

General recommendations for future EU reporting

The consortium believes that all available data sources should be used for future reporting, while giving preference to more thoroughly validated data in each case. Physical data, such as waste statistics, supplemented by physical information on the composition of the waste, represent the most reliable data set in this context.

Further work and optimisations of the system will be necessary in future in order to ensure the comprehensive and continuous collection of data on food waste.

Recommendations for action to reduce food waste

Recommendations for action to reduce food waste were developed by the consortium.

Due to the many different ways for potentially avoiding food waste, the JRC for the EU recommends defining the generally formulated targets of Sustainable Development Goal 12.3 more specifically for each of the areas in the food supply chain and for individual sectors. Developing and updating a comprehensive data set is therefore key to optimising the system in the long term. According to the JRC, sector and industry-specific waste avoidance targets should be defined, which are based on, among other things, the actual waste avoidance potential. The goals should be “SMART” (specific, measurable, achievable, relevant, time-bound) and measured using performance indicators. Performance indicators could, for example, monitor the amount of food waste and food losses in relation to the amounts of food produced so that the efficiency of processes can be measured. This is already being implemented in Germany by, amongst other things, the “dialogue forums” to collect corresponding data.

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A Annex – Delegated Decision (EU) 2019/1597

A.1 Annex I – Attribution of food waste to the different stages of the food supply chain

Figure 19: Attribution of food waste to the different stages of the food supply chain according to Annex I of Delegated Decision (EU) 2019/1597

ANHANG I

Zuordnung von Lebensmittelabfällen zu den verschiedenen Stufen der Lebensmittelkette

Stufen der Lebensmittelkette	Entsprechender Posten in der Abfallstatistik ([1]) (einschließlich der Stufe der Lebensmittelkette)	Tätigkeit, bei der die Abfälle anfallen: Entsprechender NACE-Rev.-2-Code		Tätigkeit, bei der die Abfälle anfallen: Beschreibung
Primärerzeugung	Teil von Posten 1	Abschnitt A		Land- und Forstwirtschaft, Fischerei
			Abteilung 01	*Landwirtschaft, Jagd und damit verbundene Tätigkeiten*
			Abteilung 03	*Fischerei und Aquakultur*
Verarbeitung und Herstellung	Teil von Posten 3	Abschnitt C		Verarbeitendes Gewerbe/Herstellung von Waren
			Abteilung 10	*Herstellung von Nahrungs- und Futtermitteln*
			Abteilung 11	*Getränkeherstellung*
Einzelhandel und andere Formen des Vertriebs von Lebensmitteln	Teil von Posten 17	Abschnitt G		Handel; Instandhaltung und Reparatur von Kraftfahrzeugen
			Abteilung 46	*Großhandel (ohne Handel mit Kraftfahrzeugen und Krafträdern)*
			Abteilung 47	*Einzelhandel (ohne Handel mit Kraftfahrzeugen)*
Gaststätten und Verpflegungsdienstleistungen	Teil von Posten 17	Abschnitt I		Gastgewerbe/Beherbergung und Gastronomie
			Abteilung 55	*Beherbergung*
			Abteilung 56	*Gastronomie*
		Abschnitte N, O, P, Q, R, S		
			Abteilungen zu Tätigkeiten, in denen Verpflegungsdienstleistungen erbracht werden (z. B. Kantinen, Gesundheitswesen, Bildung, Verpflegung für Reisende)	
private Haushalte	Posten 19	„Haushalte" im Sinne von Anhang I Abschnitt 8 Nummer 1.2 der Verordnung (EG) Nr. 2150/2002 zur Abfallstatistik		Abfallaufkommen aus Haushalten

([1]) Anhang I Abschnitt 8 Nummer 1 der Verordnung (EG) Nr. 2150/2002..

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Source: Delegated Decision (EU) 2019/1597

A.2 Annex II – List of the types of waste with a reporting obligation

Figure 20 List of the types of waste with a reporting obligation according to Annex II of Delegated Decision (EU) 2019/1597

ANHANG II

Abfallcodes aus dem europäischen Abfallverzeichnis für Abfallarten, die in der Regel auch Lebensmittelabfälle umfassen

Primärerzeugung

02 01 02	Abfälle aus tierischem Gewebe
02 01 03	Abfälle aus pflanzlichem Gewebe

Verarbeitung und Herstellung

02 02	Abfälle aus der Zubereitung und Verarbeitung von Fleisch, Fisch und anderen Nahrungsmitteln tierischen Ursprungs
02 03	Abfälle aus der Zubereitung und Verarbeitung von Obst, Gemüse, Getreide, Speiseölen, Kakao, Kaffee, Tee und Tabak, aus der Konservenherstellung, der Herstellung von Hefe und Hefeextrakt sowie der Zubereitung und Fermentierung von Melasse
02 04	Abfälle aus der Zuckerherstellung
02 05	Abfälle aus der Milchverarbeitung
02 06	Abfälle aus der Herstellung von Back- und Süßwaren
02 07	Abfälle aus der Herstellung von alkoholischen und alkoholfreien Getränken (ohne Kaffee, Tee und Kakao)

Einzelhandel und andere Formen des Vertriebs von Lebensmitteln

20 01 08	biologisch abbaubare Küchen- und Kantinenabfälle
20 01 25	Speiseöle und -fette
20 03 01	gemischte Siedlungsabfälle
20 03 02	Marktabfälle
16 03 06	organische Abfälle mit Ausnahme derjenigen, die unter 16 03 05 fallen

Gaststätten und Verpflegungsdienstleistungen

20 01 08	biologisch abbaubare Küchen- und Kantinenabfälle
20 01 25	Speiseöle und -fette
20 03 01	gemischte Siedlungsabfälle

private Haushalte

20 01 08	biologisch abbaubare Küchen- und Kantinenabfälle
20 01 25	Speiseöle und -fette
20 03 01	gemischte Siedlungsabfälle

Source: Delegated Decision (EU) 2019/1597

B Annex – List of waste codes taken into account in the individual stages of the food supply chain in addition to those in Delegated Decision (EU) 2019/1597

Table 36: List of the waste codes in Germany taken into account in the individual stages of the food supply chain for reporting year 2020 in addition to those in Annex II of Delegated Decision (EU) 2019/1597

Waste code	Description	Stage of the food supply chain				
		1	2	3	4	5
02 01	**Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing**					
02 01 02	Animal-tissue waste	x	o		o	
02 01 03	Plant-tissue waste	x	o		o	
02 02	**Wastes from the preparation and processing of meat, fish and other foods of animal origin**					
02 02 01	Sludges from washing and cleaning		x			
02 02 02	Animal-tissue waste	o	x	o	o	
02 02 03	Materials unsuitable for consumption or processing		x			
02 02 04	Sludges from on-site effluent treatment		x			
02 02 99	Wastes not otherwise specified	o	x	o	o	
02 03	**Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation**					
02 03 01	Sludges from washing, cleaning, peeling, centrifuging and separation		x			
02 03 02	Wastes from preserving agents		x			
02 03 03	Wastes from solvent extraction		x			
02 03 04	Materials unsuitable for consumption or processing		x			
02 03 05	Sludges from on-site effluent treatment		x			
02 03 99	Wastes not otherwise specified	o	x		o	
02 04	**Wastes from sugar processing**					
02 04 01	Soil from cleaning and washing beet		x			
02 04 02	Off-specification calcium carbonate		x			
02 04 03	Sludges from on-site effluent treatment		x			
02 04 99	Wastes not otherwise specified		x			
02 05	**Wastes from the dairy products industry**					

Waste code	Description	Stage of the food supply chain				
		1	2	3	4	5
02 05 01	Materials unsuitable for consumption or processing		x			
02 05 02	Sludges from on-site effluent treatment		x			
02 05 99	Wastes not otherwise specified	o	x	o	o	
02 06	**Wastes from the baking and confectionery industry**					
02 06 01	Materials unsuitable for consumption or processing		x			
02 06 02	Wastes from preserving agents		x			
02 06 03	Sludges from on-site effluent treatment		x			
02 06 99	Wastes not otherwise specified		x			
02 07	**Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)**					
02 07 01	Wastes from washing, cleaning and mechanical reduction of raw materials	o	x			
02 07 02	Wastes from spirits distillation		x			
02 07 03	Wastes from chemical treatment		x			
02 07 04	Materials unsuitable for consumption or processing		x			
02 07 05	Sludges from on-site effluent treatment		x			
02 07 99	Wastes not otherwise specified	o	x	o	o	
16 03	**Off-specification batches and unused products**					
16 03 06	Organic wastes other than those mentioned in 16 03 05	o	o	x	o	
20 01	**Municipal wastes: separately collected fractions**					
20 01 08	Biodegradable kitchen and canteen waste	o	o	x	x	x[1]
20 01 25	Edible oil and fat	o	o	x	x	x[1]
20 03	**Municipal wastes: other municipal wastes**					
20 03 01	Mixed municipal waste	o	o	x	x	x
20 03 02	Waste from markets	o	o	x	o	

x = Waste code for stages of the food supply chain in accordance with Annex II of Delegated Decision (EU) 2019/1597.
o = Waste code taken into account in other stages of the food supply chain based on the results of the national waste statistics. Exclusively includes the waste codes from Annex II of Delegated Decision (EU) 2019/1597.
[1] This waste code was not taken into account for stage 5 of the food supply chain because the amounts of waste in the German waste management system for this waste code are usually not generated by private households.
Source: Own illustration, StBA

C Annex – Allocation of the samples to the strata (per sampling campaign) for the biowaste analysis

Table 37: Allocation of the sample units to the strata for the biowaste analysis in reporting year 2020 (per sampling campaign)

Federal strata		Number of örE	Sample units per strata for each public waste disposal authority (örE)		
Settlement structure	Level of access to a biowaste bin		Outskirts	City	LHE
Rural (<150 i/km²)	High	4	72	24	24
	Low	2	24	6[2]	
	No access[1]	--	--	--	--
Densely populated rural area (150-750 i/km²)	High	7	144	30	30
	Low	3	42	18	6
	No access[1]	--	--	--	--
Urban/metropolitan (>750 i/km²)	High	3	18	18	18
	Low	7	57	63	45
	No access[1]	--	--	--	--

[1] No access to a biowaste bin

[2] City and LHE were combined in DE strata 2 because no differentiation was made between them in the analyses.

Source: Own research, WI, ARGUS, INFA, USTUTT

D Annex – Online survey

Figure 21: Online questionnaire

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Monitoring und Berichterstattung der Lebensmittelabfälle in Deutschland gegenüber der EU-Kommission

Herzlich Willkommen zur Umfrage der Universität Stuttgart im Auftrag des Statistischen Bundesamtes (StBA).

Mit Ihrer Teilnahme können Sie einen wichtigen Beitrag zur Ermittlung der Lebensmittelabfälle in Deutschland im Jahr 2019 und im Jahr 2020 leisten. Die Ergebnisse werden in anonymisierter und aggregierter Form gegenüber der EU-Kommission im Jahr 2022, für das Berichtsjahr 2020, berichtet.

Hintergrund:
Gemäß der EU-Abfallrahmenrichtlinie (Richtlinie 2008/98/EG) sollen Lebensmittelabfälle bis ins Jahr 2030 deutlich verringert werden. Die EU-Kommission hat im Jahr 2019 zwei konkretisierende Beschlüsse erlassen, den Durchführungsbeschluss (EU) 2019/2000 zum Übermittlungsformat der Berichte und den Delegierten Beschluss (EU) 2019/1597 zur Erhebungsmethodik. Aufgrund dieser rechtlichen Bestimmungen muss Deutschland seiner erstmaligen Berichtspflicht zu Lebensmittelabfällen zum 30.06.2022 nachkommen und danach weiterhin jährlich die Masse der entstandenen Lebensmittelabfälle erfassen und der EU-Kommission berichten. Das Statistische Bundesamt (StBA) soll diese Berichtspflicht erfüllen und baut derzeit in Zusammenarbeit mit der Universität Stuttgart ein Monitoring für Lebensmittelabfälle auf.

Grundlage für das Monitoring sind amtliche Abfallstatistikerhebungen. Durch die vorliegende Umfrage sollen Abfallkoeffizienten ermittelt werden, die den Anteil an Lebensmittelabfällen und Nicht-Lebensmittelabfällen für Abfallschlüssel des Europäischen Abfallverzeichnisses (EAV) ausweisen.

Ziel ist eine möglichst repräsentative Ausweisung der Anteile an Lebensmittelabfällen in allen Abfallarten, um damit anhand der amtlichen Abfallstatistiken die Mengen der in Deutschland entsorgten Lebensmittelabfälle ausweisen zu können.

Hierfür sind wir auf Ihre Mithilfe angewiesen. Wir möchten Sie daher freundlich um Ihre Teilnahme an unserer Online-Umfrage (ggf. auch anonym) bitten und den Online-Fragebogen bis zum **14. März 2022** auszufüllen.

Ihre Daten werden vertraulich behandelt und ausschließlich in anonymisierter und aggregierter Form für das Monitoring verwendet.

Vielen Dank, dass Sie sich kurz Zeit nehmen und an dieser Umfrage teilnehmen.

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Welche der folgenden Abfälle fielen bei Ihnen im Jahr 2019 an?

Bitte um Angabe der Abfallmenge und Anteil an Lebensmittelabfällen - sofern bekannt - in Bezug auf die nachfolgend genannten Abfallcodes aus dem europäischen Abfallverzeichnis für Abfallarten (EAV), die in der Regel auch Lebensmittelabfälle umfassen.

Weitere Erläuterungen und Ausfüllhinweise: Für diese Befragung ist es relevant, welchen Anteil die Lebensmittelabfälle an der Gesamtmenge der einzelnen Abfallschlüssel ausmachen. Bitte geben Sie in der ersten Spalte die Abfallmenge an, die aus dem Inland an die Abfallentsorgungsanlage angeliefert wurde. Bitte tragen Sie den Anteil an Lebensmittelabfällen als Masse-% in die zweite Spalte ein.

	Input Abfallentsorgungsanlage 2019 (aus Inland angeliefert und aus dem eigenen Betrieb) in t [Mg]	**Anteil Lebensmittelabfälle** in Masse-% [kg/kg]
EAV 02 01 02 (Landwirtschaft: Abfälle aus tierischem Gewebe)		
EAV 02 01 03 (Landwirtschaft: Abfälle aus pflanzlichem Gewebe)		
EAV 02 02 01 (Fleisch: Schlämme von Wasch-, Reinigungsvorgängen)		
EAV 02 02 02 (Fleisch: Abfälle aus tierischem Gewebe)		
EAV 02 02 03 (Fleisch: Für Verzehr ungeeignete Stoffe)		
EAV 02 02 04 (Fleisch: Schlämme (betriebseigene Abwasserbehandlung))		
EAV 02 02 99 (Fleisch, Fisch: Abfälle a.n.g.)		
EAV 02 03 01 (Obst: Schlämme aus Wasch-, Reinigungsprozessen)		
EAV 02 03 04 (Obst: Für Verzehr ungeeignete Stoffe)		
EAV 02 03 05 (Obst: Schlämme (betriebseigene Abwasserbehandlung))		
EAV 02 03 99 (Obst, Gemüse: Abfälle a.n.g.)		
EAV 02 04 99 (Zucker: Abfälle a.n.g.)		
EAV 02 05 01 (Milch: Für Verzehr ungeeignete Stoffe)		
EAV 02 05 02 (Milch: Schlämme (betriebseigene Abwasserbehandlung))		

Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz

Umwelt Bundesamt

DESTATIS Statistisches Bundesamt

Universität Stuttgart

	Input Abfallentsorgungsanlage 2019 (aus Inland angeliefert und aus dem eigenen Betrieb) in t [Mg]	**Anteil Lebensmittelabfälle** in Masse-% [kg/kg]
EAV 02 05 99 (Milch: Abfälle a.n.g.)		
EAV 02 06 01 (Back-, Süßwaren: Für Verzehr ungeeignete Stoffe)		
EAV 02 06 03 (Back-, Süßwaren: Schlämme (betriebseigene Abwasserbehandlung))		
EAV 02 07 01 (Getränke: Abfälle aus der Wäsche, Reinigung)		
EAV 02 07 02 (Getränke: Abfälle aus der Alkoholdestillation)		
EAV 02 07 04 (Getränke: Für Verzehr ungeeignete Stoffe)		
EAV 02 07 05 (Getränke: Schlämme (betriebseigene Abwasserbehandlung))		
EAV 02 07 99 (Getränke: Abfälle a.n.g.)		
EAV 16 03 06 (Organische Abfälle (ohne EAV 160305-U))		
EAV 20 01 08 (Biologisch abbaubare Küchen- und Kantinenabfälle)		
EAV 20 01 25 (Speiseöle und -fette)		
EAV 20 02 01 (Biologisch abbaubare Abfälle)		
EAV 20 03 01 00 (Gemischte Siedlungsabfälle nicht differenzierbar)		
EAV 20 03 01 01 (Hausmüll, hausmüllähnliche Gewerbeabfälle)		
EAV 20 03 01 02 (Hausmüllähnliche Gewerbeabfälle, getrennt gesammelt)		
EAV 20 03 01 04 (Abfälle aus der Biotonne)		
EAV 20 03 02 (Marktabfälle)		
EAV 20 03 99 (Siedlungsabfälle a.n.g.)		

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Wie haben Sie die Anteile an Lebensmittelabfällen aus der vorangegangenen Frage bestimmt?

Bitte geben Sie hier an, anhand welcher Erhebungsmethode die Daten zur Abfallzusammensetzung erhoben wurden.

☐	Information wurde Meldeschein entnommen (deklarationspflichtig)
☐	Durchführung von Abfallanalysen (z.B. Sortieranalysen)
☐	Schätzungen
☐	Sonstiges:
☐	Anteile an Lebensmittelabfällen sind nicht bekannt

Kommentare und Erklärungen

Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz | Umwelt Bundesamt | DESTATIS Statistisches Bundesamt | Universität Stuttgart

Freiwillige Angabe der Kontaktdaten und Benennung eines Ansprechpartners im Falle von Rückfragen.

Bitte um Angabe Ihrer Kontaktdaten.

Name	
Firma	
Telefonnummer	
E-Mail	

Source: Kern et al. (2022)

E Annex – Overview of the waste coefficients

Table 38: List of all waste coefficients including the methodology used to derive them for the reporting year 2020 in Germany[1]

Waste code	Description	Number of responses to survey	Methodology used to derive waste coefficient	Waste coefficient in %	Amount of waste RY 2020 in t before waste coefficient[2]	Amount of waste RY 2020 in t after waste coefficient[2]	Stage of the food supply chain
02 01	**Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing**						
02 01 02	Animal-tissue waste	2	Expert opinion (supplementing the t-distribution)	0	46,174	0	1, 2, 4
02 01 03	Plant-tissue waste	13	Expert opinion (supplementing the t-distribution)	33	634,993	209,548	1, 2, 4
02 02	**Wastes from the preparation and processing of meat, fish and other foods of animal origin**						
02 02 01	Sludges from washing and cleaning	0	100 % upper limit	100	10,917	10,917	2
02 02 02	Animal-tissue waste	2	Expert opinion (supplementing the t-distribution)	0	97,535	0	1-4
02 02 03	Materials unsuitable for consumption or processing	6	Expert opinion (supplementing the t-distribution)	43	130,606	56,161	2
02 02 04	Sludges from on-site effluent treatment	6	Expert opinion (supplementing the t-distribution)	54	362,523	195,762	2

Waste code	Description	Number of responses to survey	Methodology used to derive waste coefficient	Waste coefficient in %	Amount of waste RY 2020 in t before waste coefficient[2]	Amount of waste RY 2020 in t after waste coefficient[2]	Stage of the food supply chain
02 02 99	Wastes not otherwise specified	0	100 % upper limit	100	84,116	84,116	1-4
02 03	**Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation**						
02 03 01	Sludges from washing, cleaning, peeling, centrifuging and separation	1	100 % upper limit	100	53,174	53,174	2
02 03 02	Wastes from preserving agents	Not queried	100 % upper limit	100	0	0	2
02 03 03	Wastes from solvent extraction	Not queried	100 % upper limit	100	/	/	2
02 03 04	Materials unsuitable for consumption or processing	16	Expert opinion (supplementing the t-distribution)	71	104,324	74,070	2
02 03 05	Sludges from on-site effluent treatment	1	100 % upper limit	100	109,055	109,055	2
02 03 99	Wastes not otherwise specified	1	100 % upper limit	100	41,430	41,430	1, 2, 4
02 04	**Wastes from sugar processing**						
02 04 01	Soil from cleaning and washing beet	Not queried	100 % upper limit	100	/	/	2
02 04 02	Off-specification calcium carbonate	Not queried	100 % upper limit	100	/	/	2

Waste code	Description	Number of responses to survey	Methodology used to derive waste coefficient	Waste coefficient in %	Amount of waste RY 2020 in t before waste coefficient[2]	Amount of waste RY 2020 in t after waste coefficient[2]	Stage of the food supply chain
02 04 03	Sludges from on-site effluent treatment	Not queried	100 % upper limit	100	0	0	2
02 04 99	Wastes not otherwise specified	1	100 % upper limit	100	/	/	2
02 05	**Wastes from the dairy products industry**						
02 05 01	Materials unsuitable for consumption or processing	2	Expert opinion (supplementing the t-distribution)	100	159,888	159,888	2
02 05 02	Sludges from on-site effluent treatment	2	Expert opinion (supplementing the t-distribution)	54	52,143	28,157	2
02 05 99	Wastes not otherwise specified	0	100 % upper limit	100	19,409	19,409	1-4
02 06	**Wastes from the baking and confectionery industry**						
02 06 01	Materials unsuitable for consumption or processing	6	Expert opinion (supplementing the t-distribution)	100	275,045	275,045	2
02 06 02	Wastes from preserving agents	Not queried	100 % upper limit	100	0	0	2
02 06 03	Sludges from on-site effluent treatment	0	100 % upper limit	100	6,037	6,037	2
02 06 99	Wastes not otherwise specified	Not queried	100 % upper limit	100	764	764	2

Waste code	Description	Number of responses to survey	Methodology used to derive waste coefficient	Waste coefficient in %	Amount of waste RY 2020 in t before waste coefficient[2]	Amount of waste RY 2020 in t after waste coefficient[2]	Stage of the food supply chain
02 07	**Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)**						
02 07 01	Wastes from washing, cleaning and mechanical reduction of raw materials	0	100 % upper limit	100	1,657	1,657	1, 2
02 07 02	Wastes from spirits distillation	0	100 % upper limit	100	/	/	2
02 07 03	Wastes from chemical treatment	Not queried	100 % upper limit	100	0	0	2
02 07 04	Materials unsuitable for consumption or processing	3	Expert opinion (supplementing the t-distribution)	71	67,350	47,818	2
02 07 05	Sludges from on-site effluent treatment	1	100 % upper limit	100	5,258	5,258	2
02 07 99	Wastes not otherwise specified	0	100 % upper limit	100	3,433	3,433	1-4
16 03	**Off-specification batches and unused products**						
16 03 06	Organic wastes other than those mentioned in 16 03 05	1	100 % upper limit	100	10,046	10,046	1-4
20 01	**Municipal wastes: separately collected fractions**						
20 01 08	Biodegradable kitchen and canteen waste	8	Expert opinion (supplementing the t-distribution)	100	903,857	903,857	1-4
20 01 25	Edible oil and fat	2	Expert opinion (supplementing the t-distribution)	100	53,449	53,449	1-4

Waste code	Description	Number of responses to survey	Methodology used to derive waste coefficient	Waste coefficient in %	Amount of waste RY 2020 in t before waste coefficient[2]	Amount of waste RY 2020 in t after waste coefficient[2]	Stage of the food supply chain
20 03	**Municipal wastes: other municipal wastes**						
20 03 01[3]	Mixed municipal waste		Weighted average of the Consortium	29	22,429,665	7,287,707[5]	1-5
20 03 01 00[4]	Non-differentiable mixed municipal waste		Not determined; waste coefficient for 20 03 01 was used	29	Not possible to report amount. Amount is included in 20 03 01.		1-4
20 03 01 01[4]	Household waste, commercial waste similar to household waste		Waste sorting analysis	33	10,765,345	3,552,564	5
20 03 01 02[4]	Commercial waste similar to household waste, collected separately		Waste sorting analyses, estimate based on expert opinion	4	Not possible to report amount. Amount is included in 20 03 01.		1-4
20 03 01 04[4]	Waste from biowaste bins		Waste sorting analysis	36	5,035,581	1,812,809	5
20 03 02	Waste from markets	5	Expert opinion (supplementing the t-distribution)	100	82,426	82,426	1-4

/ = No verification due to limited statistical reliability.

[1] The reported amounts of waste for each waste code exclusively represent results aggregated by economic sector and stage of the food supply chain.

[2] Values determined from the data set for food waste monitoring for reporting year 2020, without consideration of home composting (1,130,908 t), rounded values.

[3] Including the modification "commercial waste". Further information on the redistribution of commercial waste to the different stages of the food supply chain is provided in Chapter 5.1.2.2.

[4] The waste codes are usually listed in the European List of Waste as six-digit numbers. Eight-digit numbers are sometimes used in Germany for a more detailed classification, as in the case of mixed municipal waste.

[5] This amount is the total of the values for the four eight-digit codes – after application of the waste coefficient in each case.

Source: Own research, StBA

Supplementary explanation of the methodology used to derive the waste coefficients:

The waste coefficient for mixed municipal waste (20 03 01) was derived on the basis of waste sorting analyses and an estimate based on expert opinion (see Chapter 6.1).

Waste codes with less than 1,000 t of waste in the reporting year 2019 were not included in the voluntary online survey. The waste coefficients for these waste codes were set at 100 %. This applied to eight waste codes (see Chapter 6.2.3).

The waste coefficients for waste codes with less than two responses in the voluntary online survey carried out by the consortium were also defined as 100 %. There was one response for six of the waste codes and no response for a further seven waste codes (see Chapter 6.2.5).

The waste coefficients for waste codes with at least two responses in the voluntary online survey carried out by the consortium were derived on the basis of expert opinion (supplementing the t-distribution) by the consortium. This applied to 13 waste codes (see Chapter 6.2.5).