wasteless

Waste Quantification Solutions to Limit Environmental Stress

Lead Partner: WIISE

Month: M8 – August 2023

D1.3 - Framework for activities criteria

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Executive Summary

The purpose of this deliverable (D), D1.3 - Framework for activities criteria, is to define the criteria for the WASTELESS Public Blockchain, the documents and codification of Food Loss and Waste (FLW) materials. The policy and regulatory aspects related to blockchain, and FLWs, will be used by partners in Work Package (WP) 1 (Transversal community of practice and framework for measurement and monitoring of FLW) to provide a mapping of existing aspects at European Union (EU) level (or individual Member States (MSs), where appropriate) and recommendations to foster use of blockchain and other Distributed Ledger Technologies (DLTs) in the measurement, quantification and management of FLWs.

The European Commission (EC) is broadly in favour of blockchain implementation for EU services, so much so that it has adopted a 'Blockchain Strategy', which is intended to operate as a 'gold standard' in line with the main objectives and regulatory aspects of environmental sustainability, data protection, cybersecurity, etc. The strategy has been detailed in a series of communications from the EC, promoting a range of strategies and initiatives that are needed to advance digitisation among EU citizens and economic actors, especially Small and Medium-sized Enterprises (SMEs).

The EC's actions have been supported by the European Parliament (EP), European Council (EUCO) and European Economic and Social Committee (EESC), through resolutions, conclusions, and autonomous opinions, which incentivise progress on digitisation through blockchain and other DLTs.

At present, blockchain services are not punctually standardised. They are the subject of pilot schemes to test possible implementation in certain EU market sectors (e.g., finance). Specific studies are also dedicated to implementation of blockchain within public administration, both at EU level and in individual MS.

The food sector is not excluded from the implementation of blockchain. The US has made it central to the 'New Era of Smarter Food Safety', where digital solutions were promoted and incentivised to fulfil traceability requirements. Research has already produced results in terms of publications, and possible frameworks to be adopted within Food Supply Chains (FSCs), in general or specific). However, adoption is still in its infancy, and is mainly carried out by large companies.

The application of blockchain in the measurement and management of FLWs is non-existent except for a few case studies. This is why WASTELESS aims to demonstrate, through practical application in several case studies across different FSCs (except primary production), how blockchain can be a useful tool to a) quantify and measure waste, in compliance with regulatory requirements, b) facilitate management of Food Waste (FW) for other uses, and c) reduce total amounts of FW generated within supply chains. In summary, blockchain has all the potential to contribute to the prevention and reduction of FW.

By demonstrating such capacities, WASTELESS aims to foster large-scale application of simple, functional and cost-effective blockchain technology (to benefit SMEs in particular), and stimulate adoption of dedicated policies and/or regulations and/or initiatives or other measures by the EC and/or other institutions (i.e., EP, EUCO).

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List of Acronyms

Abbreviation / acronym	Description
ABP	Animal by-product
AI	Artificial Intelligence
AH	Absolute Hazardous
ANH	Absolute Non-Hazardous
API	Application Programming Interface
B2B	Business-to-business
BBI JU	Bio-Based Industries Joint Undertaking
BIC	Bio-based Industries Consortium
BRC	British Retail Consortium
CBE JU	Circular Bio-based Europe Joint Undertaking
CEI	Circular Economy Indicator
CMO	Common Market Organisation
CN	Combined Nomenclature
CO	Certificate of Origin
CPA	Statistical Classification of Products by Activity
CPC	Central Product Classification
DG	Directorate-General
DG AGRI	Directorate-General for Agriculture and Rural Development
DG CNECT	Directorate-General for Communications, Networks, Content and Technology
DG SANTE	Directorate-General for Health and Food Safety
DLTs	Distributed Ledger Technologies
EAP	Environment Action Programme
EBP	European Blockchain Platform
EBSI	European Blockchain Service Infrastructure
EC	European Commission
ECA	European Court of Auditors

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EESC	European Economic and Social Committee
EFFPA	European Former Foodstuff Processors Association
EFSA	European Food Safety Authority
EIC	European Innovation Council
ELI	European Law Institute
EP	European Parliament
ESA	European Space Agency
ESFC	E-Submission Food Chain
ESS	European Statistical System
EU	European Union
EUCO	European Council
EWC-Stat	European Waste Classification for Statistics
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FBO	Food Business Operator
FDA	Food and Drug Administration
FEAD	Fund for European Aid to the Most Deprived
FeBO	Feed Business Operator
FL	Food Loss
FLW	Food Loss and Waste
FSAI	Food Safety Authority of Ireland
FSCs	Food Supply Chains
FSMA	Food Safety Modernization Act
FW	Food Waste
GEONOM	Geonomenclature
GIS	Geographic Information System
GISCO	Geographic Information System of the Commission
GHGs	Greenhouse gases
GRASS GIS	Geographic Resources Analysis Support System Geographic Information System
HACCP	Hazard Analysis Critical Control Point
HE	Horizon Europe
HP	Hazard Property
HS	Harmonised System
IARC	International Agency for Research on Cancer
IBM	International Business Machines Corporation
ICT	Information and communication technology
IDSS	Intelligent Decision Support System
IFIC	International Food Information Council
IFPRI	International Food Policy Research Institute
IFS	International Food Standard
IFSP	File security packet
INSPIRE	Infrastructure for Spatial Information in the European Union
IoT	Internet of Things

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IPFS	InterPlanetary File System
ISIC	International Standard Industrial Classification of All Economic Activities
ISO	International Organization for Standardization
ITGS	International Trade in Goods Statistics
JRC	Joint Research Centre
KPI	Key Performance Indicator
LAUs	Local Administrative Unit
LCA	Life Cycle Assessment
LoW	List of Waste
MH	Mirror Hazardous
MIG	Main Industrial Grouping
MNH	Mirror Non-Hazardous
MSs	Member States
NACE	Statistical classification of economic activities in the European Community
NIMEXE	Nomenclature of Goods for the External Trade Statistics of the Community and Statistics of Trade between Member States
NST/R	Standard goods classification for transport statistics/Revised
NUTS	Nomenclature of Territorial Units for Statistics
PDO	Protected Designation of Origin
PGI	Protected Geographical Indication
PoC	Proof of Concept
PRODCOM	*PRODuction COMmunautaire*
QGIS	Quantum Geographic Information System
RAMON	Reference And Management of Nomenclatures
RASFF	Rapid Alert System for Food and Feed
Reg.	Regulation
REI	Resource Efficiency Indicator
Rev.	Revision
RFID	Radio Frequency Identification
RRF	Recovery and Resilience Facility
SDGs	Sustainable Development Goals
SITC	Standard international trade classification
SMEs	Small and Medium-sized Enterprises
SOI	Sustainability-Oriented Innovation
SSD	Sewage Sludge Directive
SSD2	Standard Sample Description 2
STOA	Science and Technology Options Assessment
TARIC	*TARif Intégré Communautaire*
TFEU	Treaty on the Functioning of the European Union
TSE	Transmissible Spongiforme Encephalopathy
UAA	Utilised Agricultural Area
UN	United Nations
UNEP	United Nations Environment Programme

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UNC	University of North Carolina
USA	United States of America
UVMB	University of Veterinary Medicine Budapest
UWTD	Urban Wastewater Treatment Directive
VAT	Value Added Tax
WFD	Waste Framework Directive
WP	Work Package
XML	eXtensible Markup Language

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1. Introduction

This document aims to describe criteria for implementation of the WASTELESS[1] (Waste Quantification Solutions to Limit Environmental Stress) Public Blockchain within the project, with the aim of applying this blockchain as a tool for the measurement and quantification of Food Waste (FW) generated in different Food Supply Chains (FSCs), by Food Business Operators (FBOs).

To determine the information requested by the blockchain platform and implement the best functional strategies to ensure success, a review was carried out with regard to the following issues:

- Policies and regulations on waste and FW adopted within the European Union (EU);
- Identification of modalities for requesting and reporting information on FW produced by FBOs (i.e., EU statistics, EU indicators, food categories);
- State of the art of blockchain, and implementation in FSCs and Food Loss and Waste (FLW) management.

From the result obtained, the framework for structuring the WASTELESS Public Blockchain has been defined. It will be completed within the lifetime of project by Work Package (WP) 2 (Development of digital tools and methodologies). When the blockchain is completed, it will be tested within predetermined FSCs in the context of WP3 (Testing of the tools and methodologies in various case studies across the FSC) to verify the effectiveness of implementation and identify any improvements to simplify the adoption by food FBOs and ensure that valid results are obtained (i.e., measuring and quantifying FW).

2. Food loss and food waste framework in the European Union

FLW is defined by Food and Agriculture Organization of the United Nations (FAO)[2] as '*the decrease in quantity or quality of food along the food supply chain*'. Specific definitions were also provided for Food Loss (FL) (i.e., *result of decisions and actions by suppliers – affects the supply of food: if food losses are reduced, the supply of food into the food supply chain increases. Strictly speaking, FL therefore concerns all stages of the food supply chain up to, but excluding, the point where there is interaction with the final consumer and thus excludes retail, food service providers and consumers*) and FW (i.e., *result of purchasing decisions by consumers, or decisions by retailers and food service providers that affect consumer behaviour*).

The reduction of FLW has been appointed as a task for the EU Member States (MSs) through the implementation and adoption of measures to promote and reduce FLW, according to objectives of the 2030 Agenda for Sustainable Development[3], adopted by the United Nations (UN) General Assembly on 25 September 2015 and, in particular, Target 12[4], specifically Target 12.3 – Halve Global per Capita Food Waste from Sustainable Development Goals (SDGs), which states '*By 2030, halve per capita global food waste at the retail and consumer*

[1] https://wastelesseu.com/
[2] The definitions are included in 'State of Food and Agriculture 2019. Moving forward on food loss and waste reduction'. http://www.fao.org/3/ca6030en/ca6030en.pdf
[3] https://sdgs.un.org/2030agenda
[4] https://sdgs.un.org/goals/goal12

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levels and reduce food losses along production and supply chains, including post-harvest losses'. Those measures should aim to prevent and reduce FW in primary production, in processing and manufacturing, in retail and other distribution of food, in restaurants and food services as well as in households.

The European Commission (EC) has already developed policies and initiatives that aim directly and indirectly to contribute to the prevention and reduction of FLW. These consider also different crises that EU has faced in recent years (e.g., COVID-19 pandemic, Brexit, Ukraine-Russia war). Amongst the relevant ones, there are:

- *Green Deal*[5]: the latest EC commitment to tackle climate and environmental-related challenges, implementing the *Farm to Fork Strategy*;

- *Farm to Fork Strategy*[6]: sustainability is the key point of the strategy, accounting a) economic benefits from operators and consumers savings from FLW prevention and reduction, while promoting their reuse for the production of new food products (e.g., *upcycling*), or the recovery of nutrients, and feed uses among main different alternatives, b) environmental benefits from less disposal of FLW, and c) social benefits from the incentivisation of food recovery and redistribution. The Strategy aims also to amend actual dispositions related to *date marking* (i.e., 'use by' and 'best before' dates), which are confusing for consumers, to find the main reasons for FLWs at all production states, and implement actions at EU and national level;

- *Circular Economy Plan*[7]: implementing the dispositions of the former plan of the 2015[8], it sets the basis for a target on food waste reduction, accompanied by initiatives on reuse of food packaging, encouraging the water reuse in agriculture from the *Water Reuse Regulation* (i.e., Regulation (EU) 2020/741[9]), applied from 26th June 2023, and the implementation of an Integrated Nutrient Management Plan, to ensuring more sustainable application of nutrients and stimulating the markets for recovered nutrients, exploiting natural solutions for nutrient removal (e.g., algae). The plan is expected to be adopted by the EC in the second quarter of 2023[10];

[5] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions - The European Green Deal (COM/2019/640 final). https://eur-lex.europa.eu/legal-content/en/TXT/?uri=COM%3A2019%3A640%3AFIN

[6] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions - A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system (COM/2020/381 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381

[7] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions - A new Circular Economy Action Plan For a cleaner and more competitive Europe (COM/2020/98 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

[8] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions - Closing the loop - An EU action plan for the Circular Economy (COM/2015/0614 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614

[9] Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse. http://data.europa.eu/eli/reg/2020/741/oj

[10] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12899-Nutrients-action-plan-for-better-management_en

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- *Sustainable Bioeconomy*[11]: it covers all sectors and systems that rely on biological resources, including organic waste (e.g., FW) from the primary production up to the industrial sector. In combination with *Circular Economy Plan*, it foresees the possibility to cut FW by 50% by 2030 (e.g., FW reuse as feed, development of circular bioeconomy hubs in EU cities), creating job opportunities, reducing environmental impact and generating economical incomes for public and private companies. All types and innovations are welcomed by the EC for sustainable food and farming systems, including '*future proofing food and farming systems (terrestrial and aquatic) by addressing e.g., FW, FL and by-products (including nutrient recycling), resilience, the need for nutrition-sensitive food production, more food from the sustainable use of seas and oceans with increased share of EU aquaculture production and market uptake*'. Biological and fish waste are considered as opportunities for the creation of new bio-based value chains;

- *Food 2030*[12]: the EU's research and innovation policy to transform food systems and ensure everyone has enough affordable, nutritious food to lead a healthy life. It aims to achieve 4 key food and nutrition goals, which are: 1) Nutrition for sustainable and healthy diets (including the improvement of improving food authenticity, traceability and safety systems); 2) Food systems supporting a healthy planet; 3) Circularity and resource efficiency (including the achieving of *zero food waste*); 4) Innovation and empowering communities. Ten pathways for action are addressed and funded by Horizon Europe (HE), including the Pathway 5 – Food Waste and Resource Efficiency[13];

- *EU Platform on Food Losses and Food Waste*[14]: as previsioned in the *Circular Economy Plan* (2015), it aims to reduce FW through appropriate steps, the involvement of public and private stakeholders, the sharing of valuable and successful innovation and relevant benchmarking. Currently at its second mandate (2022-2026), it is composed of 5 subgroups, namely: 1) Sub-group on Action & implementation; 2) Sub-group on Date marking and food waste prevention; 3) Sub-group on Food donation; 4) Sub-group on Food loss and waste monitoring; 5) Sub-group on Consumer food waste prevention;

- *EU Food Loss and Waste Prevention Hub*[15]*:* it is a is a website for stakeholders who act to fight FLW, developed by the EC on the work of the REFRESH Community of Experts website, created under the EU-funded REFRESH project[16] as a database of FW prevention initiatives. It helps to share good practices, find relevant information on national actions (e.g., policies and legislative developments), and to have updates related to the thematic of FLW in the EU;

[11] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions - A sustainable Bioeconomy for Europe: Strengthening the connection between economy, society and the environment (SWD (2018) 431 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018SC0431

[12] https://research-and-innovation.ec.europa.eu/research-area/environment/bioeconomy/food-systems/food-2030_en

[13] De Froidmont-Goertz I. et al. (2020) Food 2030 pathways for action. Research and innovation policy as a driver for sustainable, healthy and inclusive food systems. *Publications Office of the European Union*, ISBN 978-92-76-18121-7, https://doi.org/10.2777/104372

[14] https://food.ec.europa.eu/safety/food-waste/eu-actions-against-food-waste/eu-platform-food-losses-and-food-waste_en

[15] https://ec.europa.eu/food/safety/food_waste/eu-food-loss-waste-prevention-hub

[16] https://eu-refresh.org/

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- *EC Library Guide on food waste*[17]: it is a repository of EU publications (e.g., Joint Research Centre (JRC) reports, EC publications), legislation, statistics, books and other materials related to FLW;

- *Soil Strategy for 2030*[18]: following the adoption of the Integrated Nutrient Management Action Plan, and the revision of the Urban Wastewater Treatment Directive (UWTD) and the Sewage Sludge Directive (SSD), and the will to oblige the separate collection of organic waste, a LIFE project is intended to be funded, for the use of high-quality compost from biowaste on soil, together with other funding destined to research related to environmentally sound recovery of organic fertilisers from bio-waste. The scarcity of soil and nutrients increases the FL within the primary production. This problem has to be coped with, together with the EU Mission: A Soil Deal for Europe[19];

- *A Clean Planet for all*[20]: FLW (i.e., agriculture loss and food waste) contributes to the growth of air pollution in the EU, especially with the increase of Greenhouse gases (GHGs), causing severe disease and premature deaths, and increasing health costs significantly. Nonetheless, the climate change (e.g., temperature increase) is a menace to food availability;

- *EU Biodiversity Strategy 2030*[21]: biodiversity is fundamental for the food production, water supply (i.e., filtration of drinkable water) and air availability. Not only preservation of soils is considered fundamental, considering the reduction of pollution through nutrients loss (to be reduced by at least 50%), but also the maintaining of fisheries stocks, which have to be harvested with sustainability and without illegal practices.

- *Protection and restoration of marine ecosystems*[22]: oceans and seas are 65% of the EU territory, and one of the greatest sources of food and biodiversity, contributing to climate mitigations, thanks to its carbon sink activity. Mobile bottom fishing is a risk for the sustainability of fisheries and the availability of fish in the medium- and longer-term, being the least selective fishing method, and producing consequently disproportionate amounts of unwanted catches and discards, leading to production of

[17] https://ec-europa-eu.libguides.com/food-waste

[18] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions – EU Soil Strategy for 2030: Reaping the benefits of healthy soils for people, food, nature and climate (COM/2021/699 final). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52021DC0699

[19] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/soil-health-and-food_en

[20] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions and the European Investment Bank – A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy (COM/2018/773 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0773

[21] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions – EU Biodiversity Strategy for 2030: Bringing nature back into our lives (COM/2020/380 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0380

[22] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions – EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries (COM/2023/102 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0102

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FLW. Protection and restoration measures are needed to prevent and reduce this kink of FLW;

- *European Partnership for a Circular Bio-Based Europe*: Circular Bio-based Europe Joint Undertaking (CBE JU)[23] is a partnership between the EU and the Bio-based Industries Consortium (BIC), which funds projects advancing competitive circular bio-based industries under HE, as the successor of Bio-Based Industries Joint Undertaking (BBI JU). It has been established by the Regulation (Reg.) (EU) 2021/2085[24], with the aim to develop renewable bio-based products, materials, processes and nutrients from waste and biomass through sustainability and circularity-driven innovation in urban, rural and coastal territories, focusing on multiscale biorefinery processing. BBI JU provided 34 recommendations, which suggested to '*involve a wider range of stakeholders including the primary sector (namely agriculture, aquaculture, fisheries and forestry) as well as providers of waste, residues and side streams, regional authorities and investors to prevent market failures and unsustainable bio-based processes*'[25].

The European Parliament (EP) has released a briefing document named 'Reducing food waste in the European Union[26]', summarising actions performed by the EU and by EU MSs (which could be find in the *EU Food and Loss Prevention Hub*) to tackle FLW. Different resolutions have been adopted since 2012 to address specific FW prevention targets, increasing their severity and their area of application every time, up to the need for an EU-wide FW reduction target of 50 % by 2030, based on a common methodology.

Consumer analyses determined a potential cause for FW is '*often a result of poor purchase planning, excess and impulse buying* (due to scarcity of time)*, confusion over labels ('best before' and 'use by'), poor in-home storing or stock management, preparation of too much food, and a lack of knowledge on how to use leftovers in other recipes instead of discarding them*'. Other findings were the need to consume a 'perfect product' (e.g., colour, shape, size), discarding other food that do meet perceived standards. Package and portion sizes may also be contributors, since they promote unnecessary buying, often leading to production of FW. Other issues might be related to generational aptitudes for particular food demands (e.g., without food additives) or being healthier, which also lead to quicker spoilage and potential production of FW.

The European Council (EUCO) conclusions on FLW have recalled the SDGs FW reduction target, and asked, *inter alia*, for a common measurement and methodology among the MSs. A series of initiatives, including better monitoring food waste, raising awareness among the general population, improving understanding and use of 'best before' and 'use by' labels (including among consumers), and making it easier to donate unsold food products to charities, were included (**Figure 1**).

[23] https://www.cbe.europa.eu/

[24] Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe and repealing Regulations (EC) No 219/2007, (EU) No 557/2014, (EU) No 558/2014, (EU) No 559/2014, (EU) No 560/2014, (EU) No 561/2014 and (EU) No 642/2014. http://data.europa.eu/eli/reg/2021/2085/oj

[25] See Recital 46 of Regulation (EU) 2021/2085.

[26] https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/659376/EPRS_BRI(2020)659376_EN.pdf

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According to the special report 'Combating Food Waste: an opportunity for the EU to improve the resource-efficiency of the food supply chain[27]' adopted by the European Court of Auditors (ECA), EU MSs are not approaching the FLW problem properly, with efforts being 'fragmented and intermittent', and lack of a common definition of FW has hampered progress. Conclusions state that '*many of the potential improvements do not require new initiatives nor [sic] more public funding, but rather involve a better alignment of existing policies, improved coordination, and clearly identifying the reduction of food waste as a policy objective*'.

The EP and the EUCO have jointly adopted Decision (EU) 2022/591[28] on a general action programme in the field of the environment, i.e., 8th Environment Action Programme (EAP), up to 31st December 2030. The 8th EAP must contribute to EU efforts to measure progress towards sustainability, well-being, and resilience, accelerating the green transition to a climate-neutral, sustainable, resilient and competitive circular economy, halting and reversing biodiversity loss. To achieve these objectives, *food systems* must change accordingly. There are six interlinked thematic priorities objectives to be achieved up to 31st December 2030, including the '*advancing towards a well-being economy that gives back to the planet more than it takes and accelerating the transition to a non-toxic circular economy, where growth is regenerative, resources are used efficiently and sustainably, and the waste hierarchy is applied*'. By 2050 at least, is expected that people will live well in a well-being economy where nothing is wasted, growth is regenerative, climate neutrality in the Union has been achieved, and inequalities have been significantly reduced.

[27] European Court of Auditors (2016) Combating Food Waste: an opportunity for the EU to improve the resource-efficiency of the food supply chain. *Publications Office of the European Union,* ISBN 978-92-872-6416-9, https://doi.org/10.2865/272895

[28] Decision (EU) 2022/591 of the European Parliament and of the Council of 6 April 2022 on a General Union Environment Action Programme to 2030. http://data.europa.eu/eli/dec/2022/591/oj

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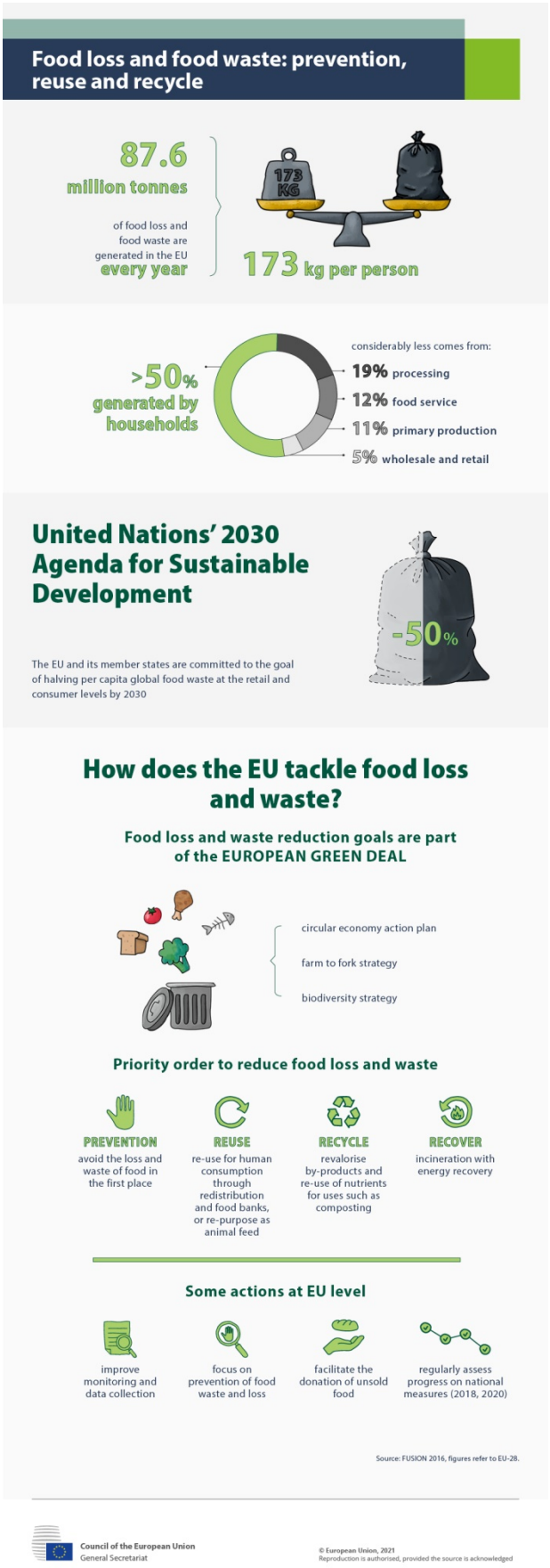

Figure 1. Food loss and waste: prevention, reuse and recycle infographic (source: EUCO)

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2.1.EU Waste Framework Directive

The latest Waste Framework Directive (WFD) (i.e., Directive 2008/98/EC[29]) has been implemented with the aim to minimise the negative effects of generating and managing waste (definitions are provided in **Annex 1**) on human health and the environment, reduce the use of resources, and favour the practical application of the waste hierarchy. Waste prevention should be the priority of waste management, and reuse and recycle preferred to energy recovery, with disposal being the last intended measure.

Within the previous WFD (i.e., Directive 2006/12/EC[30]), there was no distinction between 'waste' and 'by-product', and a legal notion of the latter, which required implementation of a communication by the EC[31], where 'by-product' was defined as '*a production residue that is not a waste*'. The production of 'by-products', destined to be in the animal feed, has been reported as the primary example in the food and drink industry. A decision tree has been realised to assist proper identification between 'waste' and 'by-products' (**Figure 2**).

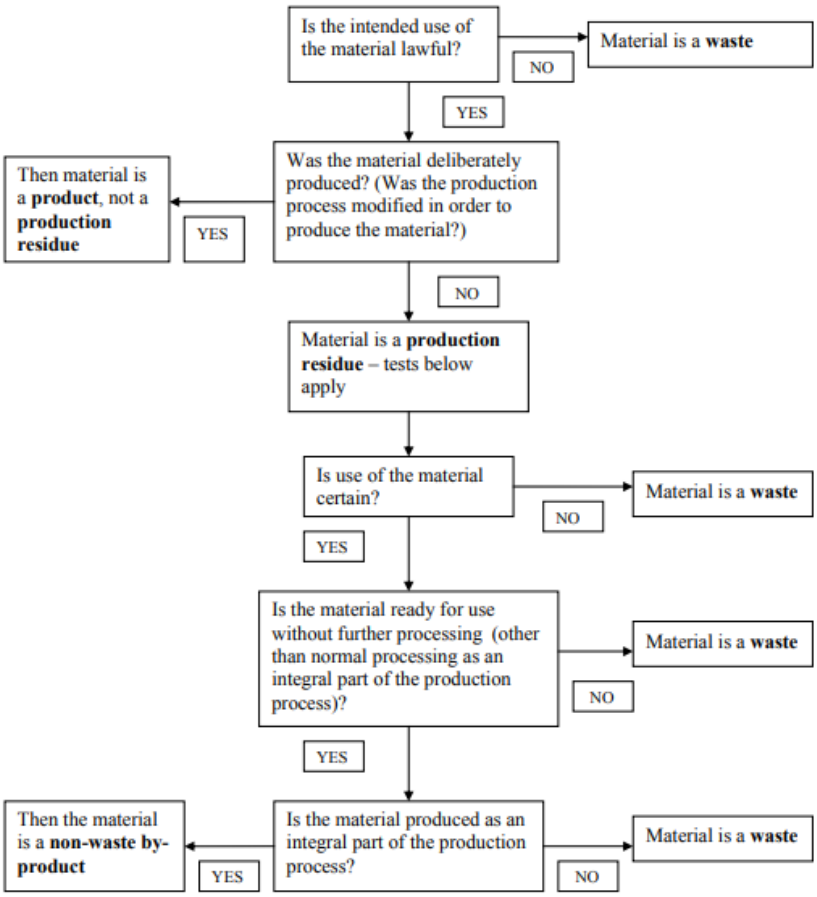

Figure 2. Decision tree for waste versus by-product decisions (source: EC)

[29] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. http://data.europa.eu/eli/dir/2008/98/oj

[30] Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste. http://data.europa.eu/eli/dir/2006/12/oj

[31] Communication from the Commission to the Council and the European Parliament on the Interpretative Communication on waste and by-products (COM(2007) 59 final). https://eur-lex.europa.eu/legal-content/IT/ALL/?uri=CELEX%3A52007DC0059

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To avoid further confusion, the new WFD implemented procedures for by-products that are not waste and waste that ceased to be waste (i.e., end-of-waste). The WFD also set a 'waste hierarchy' for the first time, prioritising waste prevention, management legislation, and policies to achieve a) prevention; b) re-use; c) recycling; d) other recovery (e.g., energy recovery) as well as e) disposal.

No specific dispositions for food were provided (food and kitchen wastes were included in the WFD as 'bio-waste'), leading to measures applied by EU MSs intended to a) separate collection of bio-waste for composting and digestion; b) treatment to assure high levels of environmental protection; and c) use of environmentally safe materials from bio-waste. It is only following revision of the WFD, achieved with the implementation of Directive (EU) 2018/851[32], that specific dispositions for food were included. A definition of FW at European level has been defined, which comprehends 'all food[33] that has become waste'. Now, however, no definition has been provided for FL. Dispositions for prevention of waste (Article 9) has been amended, with the need for MS to adopt and monitor measures to prevent FW generation that:

- reduce the generation of food waste in primary production, in processing and manufacturing, in retail and other distribution of food, in restaurants and food services as well as in households as a contribution to the UN SDG to reduce by 50 % the per capita global food waste at the retail and consumer levels and to reduce food losses along production and supply chains by 2030;

- encourage food donation and other redistribution for human consumption, prioritising human use over animal feed and the reprocessing into non-food products.

The MSs are also required to adopt specific FW prevention programmes within their waste prevention activities (from insertion of paragraph 2a in Article 29).

Finally, the application of a 'waste hierarchy' has been implemented with the addition of Annex Iva, which indicates examples of economic instruments and other measures to provide incentives for application, including fiscal incentives for donation of products, in particular food, as well as being assessed for their contribution to waste prevention, when adopted in FW prevention programmes.

The WFD contains two important principles that are intended to reduce the amount of waste generated in the EU, and incentivise application of 'waste hierarchy'. These are the 'polluter-pays principle' and the 'extended producer responsibility'.

The 'polluter-pays principle' states that the costs of disposing of waste must be borne by the holder of waste, by previous holders, or by the producers of the product from which the waste came. For this reason, fiscal incentives applied as in Annex Iva for donated food are generally related to the reduction of waste taxes.

The 'extended producer responsibility' may be incentivised by any means from legislative or non-legislative measures implemented by MSs to ensure implementation by FBOs (or any other natural or legal person who professionally develops, manufactures, processes, treats, sells or imports products (producer of the product) and strengthen the re-use and prevention, recycling and other recovery of waste.

[32] Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste. http://data.europa.eu/eli/dir/2018/851/oj
[33] According to Article 2 of Regulation (EC) No. 178/2002.

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The European List of Waste (LoW) is included in the Annex of Decision 2000/532/EC[34]. Even if this refers to previous WFDs, it still applies to current ones. It is a harmonised list of wastes that may be reviewed periodically. However, the inclusion of materials in the list does not mean they are always 'waste', but it is necessary that the definition of 'waste' provided in WFD is fulfilled.

Different types of waste are defined with a 6-digit code, with 2-digit chapter and 4-digit sub-chapter headings. Chapters of interest for FW are:

- 02 Wastes from agricultural, horticultural, hunting, fishing and aquaculture primary production, food preparation and processing;
- 16 Wastes not otherwise specified in the list;
- 20 Municipal wastes and similar commercial, industrial and institutional wastes, including separately collected fractions.

Different entries will be further discussed in the following sections, in relation to the common methodology and minimum quality requirements for the uniform measurement of levels of FW (see Chapter 2.1.1).

To support competent authorities and operators with the application of WFD, a communication document[35] has been published by the EC. This guideline is relevant for two aspects: 1) decision scheme for waste classification, and 2) details the LoW, especially hazard categories.

Each waste stream generated by a producer, from a representative sample, must be assessed and classified properly (according to **Figure 3**). If more than one type of waste is present, they must be assessed separately. This is important to prevent erroneous classification (i.e., hazardous as non-hazardous, or vice versa), or mixing with other waste being identified in time. The only exception is for mixed municipal waste from domestic households. For a proper classification, FBOs (for this specific case) must identify the applicability of FWD and, in case of positive response, the LoW category.

Entries included in the Decision 2000/532/EC are also classified as Absolute Hazardous (AH) (marked with an asterisk (*)), or as Absolute Non-Hazardous (ANH), meaning their classification as 'hazardous' or 'not-hazardous' without further assessment. Mirror entries are, instead, two or more related entries where one is hazardous and the other is not and, for this reason, a further assessment is needed for proper allocation. The alternatives are Mirror Hazardous (MH) (also marked with an asterisk (*)), and Mirror Non-Hazardous (MNH). Annex III of WFD includes the properties of waste which render it hazardous, indicated with Hazard Property (HP).

[34] 2000/532/EC: Commission Decision of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste (notified under document number C(2000) 1147). http://data.europa.eu/eli/dec/2000/532/oj

[35] Commission notice on technical guidance on the classification of waste (C/2018/1447). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018XC0409%2801%29&qid=1689607680969

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Details have been provided for LoW, indicating the specific entry type for each code. The chapter heading 02 contains only ANH entries, chapter heading 16 of interest (i.e., 16 03 06) is classifies as MNH, as there is another similar category (i.e., 16 03 05*) being classified as MH, and chapter heading 20 contains both ANH and MNH voices. They are reported and detailed in **Annex 2** (full list of food categories in the LoW).

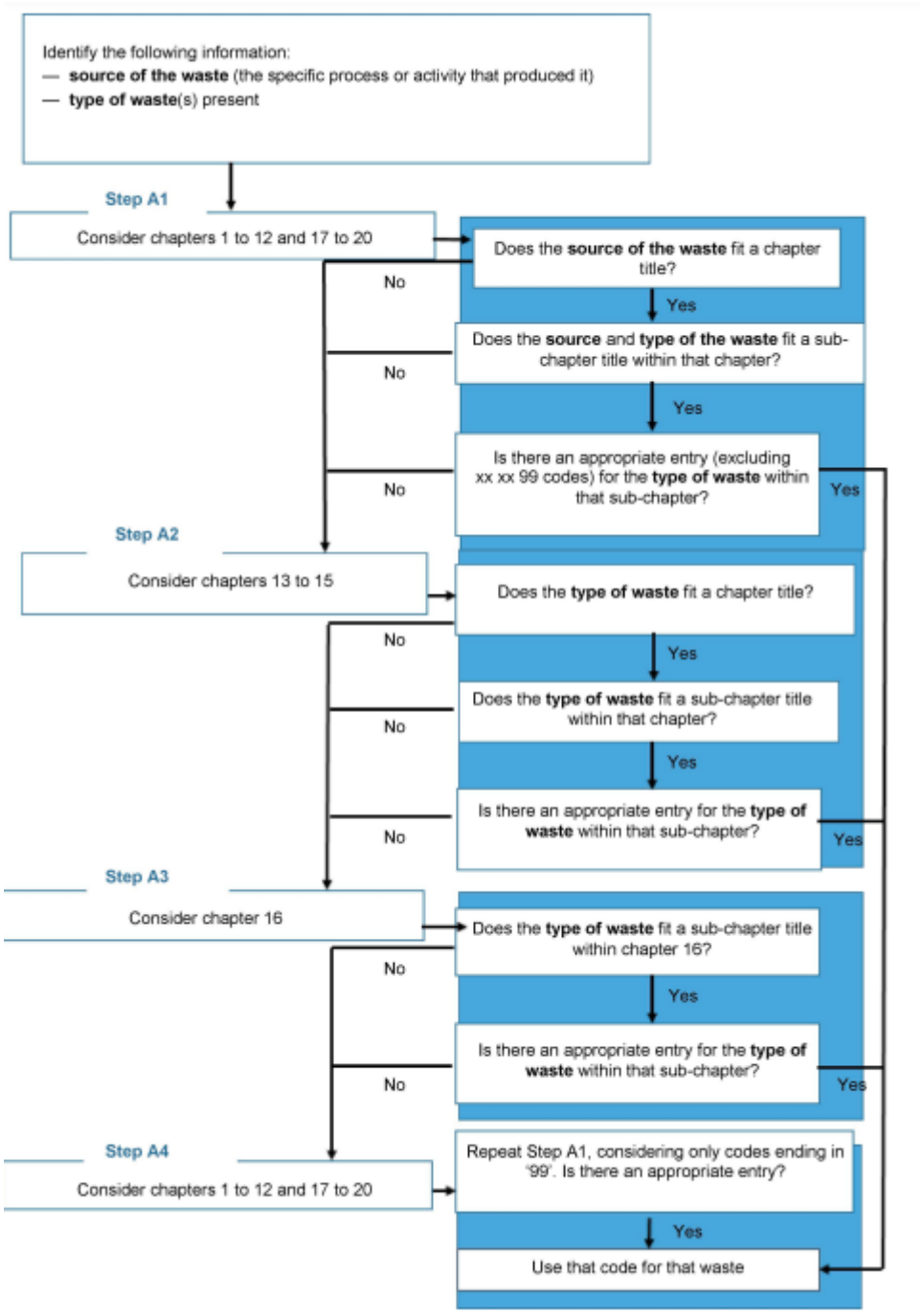

Figure 3. Decision scheme for the identification of appropriate waste entry (source: EC)

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The WFD provides some exclusions, since there is other Community legislation that cover them. The pertinent exclusions are:

- waste waters;
- Animal by-products (ABPs), except those which are destined for incineration, landfilling or use in a biogas or composting plant;
- carcasses of animals that have died other than by being slaughtered, including animals killed to eradicate epizootic diseases, and that are disposed of in accordance with Reg. (EC) No. 1069/2009[36] (i.e., *ABP Regulation*);
- substances that are destined for use as feed materials[37], and that do not consist of or contain ABPs.

2.1.1. Food Loss and Waste measurement

The FWD, as implemented by the Directive (EU) 2018/851, contains different dispositions for the EC to establish delegated or implementing acts that supplement the Directive.

Commission Delegated Decision (EU) 2019/1597[38] (from now Decision (EU) 2019/1597) has been emanated, according to Article 9(8) of the WFD and results from the EU Platform on FLW, defining a common methodology and minimum quality requirements for the uniform measurement of levels of FW. The measurement must be performed in the following FSCs: 1) primary production; 2) processing and manufacturing; 3) retail and other distribution of food; 4) restaurants and food services; 5) households.

For each FSC, FW has to be attributed to stages indicated in the Reg. (EC) No. 2150/2002[39] and, in Reg. (EC) No. 1893/2006[40] (i.e., Statistical classification of economic activities in the European Community (NACE) Revision (Rev.) 2) (these statistics will be detailed in Section 2.2), using LoW codes included in the Decision, or under any other codes that includes FW. There is some food excluded by the Decision, but it is possible to implement voluntary measurements by MSs for specific food categories/items, regarding FW levels and FW prevention data (**Table 1**).

[36] Regulation (EC) No. 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No. 1774/2002 (Animal by-products Regulation). http://data.europa.eu/eli/reg/2009/1069/oj

[37] Included in Article 3(2)(g) of Regulation (EC) No. 767/2009.

[38] Commission Delegated Decision (EU) 2019/1597 of 3 May 2019 supplementing Directive 2008/98/EC of the European Parliament and of the Council as regards a common methodology and minimum quality requirements for the uniform measurement of levels of food waste. http://data.europa.eu/eli/dec_del/2019/1597/oj

[39] Regulation (EC) No. 2150/2002 of the European Parliament and of the Council of 25 November 2002 on waste statistics. http://data.europa.eu/eli/reg/2002/2150/oj

[40] Regulation (EC) No. 1893/2006 of the European Parliament and of the Council of 20 December 2006 establishing the statistical classification of economic activities NACE Revision 2 and amending Council Regulation (EEC) No. 3037/90 as well as certain EC Regulations on specific statistical domains. http://data.europa.eu/eli/reg/2006/1893/oj

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Table 1. FW excluded or subjected from voluntary measurement, according to Decision (EU) 2019/1597

<table>
<tr><th colspan="2">Food waste measurement (Decision (EU) 2019/2157)</th></tr>
<tr><th>Exclusions</th><th>Voluntary measurement</th></tr>
<tr><td>Agricultural material</td><td rowspan="3">Amounts of FW regarded as composed of parts of food intended to be ingested by humans</td></tr>
<tr><td>ABPs</td></tr>
<tr><td>FW residues collected within packaging waste classified under waste code ‘15 01 — Packaging (including separately collected municipal packaging waste)</td></tr>
<tr><td>FW residues collected within waste classified under waste code: ‘20 03 03 — Street cleaning residues’</td><td rowspan="2">Amounts of food which has been redistributed for human consumption</td></tr>
<tr><td>Non-food materials that are mixed together with food waste when collected, to the extent possible</td></tr>
<tr><td colspan="2">Food waste drained as or with wastewater</td></tr>
<tr><td colspan="2">Substances that are destined for use as feed materials (i.e. former foodstuffs, food no longer intended for human consumption placed on the market for transformation into feed by a Feed Business Operator (FeBO)</td></tr>
</table>

Measurement has to be done with one of the methodologies described in Annex III or Annex IV of the Decision (EU) 2019/1597 (**Table 2**), reporting FW amount in metric tons (i.e., tonnes) of fresh mass. Annex IV provides that FW amount is calculated using one of the following methods, or combining them:

a) Calculation of the amount of food waste on the basis of the latest available data on the share of food waste in a given stage of the food supply chain (established in accordance with Annex III) and total waste generation in that stage. The total waste generation in a given stage of the food supply chain shall be established on the basis of the data reported in accordance with the requirements of Reg. (EC) No. 2150/2002 for each of the stages of the food supply chain referred to in Annex I. In cases where such data is not available for a given year, the data for the previous year shall be used;

b) Calculation of the amount of food waste on the basis of socioeconomic data relevant for the respective stages of the food supply chain. The calculation of food waste shall be based on the latest data on amounts of food waste generated within a stage of the food supply chain and the increase or decrease, in the period from the year of the latest measurement of that data to the current reporting period, of the level of one or more of the following socioeconomic indicators.

Table 2. Methodologies for the measurement of FW in EU MSs

<table>
<tr><th colspan="3">FW measurement methodologies (Decision (EU) 2019/1597)</th></tr>
<tr><th>FSC stage</th><th>Annex III (methodologies)</th><th>Annex IV (indicators[41])</th></tr>
<tr><td>Primary production</td><td rowspan="2">- Direct measurement
- Mass balance
- Questionnaires and interview
- Coefficients and production statistics</td><td>- Food production in agriculture, fishery and hunting</td></tr>
<tr><td>Processing and manufacturing</td><td>- Production of processed food — based on Production</td></tr>
</table>

[41] Other indicators may be used, if there is a better correlation with FW generation within a specific FSC stage.

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	- Waste composition analysis	Communautaire (PRODCOM) data.
Retail and other distribution of food	- Direct measurement - Mass balance - Waste composition analysis - Counting/scanning	- Turnover of food products - Population
Restaurants and food services	- Direct measurement - Waste composition analysis - Counting/scanning - Diaries	- Turnover - Employment (in Full Time Equivalents)
Households	- Direct measurement - Waste composition analysis - Diaries	- Population - Households disposable income (Eurostat data)

Commission Implementing Decision (EU) 2019/2000[42] (from now Decision (EU) 2019/2000) includes the format for reporting data on FW levels, measured with the methodologies set in Decision (EU) 2019/1597, together with the format for the quality check report accompanying these data.

The general structure of the formats described in **Table 3**.

Table 3. Formats for FW data and quality check measured by methodologies set in Decision (EU) 2019/1597

FW reporting formats (Decision (EU) 2019/2000)	
A. FW levels reporting format	**B. Quality check report format**
Data on food waste amounts (in metric tons of fresh mass) - Total food waste - Fraction of total food waste, composed of parts of food intended to be ingested by humans - Food waste drained as or with wastewaters	1) Objectives of the report
	2) General information
	3) General information on data collection (indication of the methodologies used for each FSC stage)
Data on management of food surplus related to food waste prevention (in metric tons of fresh mass) - Food redistributed for human consumption - Food placed on the market for transformation into feed - Former foodstuffs	4) Information concerning measurement using the methodology set out in Annex III - General description for data source - Specific description for the method(s) used
	5) Information concerning measurement using the methodology set out in Annex IV to Delegated Decision (EU) 2019/1597
	6) Voluntary reporting
	7) Methodological changes and problems notifications

[42] Commission Implementing Decision (EU) 2019/2000 of 28 November 2019 laying down a format for reporting of data on food waste and for submission of the quality check report in accordance with Directive 2008/98/EC of the European Parliament and of the Council (notified under document C (2019) 8577). http://data.europa.eu/eli/dec_impl/2019/2000/oj

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	- Description of methodological changes (if applicable) - Explanation of tonnage difference (if applicable) - Notification of problems (if any)
	8) Confidentiality
	9) Main national websites, reference documents and publications

Text written in black indicates mandatory data, text written in grey indicates voluntary data

The EC has developed a common methodology for bio-waste (which includes FW) separated and recycled at source from people that generate it, establishing from it the Commission Implementing Decision (EU) 2019/1004[43] (from now Decision (EU) 2019/1004).

Recycled municipal bio-waste to be calculated includes only materials that undergo aerobic or anaerobic treatment, and all materials (including biodegradable materials) must be excluded, if mechanically removed during or after recycling operations. From 1st January 2027, bio-waste may be counted as 'recycled' only if it is: a) separately collected at source; b) collected together with waste with similar biodegradability and compost ability properties; c) separated and recycled at source.

Data collection must be performed with the methodology set in Annex II of the Decision to calculate municipal bio-waste amount separated and recycled at source; this is to be included both in the amount of municipal waste recycled and in the total amount of municipal waste generated. Establishments or undertakings managing waste, as appropriate, must provide these data, and MSs must consider the potential to use electronic registries to record data on municipal waste.

Alternatively, if data are collected based on surveys, the following minimum requirements have to be fulfilled: a) they shall be carried out at regular, specified intervals, and shall adequately meet the variation in the data to be surveyed; (b) they shall be based on a representative sample of the population to which their results are applied.

The amount of municipal bio-waste separated and recycled at source shall be calculated using:

$$m_{MBWRS} = \Sigma\, n_{ARUi} \times (m_{Fi} + m_{Gi})$$

where:

m_{MBWRS}: mass of municipal bio-waste separated and recycled at source;

n_{ARUi}: number of active recycling units for the recycling of municipal bio-waste at source[44] in subsample i;

[43] Commission Implementing Decision (EU) 2019/1004 of 7 June 2019 laying down rules for the calculation, verification and reporting of data on waste in accordance with Directive 2008/98/EC of the European Parliament and of the Council and repealing Commission Implementing Decision C (2012) 2384. http://data.europa.eu/eli/dec_impl/2019/1004/oj

[44] The number includes only those recycling units that are used by waste producer, retrieved from registers of such units or obtained through surveys of households.

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m_{Fi}: mass of food and kitchen municipal bio-waste recycled at source per active recycling unit in subsample i; and

m_{Gi}: mass of garden and park municipal bio-waste recycled at source per active recycling unit in subsample i.

The amount of municipal bio-waste that is recycled at source per active recycling unit must be determined through direct or indirect measurement of bio-waste entering active recycling units. The requirements for the measuring for both direct and indirect measurements are reported in **Table 4**.

Table 4. Direct and indirect measurements requirements for bio-waste entering active recycling units

Direct measurement	Indirect measurement
a) the measurement shall be carried out, where feasible, by or on behalf of public authorities	a) the amount of bio-waste contained in collected municipal waste that is generated by households or in areas where waste is separated and recycled at source
b) where the measurement is carried out by the waste producers themselves, MSs shall ensure that the reported amounts are subject to plausibility checks and are adjusted to the effect that the amount of bio-waste separated and recycled at source per person in no case exceeds the average amount per capita of municipal biowaste collected by waste operators at national, regional or local level	b) the amount of bio-waste contained in collected municipal waste that is generated by households or in areas with characteristics that are similar to the characteristics of households or areas referred to in point (a), where waste is not separated and recycled at source
c) where the output of an active recycling unit is measured, a reliable coefficient shall be applied in order to calculate the amount of the input	c) the amount of municipal bio-waste that is separated and recycled at source shall be determined based on the difference between the amounts specified in points (a) and (b).

These methodologies, in particular surveys for data collection, have to at least reflect the following factors: a) size and type of households that use an active recycling unit in the case of food and kitchen waste; (b) size and management of gardens and parks served by an active recycling unit in the case of garden and park waste; c) available collection system, in particular the complementary use of waste collection services for bio-waste and mixed municipal waste; d) level and seasonality of municipal bio-waste generation.

If the share of municipal bio-waste separated and recycled at source in all municipal waste generated is less than 5 % at national level, MS may use a simplified methodology to calculate municipal bio-waste separated and recycled at source:

$$m_{MBWRS} = n_P \times m_{BWpp} \times q_{RS}$$

where:

m_{MBWRS}: mass of municipal bio-waste separated and recycled at source;

n_P: number of persons involved in municipal bio-waste recycling at source;

m_{BWpp}: mass of generated municipal bio-waste per capita[45]; and

[45] It has to be is calculated on the basis of surveys on the composition of separately collected and mixed municipal waste at national, regional or local level as appropriate.

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q_{RS}: coefficient representing the share of municipal bio-waste generated that is likely to be separated and recycled at source in the total amount of municipal bio-waste generated[46].

Both formulae may be applied to all municipal bio-waste separated and recycled at source or only to food and kitchen municipal bio-waste separated and recycled at source. Surveys for data collection must be carried out for the first year and, after that, every five years (unless significant changes are expected). They must be based on representative samples and appropriate sub-samples and be statistically significant according to accepted scientific techniques. Appropriate measures must be adopted to ensure that the reported amounts of municipal bio-waste that are separated and recycled at source are not over-estimated.

This Decision also provided an obligation for data and quality check reports submission, according to Annex IV or to its Annex V. The formats are similar to the one established for Decision (EU) 2019/2000.

Decision (EU) 2021/19[47] (from now on Decision (EU) 2021/19) set a common methodology and a format for reporting reuse. This imposes the adoption of a qualitative and quantitative monitoring of measures on reuse.

Qualitative monitoring must be carried once per year, and it must include an identification and description of measures on reuse and an assessment of their impacts, or expected impacts, on the basis of the available data. The measurement includes reuse generated by reuse operators or households in accordance with any of the following methods or a combination of those methods or any other method equivalent in terms of relevance, representativeness, and reliability:

(a) direct measurement of reuse by using a measuring device to determine the mass of reused products;

(b) mass balance calculation of reuse on the basis of the mass of inputs and outputs of products in reuse operations;

(c) questionnaires and interviews of reuse operators or households;

(d) diaries of individuals keeping a record or log of information on reuse on a regular basis.

Quantitative monitoring must be performed once every three years, ensuring data reliability and accuracy, and the reference to a representative sample of the population or reuse operators or households, as applicable.

Also, in this case, the reporting is like the one defined for Decision (EU) 2019/2000. Although there is no specific reference to FW, 'other' gives the potential to include 'FW reuse' in the reports.

Facilitation of reuse and recycle by MSs is an obligation set in Article 11(1) of WFD. To assure compliance, and a high level of resource efficiency for a European Circular Economy, MSs have to take the necessary measures designed to achieve different targets including:

[46] The factors to be considered for methodologies application have to be taken into account.
[47] Commission Implementing Decision (EU) 2021/19 of 18 December 2020 laying down a common methodology and a format for reporting on reuse in accordance with Directive 2008/98/EC of the European Parliament and of the Council (notified under document C (2020) 8976). http://data.europa.eu/eli/dec_impl/2021/19/oj

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- by 2025, the preparing for re-use and the recycling of municipal waste shall be increased to a minimum of 55 % by weight;

- by 2030, the preparing for re-use and the recycling of municipal waste shall be increased to a minimum of 60 % by weight;

- by 2035, the preparing for re-use and the recycling of municipal waste shall be increased to a minimum of 65 % by weight.

To verify compliance, there are rules and calculation methods set in Commission Decision 2011/753/EU[48] (from now Decision 2011/753/EU). Municipal waste also includes household waste and similar waste (i.e., waste in nature and composition comparable to household waste, excluding production waste and waste from agriculture and forestry).

Calculation method 3 (included in Annex I) determines recycling rates of household waste as %:

$$\frac{\text{Recycled amount of household waste}}{\text{Total household waste amounts excluding certain waste categories}}$$

Activities must be reported using national data and be submitted with a report explaining materials covered in Annex II of the Decision as well as the method for calculation of amounts. These materials include 'biodegradable kitchen and canteen waste', 'biodegradable garden and park waste', 'other municipal waste' and 'municipal waste not mentioned above' (to be specified).

A calculation method is available for preparation for reuse and recycling of municipal waste (i.e., calculation method 4), which determines the recycling of municipal waste in %:

$$\frac{\text{Municipal waste recycled}}{\text{Municipal waste generated}}$$

The MSs shall rely on the statistical data on municipal waste reported annually to the EC (i.e., Eurostat).

2.1.2. FLW prevention and reduction practices

Generation of surplus food is one of the main sources of FW. A solution to prevent waste of surplus is to donate it. Thus, food redistribution and donation are considered the first strategy to follow, to achieve prevention and reduction of FW in EU. This is in line with the 'waste hierarchy' and achieves economic savings (e.g., avoiding of disposal costs), environmental benefits (e.g., avoiding of disposal), and social welfare (e.g., providing food for people who needs it).

[48] 2011/753/EU: Commission Decision of 18 November 2011 establishing rules and calculation methods for verifying compliance with the targets set in Article 11(2) of Directive 2008/98/EC of the European Parliament and of the Council (notified under document C (2011) 8165). http://data.europa.eu/eli/dec/2011/753/oj

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To promote redistribution and donation in different EU MSs, the EC has published a communication guideline[49] that explain the issue of FW, describing stakeholders and their obligation within FSCs, especially as related to hygiene/food safety. In fact, the donation of food does not exclude operators' responsibilities under *General Food Law* (i.e., Reg. (EC) No. 178/2002[50]), *Hygiene Regulations* (i.e., Reg. (EC) No. 852/2004[51], and Reg. (EC) No. 853/2004[52]), and FIC Regulation (i.e., Reg. (EU) No. 1169/2011[53]), such as proper labelling, traceability, implementation of a Hazard Analysis Critical Control Point (HACCP) plan and, first of all, that redistributed food is safe (i.e., injurious to health and/or unfit for human consumption). For this, FBOs are also subjected to related official controls, as implemented by Official Controls Regulation (i.e., Reg. (EU) 2017/625[54]), its implementation, and delegated acts.

Operators must consider different Value Added Tax (VAT) disposition from national laws, implementing Directive 2006/112/EC[55], since payment can be required even in the case of food donations. There are national laws that permit fiscal incentives (e.g., tax deductions). At EU level, there are funding programmes, such as Fund for European Aid to the Most Deprived (FEAD) (disciplined by Reg. (EU) No. 223/2014[56]) that support purchase and donation of food for most deprived people, including cost activities for the collection, transportation, storage, and distribution, contributing to reduce FW. The Common Market Organisation (CMO) for fruit and vegetable

[49] Commission notice — EU guidelines on food donation (C/2017/6872). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017XC1025(01)

[50] Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. http://data.europa.eu/eli/reg/2002/178/oj

[51] Regulation (EC) No. 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. http://data.europa.eu/eli/reg/2004/852/oj

[52] Regulation (EC) No. 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. http://data.europa.eu/eli/reg/2004/853/oj

[53] Regulation (EU) No. 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, amending Regulations (EC) No. 1924/2006 and (EC) No. 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No. 608/2004. http://data.europa.eu/eli/reg/2011/1169/oj

[54] Regulation (EU) 2017/625 of the European Parliament and of the Council of 15 March 2017 on official controls and other official activities performed to ensure the application of food and feed law, rules on animal health and welfare, plant health and plant protection products, amending Regulations (EC) No. 999/2001, (EC) No 396/2005, (EC) No. 1069/2009, (EC) No. 1107/2009, (EU) No. 1151/2012, (EU) No. 652/2014, (EU) 2016/429 and (EU) 2016/2031 of the European Parliament and of the Council, Council Regulations (EC) No. 1/2005 and (EC) No. 1099/2009 and Council Directives 98/58/EC, 1999/74/EC, 2007/43/EC, 2008/119/EC and 2008/120/EC, and repealing Regulations (EC) No. 854/2004 and (EC) No. 882/2004 of the European Parliament and of the Council, Council Directives 89/608/EEC, 89/662/EEC, 90/425/EEC, 91/496/EEC, 96/23/EC, 96/93/EC and 97/78/EC and Council Decision 92/438/EEC (Official Controls Regulation). http://data.europa.eu/eli/reg/2017/625/oj

[55] Council Directive 2006/112/EC of 28 November 2006 on the common system of value added tax. http://data.europa.eu/eli/dir/2006/112/oj

[56] Regulation (EU) No. 223/2014 of the European Parliament and of the Council of 11 March 2014 on the Fund for European Aid to the Most Deprived. http://data.europa.eu/eli/reg/2014/223/oj

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products (i.e., Reg. (EU) No. 1308/2013[57]) and for fisheries and fishery products (i.e., Reg. (EU) 1379/2013[58]) also offer contributions to prevent FW (e.g., processing of food withdrawn from the market for economic issues) and also donating it.

The donation guidelines do not include regulatory updates following their adoption. For example, Communication 2020/C 199/01[59] provides guidance on food safety management systems for food retail activities, including food donations, together with Communication 2022/C 355/01[60], which extend this guidance to all food businesses.

Food redistribution was regulated differently by MSs but, with Reg. (EU) 2021/382[61], it is possible for FBOs to redistribute food (for food donation only), provided dispositions are verified periodically in compliance with *General Food Law* requirements (especially that food donated is not unsafe), considering:

- date marking (expire date or minimum conservability date),
- integrity of packaging,
- proper storage and transport conditions (including temperature),
- date of freezing for food products of animal origin,
- organoleptic conditions,
- assurance of traceability (especially for products of animal origin[62]).

Some dispositions from Communication 2020/C 199/01 are now obsolete, after the publication of Commission Delegated Reg. (EU) 2021/1374[63] (from now on Reg. (EU) 2021/1374), which provides some dispositions for food retailers that permit them to freeze meat for redistribution as food donations.

For this, it is important that:

[57] Regulation (EU) No. 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No. 922/72, (EEC) No. 234/79, (EC) No. 1037/2001 and (EC) No. 1234/2007. http://data.europa.eu/eli/reg/2013/1308/oj

[58] Regulation (EU) No 1379/2013 of the European Parliament and of the Council of 11 December 2013 on the common organisation of the markets in fishery and aquaculture products, amending Council Regulations (EC) No. 1184/2006 and (EC) No. 1224/2009 and repealing Council Regulation (EC) No. 104/2000. http://data.europa.eu/eli/reg/2013/1379/oj

[59] Commission Notice providing guidance on food safety management systems for food retail activities, including food donations (2020/C 199/01). https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52020XC0612%2808%29

[60] Commission Notice on the implementation of food safety management systems covering Good Hygiene Practices and procedures based on the HACCP principles, including the facilitation/flexibility of the implementation in certain food businesses (2022/C 355/01). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022XC0916%2801%29&qid=1689780134987

[61] Commission Regulation (EU) 2021/382 of 3 March 2021 amending the Annexes to Regulation (EC) No. 852/2004 of the European Parliament and of the Council on the hygiene of foodstuffs as regards food allergen management, redistribution of food and food safety culture. http://data.europa.eu/eli/reg/2021/382/oj

[62] In accordance with Regulation (EU) No. 931/2011.

[63] Commission Delegated Regulation (EU) 2021/1374 of 12 April 2021 amending Annex III to Regulation (EC) No. 853/2004 of the European Parliament and of the Council on specific hygiene requirements for food of animal origin. http://data.europa.eu/eli/reg_del/2021/1374/oj

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- in the case of meat for which a 'use by' date is applied, freezing has to be done before the expiry of that date;
- without undue delay to a temperature of -18 °C or lower;
- ensuring that the date of freezing is documented and provided either on the label or by other means;
- excluding meat that has been frozen before (defrosted meat); and,
- in accordance with any condition laid down by the competent authorities for freezing and further use as food.

To assist FBOs in food redistribution and donation, there are some EU publications that further support these activities and tackle some regulatory issues (e.g., fiscal taxes). They are a collection of regulatory and policies adopted in different EU MSs, and good practices to assist in food donation activities, prepared by the EU Platform on FLW[64] or Directorate-General for Health and Food Safety (DG SANTE)[65,66].

Food need to be safe to be donated. When food is considered unsafe (only in the case that is no longer intended for human consumption), FBOs and FeBOs can recover this food and use it as an ingredient for feed production. There are complications in this, derived from dispositions made by WFD, *General Food Law*, and *ABP Regulation*, which may hinder use of food no longer intended for human consumption as feed. To guide FBOs and FeBOs in this regulatory framework issue, the Communication 2018/C 133/02[67] has been published.

It is fundamental that foodstuffs no longer intended for human consumption are properly classified, and either withdrawn or recalled from the market. It can become feed directly (if it is considered to be a *by-product* from manufacturing processes, or if it is a final product), it may become waste (if it is a final product), or become ABP, if products consist of, contain, or are contaminated with products of animal origin.

Operatively, the main issue is related to the origin of foodstuffs no longer intended for human consumption (i.e., non-animal origin, or animal origin). Accordingly, there are different regulatory conditions for the reuse of this food for feed production:

- Food of non-animal origin may derive from a production process, being a *by-product*, or being destined after the production process, or have been placed on the market, to feed production[68] (changing its status from food to feed). These two different options determine the provision of 'products provided as

[64] EU Platform on Food Losses and Waste (2019) Redistribution of surplus food: Examples of practices in the Member States. https://food.ec.europa.eu/system/files/2019-06/fw_eu-actions_food-donation_ms-practices-food-redis.pdf

[65] DG SANTE et al. (2020) Food redistribution in the EU: Mapping and analysis of existing regulatory and policy measures impacting food redistribution from EU Member States. *Publication Office of the European Union*, ISBN 978-92-76-18993-0, https://doi.org/10.2875/406299

[66] DG SANTE et al. (2020) Food redistribution in the EU: Mapping and analysis of existing regulatory and policy measures impacting food redistribution from EU Member States – Annexes. *Publication Office of the European Union*, ISBN 978-92-76-19434-7, https://doi.org/10.2875/873698

[67] Commission Notice — Guidelines for the feed use of food no longer intended for human consumption (2018/C 133/02). https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52018XC0416%2801%29&qid=1689775942040

[68] This disposition is legally possible after implementation of Directive (EU) 2018/851.

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feed' or 'products provided as waste for recovery';

- Food of animal origin is therefore considered as ABP, and it is not possible to revert it as 'food'. As such, it must comply with provisions set by *ABP Regulation* and the implementing measures set by Reg. (EU) No. 142/2011[69], which includes the requirements for ABP reuse as feed. Some restriction may be provided for ABP categories that may be harmful (e.g., from Transmissible Spongiforme Encephalopathy (TSE) contamination). In this case, ABP cannot be destined for its use as 'feed'.

It is fundamental for FBOs and FeBOs to comply with regulatory dispositions to use foodstuffs no longer fit for human consumption as feed (**Figure 4**). The guidance describes other requirements, such as the need for registration and compliance with *General Food Law* and the Reg. (EC) No. 183/2005[70], which set requirements for feed hygiene/safety. It is also necessary to assure the safety of products that have passed 'use by' or 'best before date', and guarantee the hygiene of food collected from the floor. Finally, feed included in the market must comply with provisions set by Reg. (EC) No. 767/2009[71], especially for foods that need further processing before their use as feed, due to excess chemical contamination (defined in Directive 2002/32/EC[72]) or microbiological contamination[73].

European Former Foodstuff Processors Association (EFFPA) is the European Association that collects all operators that intend to use 'former foodstuffs' for production of feed, in compliance with the above regulations and Reg. (EU) No. 68/2013[74], which defines feed materials. The association support food donation as the first solution but, when food no longer complies with *General Food Law* and other dispositions for human consumption, EFFPA promotes and supports the valorisation of these 'former foodstuffs' for the production of feed. These may derive from production errors leading to products damaged or sensory not accepted (e.g., colour, aspect), with labelling mistakes, or other issues that hinder destination as 'food[75].

For ABPs, there are also other destination of use permitted by *ABP Regulation* and related implementation measures, which are part of or go out from the food sector, but permits recovery and reuse for *upcycling*

[69] Commission Regulation (EU) No. 142/2011 of 25 February 2011 implementing Regulation (EC) No. 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive. http://data.europa.eu/eli/reg/2011/142/oj

[70] Regulation (EC) No. 183/2005 of the European Parliament and of the Council of 12 January 2005 laying down requirements for feed hygiene. http://data.europa.eu/eli/reg/2005/183/oj

[71] Regulation (EC) No. 767/2009 of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed, amending European Parliament and Council Regulation (EC) No. 1831/2003 and repealing Council Directive 79/373/EEC, Commission Directive 80/511/EEC, Council Directives 82/471/EEC, 83/228/EEC, 93/74/EEC, 93/113/EC and 96/25/EC and Commission Decision 2004/217/EC. http://data.europa.eu/eli/reg/2009/767/oj

[72] Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed. http://data.europa.eu/eli/dir/2002/32/oj

[73] ABPs categorised as Category 1 or Category 2 materials cannot change their category after a decontamination or detoxification process.

[74] Commission Regulation (EU) No. 68/2013 of 16 January 2013 on the Catalogue of feed materials. http://data.europa.eu/eli/reg/2013/68/oj

[75] https://www.effpa.eu/what-are-former-foodstuffs/

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purposes, realising products with added value, such as pharmaceutics, cosmetics, fertilisers, soil amendment, oils, packaging materials, and other.

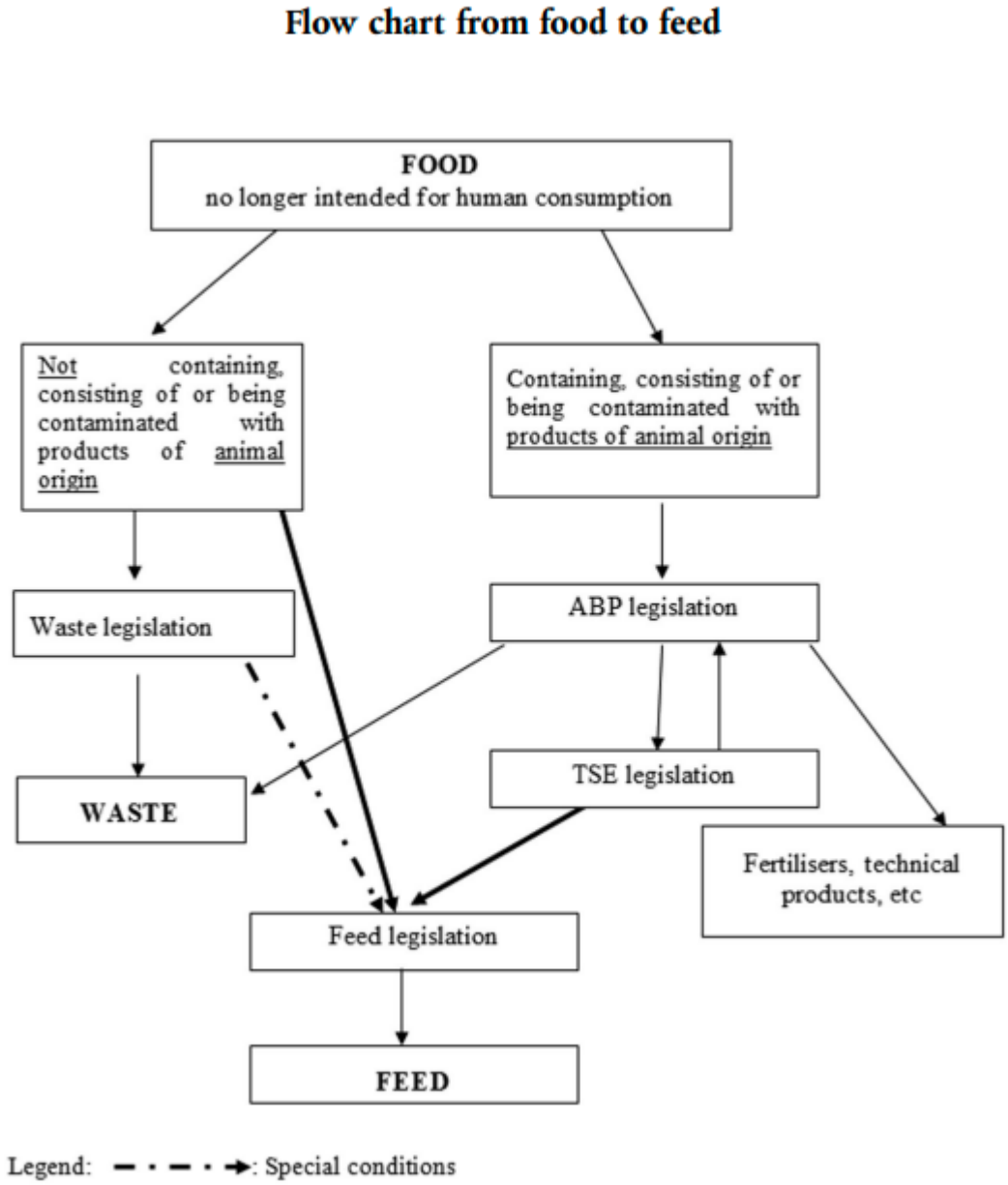

Figure 4. Different regulatory paths for food no longer intended for human consumption according to its origin (i.e., animal or non-animal origin) (source: EC)

2.1.3. Proposal of FWD amendment

EC has presented a proposal for the amendment of Directive 2008/98/EC[76] to reinforce and accelerate EU and MSs' actions to ensure environmental sustainability of food sector, in line with the European Green Deal and the Circular Economy Action Plan. According to the proposal, 'food' is the first most resource intensive sector and it does not fully adhere to fundamental EU waste management principles set out by the waste hierarchy, which

[76] Proposal for a Directive of the European Parliament and of the Council amending Directive 2008/98/EC on waste (COM/2023/420 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A0420%3AFIN

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requires prioritisation of waste prevention followed by re-use and recycling. This is why amendment of WFD is considered necessary; to reduce environmental and climate impacts of food systems associated with food waste generation. Preventing food waste would also contribute to food security.

Different FBOs are now interested in reducing FW generation and improving resource efficiency, making serious commitments to reduce waste in their operations, under the EU Code of Conduct for Food Business and Marketing Practices[77]. Even so, these commitments, together with EU regulatory and policy implementations, are not enough to reduce FW generation sufficiently along FSCs.

The EC document 'Drivers of food security[78]' has also considered the influence of FW to 'food demand', influencing also 'food prices' and 'food choices', and potentially contributing (positively or negatively) to FW generation, through other factors such as promotion, advertising, awareness raising campaigns or private market advertisement. Population growth and urbanisation may also exacerbate these aspects, leading to greater food consumption and waste.

FLW reduces productivity and, potentially, food availability. Food systems change are necessary, together with consumer behavioural changes, avoiding unnecessary discarding of food. However, the link between reduction of FLW and 'food security' is not always direct. This is particularly true for FW, considering that reduction must be carried out properly within the 'food use' hierarchy, prioritising uses [preferably of high (added) value] in food and feed chains.

Different stakeholders have been involved from EU and third countries in public consultation[79] to explore (most positively) opinions about the proposed amendment to WFD and, consequently, benefits deriving from FW reduction. Among these, the European Citizens' Food Waste Panel[80] derived from a conference on the Future of Europe[81] (where the first of 49 proposals included the promotion of measures against FW) involving citizens representative of wider society provides recommendations around implementation of WFD. Citizens (147) provided 23 recommendations[82] (**Figure 5**) covering three topics: 1) Cooperation in the food value chain: from farm to fork; 2) Food business initiatives; and 3) Supporting consumer behavioural change.

Another novelty reported is publication of best practice[83] from the European Consumer Food Waste Forum[84], set up by JRC and DG SANTE, which included 15 practitioners and researchers. The compendium comprises results from the European Consumer Food Waste forum, where the importance of adopting a systemic approach that

[77] https://food.ec.europa.eu/system/files/2021-06/f2f_sfpd_coc_final_en.pdf
[78] Commission Staff Working Document – Drivers of food security (SWD (2023) 4 final). https://commission.europa.eu/system/files/2023-01/SWD_2023_4_1_EN_document_travail_service_part1_v2.pdf
[79] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13225-Environmental-impact-of-waste-management-revision-of-EU-waste-framework_en
[80] https://citizens.ec.europa.eu/food-waste-panel_en
[81] https://futureu.europa.eu/it/pages/reporting
[82] https://food.ec.europa.eu/system/files/2023-02/flw_eu-actions_fwrt_20230210_recom-cit_0.pdf
[83] Candeal T. et al. (2023) Tools, best practices and recommendations to reduce consumer food waste - A compendium. *Pubblication Office of the European Union*, ISBN 978-92-68-05055-2, https://doi.org/10.2760/967005
[84] https://knowledge4policy.ec.europa.eu/projects-activities/european-consumer-food-waste-forum_en

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considers key factors and levers of change is underlined when aiming to reduce FW at the consumer level. It encourages collaboration and concrete actions to tackle FW and promotes the creation of sustainable food systems. Two JRC reports[85,86] were considered relevant for supporting an impact assessment on revision of WFD, in particular the feasibility of setting food waste reduction targets.

[85] De Laurentiis V. et al. (2023) Setting the scene for an EU initiative on food waste reduction targets - Outcomes of consultation activities and analysis of efforts on food waste reduction. *Pubblication Office of the European Union*, ISBN 978-92-68-04609-8, https://doi.org/10.2760/13859

[86] De Jong B. et al. (2023) Assessing the economic, social and environmental impacts of food waste reduction targets - A model-based analysis. *Pubblication Office of the European Union*, ISBN 978-92-68 04590-9, https://doi.org/10.2760/77251

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No.	Title of the recommendation	In favour	Against	Abstained
1	The closer the farmer, the happier the consumer: Less waste, more sustainability	120	15	5
2	Tastes of home: Public and private support for local farming to reduce food waste	119	9	12
3	Share don't waste!	93	31	16
4	Sharing of data and best practices across Europe	97	27	16
5	Gathering data across the food supply chain	101	28	11
6	Citizens' voices matter: Citizen participation in European food policy	91	37	12
7	Just picked: The value of seasonal food	103	26	11
8	EU-wide food exchange network	84	41	14
9	Planned purchases and redistribution	85	38	16
10	Restaurants stand for "enjoy without wasting"	113	17	9
11	All waste has a weight	73	48	18
12	A mandatory reporting system for transparency coupled with penalties and rewards	68	56	15
13	EU-wide legislation on the destruction of unsold food products - a peer learning approach across Member States	109	20	10
14	Transparency on food waste for visibility and action	102	22	15
15	Innovation in packaging and use of packaging when needed	116	18	5
16	Broadening the definition of food waste in order to save unharvested food	110	19	10
17	Encouraging adults to take action on food waste as a priority	113	20	6
18	Nutritional awareness and sustainable food in primary and secondary schools	123	9	7
19	Promote and support food sharing applications and platforms connecting consumers with each other	97	25	17
20	Save food, save money: A European campaign against food waste in cooperation with food retailers on four weekends a year	98	31	10
21	"Stop food waste": A week of food waste awareness at school	116	16	7
22	To provide consumers keys to be aware and independent on their impact on food waste and to understand how to process, preserve and reuse a product before and after the date has passed. ("use by" date is a safety date after which a product should not be consumed; "best before" indicates the date until which a product keeps its optimal quality)	108	26	5
23	The implementation of standardized practices at the retail level when promoting to consumers products close to the expiration date.	109	18	12

Figure 5. 23 recommendations provided by the European Citizens' Food Waste Panel (source: EC)

The amendments proposed inclusion of Article 9a (Prevention of food waste generation), which imposes adoption of appropriate and specific measures to prevent FW in all FSC stages at MSs level. Measures required are:

- developing and supporting behavioural change interventions to reduce food waste, and information campaigns to raise awareness about food waste prevention;

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- identifying and addressing inefficiencies in the functioning of the food supply chain and support cooperation amongst all actors, while ensuring a fair distribution of costs and benefits of prevention measures;

- encouraging food donation and other redistribution for human consumption, prioritising human use over animal feed and the reprocessing into non-food products;

- supporting training and skills development as well as facilitating access to funding opportunities, in particular for small and medium sized enterprises and social economy actors.

All actors in the supply chain must be involved proportionately to their capacity and role in preventing the FW generation along the FSC, with a specific focus on preventing disproportionate impact on Small and Medium-sized Enterprises (SMEs).

The MSs must monitor and assess the implementation of FW prevention measures by measuring FW based on a common methodology established by a delegated act, defining minimum quality requirements for the uniform measurement of these FW levels[87]. Compliance with food reduction targets also has to be monitored and assessed. By 31st December 2030, FW targets will be: a) reduction of FW generation in processing and manufacturing by 10 % in comparison to the amount generated in 2020; and b) reduction of FW generation per capita, jointly in retail and other distribution of food, in restaurants and food services and in households, by 30 % in comparison to the amount generated in 2020.

New specific dispositions are proposed for FW prevention programmes (Article 29a), which must include provisions to achieve new FW reduction targets and measures for waste and FW prevention, together with measures provided in Annex IV and Annex IVa of the WFD (where relevant). For the coordination of FW reduction measures, competent authorities must be designated by MSs, to ensure FW reduction targets are achieved and inform the EC in time (to be defined), so this information can be published online.

The Directive proposal is now subject to negotiation with the EP and EUCO, in view of its adoption by legislators according to the ordinary legislative procedure (co-decision).

2.2. Statistics, indicators and categories

This section aims to describe the statistics and related regulatory references on food waste, together with the indicators and food categories currently applied. It is also intended to highlight the potential of adopting a different approach, considering different statistics, indicators and food categories, which might complement and/or improve the approach currently in force across the EU (with particular reference to Decision (EU) 2019/1597).

[87] It is not known if the delegated act (if adopted) is intended to amend, to abrogate, or to complement the Decision (EU) 2019/1597.

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2.2.1. EU statistics

Statistics at the EU level are enshrined in Art. 338 of the Treaty on the Functioning of the European Union (TFEU)[88], subject to requirements for the performance of the activities of the Union, in an impartial, objective, scientifically independent and confidential (where necessary) manner. The European Statistical System (ESS)[89] is governed by Reg. (EC) No. 223/2009[90]. There are special conditions defined by Reg. (EU) No. 557/2013[91] for it to be possible to have access to confidential data transmitted to the EC (Eurostat) and rules for collaboration between Eurostat and national statistical authorities to enable statistical analysis to be carried out for scientific purposes.

Eurostat[92] is the EU platform for the collection and processing of statistical data on the EU and individual MSs, as described in Decision 2012/504/EU[93]. It operates under the Code of European Statistics[94] , presented in Recommendation COM/2005/217[95].

Official statistics are considered necessary to support evidence-based decision-making by politicians and business leaders. Such data are needed in all areas and, to achieve high quality collection and interpretation (i.e., they are 'fit for use'), following criteria are also needed: relevance; accuracy; comparability and coherence; timeliness and punctuality; and accessibility and clarity. These statistics are also crucial for collection and allocation of EU funds, and are essential for businesses, researchers, and the public at large.[96]

[88] Consolidated versions of the Treaty on European Union and the Treaty on the Functioning of the European Union. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=celex%3A12016ME%2FTXT

[89] It is the partnership between the Community Statistical Authority, i.e., the Commission (Eurostat), the National Statistical Institutes (NSIs) and other national authorities responsible in each Member State for the development, production and dissemination of European statistics. For more info: https://ec.europa.eu/eurostat/web/european-statistical-system/overview

[90] Regulation (EC) No. 223/2009 of the European Parliament and of the Council of March 11, 2009 , on European Statistics and repealing Regulation (EC, Euratom) No. 1101/2008 of the European Parliament and of the Council on the transmission of data subject to statistical confidentiality to the Statistical Office of the European Communities, Council Regulation (EC) No. 322/97 on Community Statistics, and Council Decision 89/382/EEC, Euratom establishing a Committee on the Statistical Programmes of the European Communities. http://data.europa.eu/eli/reg/2009/223/oj

[91] Commission Regulation (EU) No. 557/2013 of June 17, 2013, implementing Regulation (EC) No. 223/2009 of the European Parliament and of the Council on European statistics concerning access to confidential data intended for scientific purposes and repealing Regulation (EC) No. 831/2002. http://data.europa.eu/eli/reg/2013/557/oj

[92] https://ec.europa.eu/eurostat

[93] 2012/504/EU: Commission Decision of 17 September 2012, on Eurostat. http://data.europa.eu/eli/dec/2012/504/oj

[94] Eurostat (2018) European statistics code of practice - For the national statistical authorities and Eurostat (EU statistical authority). *Publications Office of the European Union*, ISBN 978-92-79-80014-6, https://doi.org/10.2785/798269

[95] Recommendation of the Commission on the independence, integrity and accountability of the national and Community statistical authorities (COM/2005/0217 final). https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52005PC0217

[96] European Court of Auditors (2022) European Statistics – Potential to further improve quality. *Publications Office of the European Union*, https://op.europa.eu/webpub/eca/special-reports/european-statistics-26-2022/en/

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Statistics are also considered essential to foster growth of the internal market and promote competitiveness of enterprises (including SMEs) in the plant, animal, food and feed sectors, as well as to protect consumers. Through Reg. (EU) 2021/690[97], the programme and eligible actions (including the development of statistics), over the period 2021-2027 have been defined.

Between the specific objectives of the programme, there is (Article 3(2)(e)): '*contributing to a high level of health and safety for humans, animals and plants in plant, animal, food and feed areas, inter alia, by preventing, detecting and eradicating animal diseases and plant pests, including by means of emergency measures that are taken in the event of large-scale crisis situations and unforeseeable events affecting animal or plant health, and by supporting the improvement of the welfare of animals, the fight against antimicrobial resistance and the development of sustainable food production and consumption, as well as by stimulating the exchange of best practices between stakeholders in those fields*'. Eligible actions for the implementation of this objective (Annex I) includes also '*activities for preventing FW and combating food fraud*', and '*implementation of information and awareness raising initiatives by the Union and MS with the aim of ensuring improved, compliant and sustainable food production and consumption, including food waste prevention contributing to the circular economy and food fraud prevention activities, as well as other initiatives contributing to a high level of health for plants and animals, and food and feed safety, as part of the implementation of the rules in the area of the specific objective referred to in Article 3(2)(e)*'.

Waste statistics are defined by Reg. (EC) No. 2150/2002[98], which establishes a framework for production of Community statistics, by the MSs and the EC, on waste generation (Annex I), and recovery and disposal (waste) (Annex II), based on a specific prefixed nomenclature (Annex III) that considers Decision 2000/532/EC. Data collection by MSs is planned on the basis of the following methods:

- Surveys,
- Administrative or other sources (e.g., waste management reporting requirements),
- Statistical estimation procedures, based on spot checks or related waste estimators,
- Combination of the previous methods.

To reduce the administrative burden, there is no requirement for data to be provided by businesses with fewer than 10 employees (unless they contribute significantly to waste generation).

Waste statistics are compiled for all activities classified in Sections A to U (production) of NACE Rev. 2, under which all economic activities are covered, and certain recovery and disposal facilities, which are part of specific economic activities (recovery and disposal) under NACE Rev. 2. Waste generation, as defined in Annex I, covers all economic activities in NACE Rev. 2, but also household waste and waste from recovery and/or disposal operations. It does not, however, include waste recycled where it was generated.

97

98 Regulation (EC) No. 2150/2002 of the European Parliament and of the Council of November 25, 2002 on waste statistics. http://data.europa.eu/eli/reg/2002/2150/oj

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Waste categories are established based on European Waste Classification for Statistics (EWC-Stat) Ver. 4 classifications, as implemented by Reg. (EU) No. 849/2010[99]. Annex III allows for the identification of concordance between EWC-Stat and waste classification, according to Decision 2000/532/EC. For food, the categories of main relevance are:

- Entry 31 (09.1): Wastes from food preparation and food products of animal origin (non-hazardous),
- Entry 32 (09.2): Plant residues (non-hazardous),
- Item 34 (10.1): Household and similar wastes.

The most relevant NACE rev. 2 economic activities for FW categories are:

- Item 1 (section A): agriculture, forestry and fishing,
- - Item 3 (division 10): food industries,
- - Item 3 (division 11): beverage manufacturing,
- Item 14 (division 36): collection, treatment and supply of water (Decision 2019/1597 does not include water),
- - Item 15 (division 38): waste collection, treatment and disposal activities; materials recovery,
- - Item 18 (class 46.77): wholesale trade of scrap and waste,
- - Item 19 (no NACE): household waste.

The unit of measurement used for all waste categories is 1 tonne of wet (normal) waste. In the case of populations served by a collection system for mixed household and similar, the percentage of the population served is considered.

Measurement of waste recovery and disposal does not consider treatment activity limited to recycling, and considers the same parameters used in measuring waste generation. The recovery and disposal operations (codes for which are defined in Annex I and Annex II of Directive 2008/98/EC) of most interest for FW are:

Incineration

- Item 1 (R1): Use primarily as a fuel or other means to produce energy,

Recovery

[99] Commission Regulation (EU) No. 849/2010 of September 27, 2010, amending Regulation (EC) No. 2150/2002 of the European Parliament and of the Council on waste statistics. http://data.europa.eu/eli/reg/2010/849/oj

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- Item 3a (R3 +): Recycling/recovery of organic substances not used in solvents (including composting operations and other biological transformations),
- Item 3a (R9 +): regeneration or other reuse of oils,
- Item 3a (R10 +): treatment in the terrestrial environment for the benefit of agriculture or ecology,
- Item 3a (R11): utilization of waste obtained from any of the operations listed from R1 to R10

Disposal

- See relevant operations as appropriate (e.g., D1 + - deposit on or in soil (e.g., landfill), D2 + - treatment in terrestrial environment (e.g., biodegradation of liquid waste or sludge in soils)).

The format for transmission of waste statistics results is defined by Reg. (EC) No. 782/2005[100] , while the quality assessment criteria and waste statistics quality reports are defined by Reg. (EC) No. 1445/2005[101].

Data on waste can be consulted on Eurostat in summary[102] or processed[103] forms, or a dedicated section related to the *Green Deal*[104]. In the application of Reg. (EC) No. 2150/2002, a guidance manual[105] has been published by the EC, together with a supplement on EWC-Stat classification[106]. Other documents can be downloaded from the 'Methodology' section[107]. Periodically, the EC produces a report on implementation of Reg.n (EC) No. 2150/2002 (e.g., COM/2020/54[108], referring to the last update on waste statistics for 2020).

[100] Commission Regulation (EC) No. 782/2005 of May 24, 2005, establishing the format for the transmission of results of waste statistics. http://data.europa.eu/eli/reg/2005/782/oj
[101] Commission Regulation (EC) No. 1445/2005 of September 5, 2005, defining the appropriate quality assessment criteria and contents of quality reports on waste statistics for the purposes of Regulation (EC) No. 2150/2002 of the European Parliament and of the Council. http://data.europa.eu/eli/reg/2005/1445/oj
[102] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics#Total_waste_generation
[103] https://ec.europa.eu/eurostat/web/waste/data/database
[104] https://ec.europa.eu/eurostat/cache/egd-statistics/
[105] European Commission (2013) Manual on waste statistics – A handbook for data collection on waste generation and treatment. https://ec.europa.eu/eurostat/documents/3859598/5926045/KS-RA-13-015-EN.PDF/055ad62c-347b-4315-9faa-0a1ebcb1313e
[106] European Commission (2010) Guidance on classification of waste according to EWC-Stat categories. https://ec.europa.eu/eurostat/documents/342366/351806/Guidance-on-EWCStat-categories-2010.pdf/0e7cd3fc-c05c-47a7-818f-1c2421e55604
[107] https://ec.europa.eu/eurostat/web/waste/methodology
[108] Report from the Commission to the European Parliament and the Council on statistics compiled pursuant to Regulation (EC) No. 2150/2002 on waste statistics and their quality (COM/2020/54 final). https://eur-lex.europa.eu/legal-content/en/TXT/?qid=1583142241609&uri=CELEX:52020DC0054

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The first EU statistics dedicated to FW were published following implementation of Decisions (EU) 2019/1597 and (EU) 2019/2000 (**Figure 6**). On the Eurostat website, data are reported as 'Food waste and food waste prevention by NACE Rev. 2 activity - tonnes of fresh mass'[109], distinguishing between MSs and EU27, economic activities (i.e., NACE classification) and unit measure (i.e., tonnes, kilograms per capita).

The following documents are useful to support comprehension and implementation of FW reporting and data collection:

- Guidance on food waste data reporting and food waste prevention (according to Commission Implementing Decision (EU) 2019/2000)[110],
- Q&A on measuring and reporting food waste[111] and data collection[112],
- Description of the Mass Flow Analysis Estimation Tool[113] (also via webinar[114]).

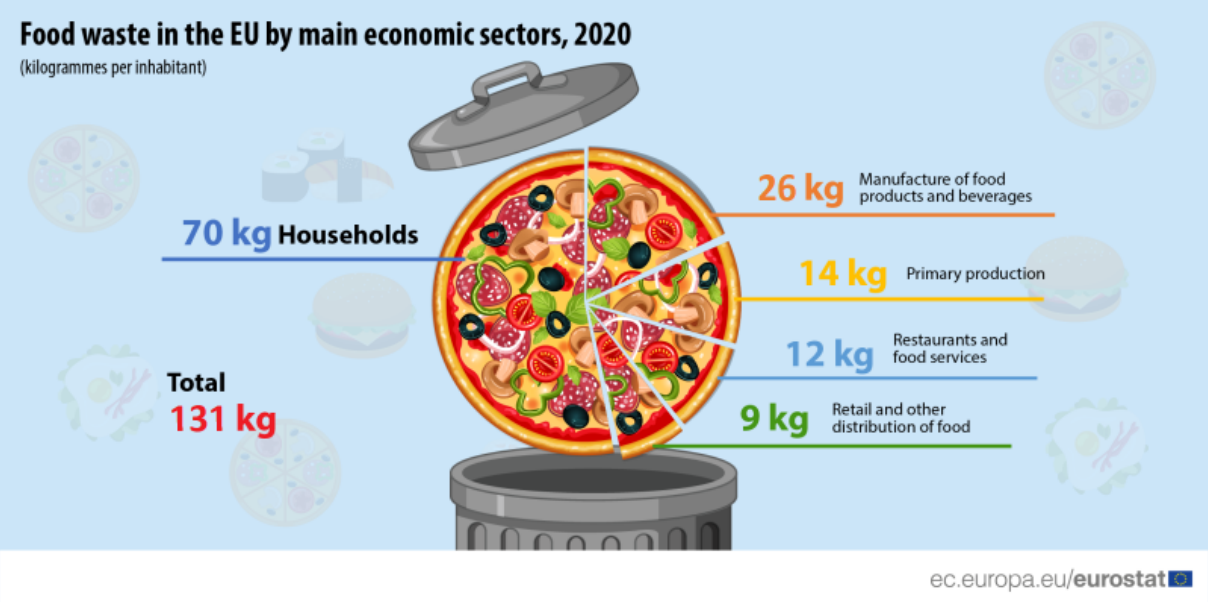

Figure 6. Results of EU-wide FW monitoring in 2020 (source: Eurostat)

[109] https://ec.europa.eu/eurostat/web/products-datasets/-/env_wasfw
[110] https://ec.europa.eu/eurostat/documents/342366/351811/Food+-+Guidance+on+food+waste+reporting.pdf/5581b0a2-b09e-adc0-4e0a-b20062dfe564?t=1654175854418
[111] https://ec.europa.eu/eurostat/documents/342366/351811/Food+-+Questions+and+answers+on+FW+measurement+and+reporting.pdf/ce93a186-161d-91eb-5ee5-d7f0ed8d1fb3?t=1657802611905
[112] https://ec.europa.eu/eurostat/documents/342366/351811/Food+-+Questionnaire+for+food+waste+and+food+waste+prevention.xlsm/5d61c057-6408-5453-90b3-dae0b84a2a5e?t=1657804053210
[113] https://ec.europa.eu/eurostat/documents/342366/351811/Food+-+Webinar+on+Mass+Flow+Analysis+Estimations+Tool.pdf/32d42ad2-12a0-b503-417d-e8c803f03142?t=1657802952635
[114] https://ec.europa.eu/eurostat/documents/342366/351811/Food+-+webinar+on+food+waste.mp4/b1d35dbb-fb59-e509-ecbc-096033f009f6?t=1654176182607

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Another example of a tool for measuring food waste is the FAO's FLW database[115]. Compared with Eurostat, the FLW database has the advantage of being slightly more up to date (currently up to 2021) and refers not only to measurements from individual EU MSs, but also to publications, reports from national and international organizations (e.g., FAO, World Bank), scientific studies, and other databases (e.g., Food and Agriculture Organization Corporate Statistical Database (FAOSTAT)[116]), as well as access being free to obtain FLW data. In addition, it is possible to discern information based on specific supply chain stages (e.g., harvest, post-harvest, processing, distribution). Instructions on the proper operation of the FLW Database[117] are also provided for users.

The FAO has made available an online course (in English, French and Spanish) on the methodology of a case study for FL analysis[118]. This method focuses on revealing and analysing multidimensional causes of losses in selected food supply chains, identifying critical loss points, and recommending feasible solutions and strategies to reduce these losses. In addition, there are numerous publications on FLW[119], of which the most relevant for this topic may be:

- United Nations Environment Programme (UNEP) Food Waste Index Report 2021[120], which also includes a methodology for measuring FLWs,
- Voluntary Code of Conduct for Food Loss and Waste Reduction[121], which somewhat summarizes what UNEP has said,
- Food Waste Management and Circular Economy in Mediterranean Cities[122], with case studies of solutions implemented to counter FLWs.

NACE describes EU economic activities, as implemented in the Decision (EU) 2019/1597. However, this is not its primary function and this description does not reflect the complex integrated system behind NACE. There are other statistics that complement NACE, or substitute in the identification of FW generated by different FSCs. Nevertheless, NACE makes it possible to provide a framework for collecting and presenting statistical data from different sectors of economic activities (e.g., business statistics). Statistics produced on this basis are comparable both at the European level (mandatory in the ESS) and worldwide[123]. NACE is part of an integrated system of statistical classifications, which can be represented as follows (**Figure 7**):

115 https://www.fao.org/platform-food-loss-waste/flw-data/en/
116 https://www.fao.org/faostat/en/
117 https://www.fao.org/platform-food-loss-waste/flw-data/user-guide/en
118 https://elearning.fao.org/course/view.php?id=374
119 https://www.fao.org/platform-food-loss-waste/resources/publications/en
120 https://www.unep.org/resources/report/unep-food-waste-index-report-2021
121 https://www.fao.org/3/cb9433en/cb9433en.pdf
122 https://www.fao.org/3/cc1926en/cc1926en.pdf
123 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=NACE_background

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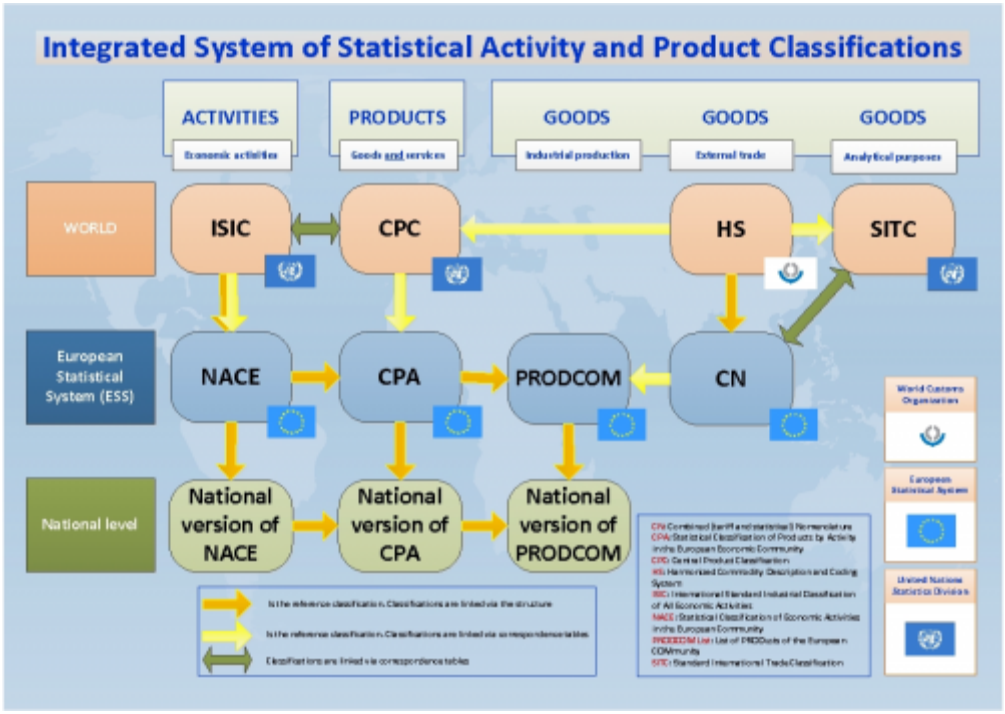

Figure 7. Integrated system of Statistical Activity and Product Classifications (source: Eurostat)

Where:

- International Standard Industrial Classification of All Economic Activities (ISIC) is the international standard industrial classification of all economic activities[124],
- Central Product Classification (CPC) is the central product classification[125],
- Harmonised System (HS) is the harmonized commodity description and coding system[126],
- Statistical Classification of Products by Activity (CPA) is the European classification of products by activity[127],
- PRODCOM is the classification of goods used for industrial production statistics in the EU[128],
- Combined Nomenclature (CN) stands for Combined Nomenclature, a European classification of goods used for external trade statistics[129].

[124] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:International_standard_industrial_classification_of_all_economic_activities_(ISIC)
[125] https://unstats.un.org/unsd/classifications/Family/Detail/1074
[126] https://unstats.un.org/unsd/classifications/Family/Detail/32
[127] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Statistical_classification_of_products_by_activity_(CPA)
[128] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:PRODCOM
[129] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Combined_nomenclature_(CN)

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This integrated system enables interoperability of statistics produced in different domains. As a result, for example, statistics on the production of goods (reported in the EU according to PRODCOM surveys) can be compared with statistics on trade (in the EU produced according to CN).

NACE is derived from ISIC (currently at Rev. 4[130]), but is more detailed. ISIC and NACE have the same items at higher levels, while NACE is generally more detailed at lower levels. To ensure international comparability, definitions and guidelines established for NACE within the EU are consistent with those published in the Introduction to ISIC.

Economic activities[131] are subdivided in such a way that a NACE code can be associated with a statistical unit that performs them (as defined by Reg. (EEC) No. 696/93[132]). NACE classification, governed at the regulatory level by Reg. (EC) No. 1893/2006, determines division of economic activities into four levels (sections, divisions, groups, and classes), each identified by one or two alphabetical letters and two to four digits. The regulations apply only to the use of classifications for statistical purposes and do not oblige EU countries to collect, publish or provide such data. Sections of interest for FW categories in NACE Rev. 2, shown in its Annex, could be:

- Section A - Agriculture, forestry and fishing, with all primary production activities of food of plant and animal origin,
- Section C - Manufacturing, which includes the processes of food processing industries,
- Section E - Water supply; sewerage, waste treatment and sanitation activities, which includes waste collection, recovery, treatment,
- Section G - Wholesale and retail trade; repair of motor vehicles and motorcycles, which also covers trade in food and miscellaneous animals,
- Section H - Transportation and warehousing, for the part relating to transportation of goods,
- Section I - Accommodation and food services, for food and beverage activities,
- Section M - Professional, scientific and technical activities, for university and private research and development activities,

[130] https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

[131] An economic activity occurs when resources such as capital goods, labour, production techniques or intermediate products are combined to produce specific goods or services. Thus, an economic activity is characterized by an input of resources, a production process, and an output of products (goods or services). An activity as defined here can consist of a simple process (e.g., weaving), but it can also cover a whole range of subprocesses, each mentioned in different categories of the classification (e.g. the production of a car consists of specific activities such as casting, forging, welding, assembling, painting, etc.). If the production process is organised as an integrated series of elementary activities within the same statistical unit, the whole combination is considered as a single activity.

[132] Council Regulation (EEC) No. 696/93 of March 15, 1993 on statistical units for the observation and analysis of the production system in the Community. http://data.europa.eu/eli/reg/1993/696/oj

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- Section N - Administrative and support activities, if you want to consider the social part through the activities of employment and temporary employment agencies,

- Section T - Activities of households and cohabitations as employers for domestic staff; production of undifferentiated goods and services for own use by households and cohabitations, for all domestic part.

Close attention must be paid to NACE classification update, since NACE Rev. 2.1 has been implemented through Delegated Reg. (EU) 2023/137[133], which will amend the annex of Reg. (EC) No. 1893/2006. However, the transmission of statistical data to Eurostat will start from 1st January 2025 (and subsequent periods, for certain provisions).

Summaries of data on NACE rev. 2 can be found on Eurostat's Reference And Management of Nomenclatures (RAMON) page[134], in the summarized version reported by Eurostat[135], which subdivides economic activities by sector, or in the appropriate document prepared for description of the classifications[136].

CPA is used to bring together products that have common characteristics. They are used for collecting and calculating statistics on production, trade, consumption, international trade, and transport of products. Each CPA product (transportable good or not, or even a service) is associated with a single NACE activity. CPA has a hierarchical structure with six levels, each identified with a specific code:
In common with NACE

- first level: 21 sections (alphabetical code);

- second level: 88 divisions (two-digit numerical code);

- third level: 261 groups (three-digit numerical code);

- fourth level: 575 classes (four-digit numerical code).

Specific for CPA

- fifth level: 1,342 categories (five-digit numerical code);

- sixth level: 3,142 subcategories (six-digit numerical code).

[133] Commission Delegated Regulation (EU) 2023/137 of October 10, 2022 amending Regulation (EC) No. 1893/2006 of the European Parliament and of the Council establishing the statistical classification of economic activities NACE Revision 2. http://data.europa.eu/eli/reg_del/2023/137/oj

[134] https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2&StrLanguageCode=EN

[135] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Business_economy_by_sector_-_NACE_Rev._2

[136] https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF

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CPA classification is governed by Reg. (EC) No. 415/2008[137] and allows MS to adopt national classifications derived from CPA. Its annex includes CPA designations and codes. There is analogy with the NACE classification, so it is sufficient to refer to the same sections identified in the Annex of Reg. (EC) No. 1893/2006 and identify the codes of interest in the Annex of Reg. (EC) No. 415/2008.

The version currently in force is CPA ver. 2.1, while the "native" version, adopted with Reg. (EC) No. 415/2008, was CPA 2008. Except for some changes to implement functionality and more subcategories, the coding system remains the same[138]. On RAMON, it is possible to find metadata for both versions[139] [140].

CN classifies goods for customs (import into the EU and adoption of *TARif Intégré Communautaire* (TARIC)[141]) and the development of International Trade in Goods Statistics (ITGS) in EU. ITGS measure the value and quantities of goods traded between EU MSs (intra-EU trade) and goods traded by MSs with non-EU countries (extra-EU trade). Statistics on international trade in goods are published on Eurostat[142] including also import and export of food and drink. The frequency with which data are compiled (data periodicity) and product nomenclature differ depending on the dataset, but the following statistical fields are always available:

- reporting country: country or geo-economic area (EU or euro area);
- partner country: EU member state, third country or geo-economic area;
- reference period: month or year;
- trade flows: import and export;
- product according to the relevant classification.

CN is reported in Reg. (EEC) No. 2658/87[143], which stipulates that the CN consists of subheadings formed by an eight-digit numerical code. The first six digits are the numerical codes assigned to the headings and subheadings of the HS nomenclature, while the seventh and eighth digits identify the CN subheadings[144]. The ninth and 10th

[137] Regulation (EC) No. 451/2008 of the European Parliament and of the Council of April 23, 2008, establishing a new statistical classification of products associated with activities (CPA) and repealing Council Regulation (EEC) No. 3696/93. http://data.europa.eu/eli/reg/2008/451/oj

[138] https://ec.europa.eu/eurostat/web/cpa/cpa_2.1

[139] https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CPA_2_1&StrLanguageCode=EN&IntPcKey=33101722&StrLayoutCode=HIERARCHIC

[140] https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CPA_2008&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC

[141] It includes all community and trade measures applied to goods imported and exported out of the EU.

[142] https://ec.europa.eu/eurostat/web/international-trade-in-goods/data

[143] Regulation (EEC) No. 2658/87 of July 23, 1987 on the tariff and statistical nomenclature and on the Common Customs Tariff. http://data.europa.eu/eli/reg/1987/2658/oj

[144] When HS headings and subheadings are not further subdivided for community requirements, the seventh and eighth digits are '00'.

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digits identify the TARIC sub-code[145], which, together with the eight digits, determine the formation of the TARIC code. TARIC statistical codes are given in Annex 10 of the Regulation.

The sections of the Regulation of interest to WASTELESS for food are:

- Section I - Live animals and products of the animal kingdom;
- Section II - Products of the vegetable kingdom;
- Section III - Animal, vegetable and microbial fats and oils and their cleavage products; processed edible fats; waxes of animal or vegetable origin;
- Section IV - Products of the food industries; beverages, alcoholic liquids and vinegar; tobacco and manufactured tobacco substitutes; products, not containing or containing nicotine, intended for inhalation without combustion; other products containing nicotine intended for the intake of nicotine into the human body (except 24 on tobacco);
- Section VI - Products of the chemical or allied industries (Chapter 35 only).

CN is used also in Reg. (EU) No. 1308/2013 and Reg. (EU) No. 1379/2013 to refer to agricultural products, livestock and meat, milk and milk products, fisheries and fishery products covered by CMO.

With international trade of goods in mind, it is essential to know the nomenclature of countries and territories for production of the relevant statistics. For this purpose, Reg. (EU) 2020/1470[146] was adopted and defines coding (Annex I) based on the International Organization for Standardization, ISO 3166 alpha 2. In Reg. (EU) 2020/1470, Annex II, disaggregation is achieved on the basis of six GEO levels defined as:

1) Foreign-controlled enterprises,
2) Overseas enterprises with ultimate parent institutional units of the reporting country,
3) Foreign-controlled enterprises and enterprises abroad with ultimate parent institutional units of the reporting country;
4) International trade in services,
5) International trade in services,
6) International trade in services.

[145] In the absence of community subdivisions, the ninth and tenth digits are '00'. Exceptionally, additional four-character Taric codes may be applied that are not encoded or not fully encoded by the ninth and tenth digits.

[146] Commission Implementing Regulation (EU) 2020/1470 of 12 October 2020 on the nomenclature of countries and territories for European statistics on international trade in goods and the geographical breakdown for other business statistics. http://data.europa.eu/eli/reg_impl/2020/1470/oj

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Information on food and beverage imports[147] and exports[148] is also available on Eurostat. Other relevant data referring to ITGS can be found in the 'database' section, also with reference to the NACE Rev. 2 classification. Data are classified as: aggregate, detailed, trade by enterprise characteristics, trade by invoicing currency.

Manuals are available for understanding how these statistics are collected, compiled, processed and published[149] as well as the general operation of statistics on ITGS[150]. In the 'Classifications' section, there are references for other types of nomenclature (i.e., HS, Nomenclature of Goods for the External Trade Statistics of the Community and Statistics of Trade between Member States (NIMEXE), Standard international trade classification (SITC) Rev. 4, Standard goods classification for transport statistics/Revised NST/R, Geonomenclature (GEONOM)).

Industrial production statistics are presented according to the PRODCOM survey and reported in a list of the same name. It includes about 4,000 items related to industrial products and services, detailed at an eight-digit level, characterized as follows:

- The first four digits refer to the equivalent class within NACE,
- The next two digits refer to the subcategories of CPA,
- The last digits tend to correspond to the CN codes.

Enterprises, operating in the national territory, carry out one or more activities at one or more locations and may include one or more legal units[151]. When an enterprise is engaged in more than one economic activity, the value added and turnover it generates, people it employs, and values of other statistical variables will be classified in the enterprise's main activity. The main activity is normally the one that generates the largest amount of value added. For PRODCOM statistics, the survey population consists of enterprises the main or secondary activities of which are production of goods during the reference period.

PRODCOM statistics are compiled from enterprises covering at least 90 percent of national production based on NACE class and employing at least 20 persons (countries may adopt different thresholds). The territory covered in each country refers to specifications of the nomenclature of countries and territories for Community external trade statistics and statistics of trade between MSs (i.e., GEONOM[152]).

147 https://ec.europa.eu/eurostat/databrowser/view/teiet120/default/table?lang=en
148 https://ec.europa.eu/eurostat/databrowser/view/teiet020/default/table?lang=en
149 https://ec.europa.eu/eurostat/web/international-trade-in-goods/methodology/manuals-and-guidelines
150 https://ec.europa.eu/eurostat/documents/3859598/12137783/KS-GQ-20-012-EN-N.pdf/f982fc06-3ff8-d37b-298f-9c76c843ae52?t=1608633443374
151 Legal units include: a) legal persons whose existence is recognized by law independently of the individuals or institutions which may own them or are members of them; b) natural persons who are engaged in an economic activity in their own right. The legal unit always forms, either by itself or sometimes in combination with other legal units, the legal basis for the statistical unit known as the enterprise.
152 GEONOM includes the terminology used for compiling international trade statistics. In particular, it makes possible to identify the actors involved in international trade (i.e., the reporting country and the partner country).

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PRODCOM statistics consist of several indicators:

- physical volume of production sold during the survey period,
- value of production sold during the survey period,
- physical volume of actual production during the survey period, including production incorporated in the manufacture of other products of the same enterprise.

PRODCOM statistics also cover the industrial production covered in NACE Rev. 2, with emphasis on:

- Section C - Division 10: Manufacture of food products,
- Section C - Division 11: Manufacture of beverages.

PRODCOM statistics can be used to answer questions such as:

- Which countries specialize in the production of a particular product?
- How productive is a particular industry in terms of physical volume and value of output sold during a year?
- What portion of production is produced under subcontracted operations?
- Which country has the lowest or highest unit value for the production of a particular product?
- Is there a change or trend in the production of a product group over the years?

Regulations underpinning PRODCOM are Reg. (EC) No. 3924/91 and Reg. (EC) No. 912/2004, both of which were repealed by Reg. (EU) 2019/2152[153,154]. The last available annual regulation on the PRODCOM list, prior to the two repeals, is Reg. (EU) 2019/1933[155].

Implementing regulations are Reg. (EU) 2020/1197[156,157] and Reg. (EU) 2022/2552[158]. The latter implemented the latest version, currently in force, of the PRODCOM list (see PRODCOM annex). NACE headings of interest to

[153] Regulation (EU) 2019/2152 of the European Parliament and of the Council of 27 November 2019 on European business statistics, repealing ten legal acts in the field of business statistics. http://data.europa.eu/eli/reg/2019/2152/oj

[154] Regulation (EU) 2019/2152 and its implementing regulations also had an effect on other statistical data (e.g. import-export, CPA, NACE).

[155] Commission Regulation (EU) 2019/1933 of November 6, 2019, establishing the "Prodcom list" of industrial products referred to in Council Regulation (EEC) No. 3924/91. http://data.europa.eu/eli/reg/2019/1933/oj

[156] Commission Implementing Regulation (EU) 2020/1197 of 30 July 2020 laying down the technical specifications and modalities pursuant to Regulation (EU) 2019/2152 of the European Parliament and of the Council on European business statistics, repealing ten legal acts in the field of business statistics. http://data.europa.eu/eli/reg_impl/2020/1197/oj

[157] Regulation that implemented provisions to define major industry groupings (MIGs) in Article 2 and Annex II (including certain food enterprises).

[158] Commission Implementing Regulation (EU) 2022/2552 of December 12, 2022, laying down the technical specifications for data requirements for statistics on the detailed topic "industrial production", defining the breakdown of the classification of industrial products pursuant to Regulation (EU) 2019/2152 of the European Parliament and of the Council, and amending

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WASTELESS may be:

- NACE 10.11: Processing and preserving of meat,
- NACE 10.12: Processing and preserving of poultry meat,
- NACE 10.13: Production of meat products (including poultry meat),
- NACE 10.20: Processing and preserving of fish, crustaceans and molluscs,
- NACE 10.31: Processing and preserving of potatoes,
- NACE 10.32: Manufacture of fruit and vegetable juices,
- NACE 10.39: Other processing and preserving of fruits and vegetables,
- NACE 10.41: Manufacture of oils and fats,
- NACE 10.42: Manufacture of margarine and similar edible fats,
- NACE 10.51: Manufacture of milk and dairy products,
- NACE 10.52: Manufacture of ice cream,
- NACE 10.61: Manufacture of grain processing,
- NACE 10.62: Manufacture of starches and starch products,
- NACE 10.71: Manufacture of bread; fresh bakery products,
- NACE 10.72: Manufacture of rusks and cookies; manufacture of preserved pastry goods and cakes,
- NACE 10.73: Manufacture of pasta, couscous and similar farinaceous products,
- NACE 10.81: Manufacture of sugar,
- NACE 10.82: Manufacture of cocoa, chocolate, candy and confectionery,
- NACE 10.83: Manufacture of tea and coffee,
- NACE 10.84: Manufacture of condiments and spices,
- NACE 10.85: Manufacture of prepared meals and dishes,
- NACE 10.86: Manufacture of homogenized preparations and dietetic foods,
- NACE 10.89: Manufacture of other food products not elsewhere classified,
- NACE 10.91: Manufacture of feed for farm animals (consider as a form of reuse?).
- NACE 10.92: Manufacture of products for domestic animal feed (as above),
- NACE 11.01: Distillation, rectification and blending of spirits (exclude due to no (effective) expiry date?),
- NACE 11.02: Manufacture of wine from grapes (as above),
- NACE 11.03: Manufacture of cider and other fruit wines (as above),
- NACE 11.04: Manufacture of other non-distilled fermented beverages (as above),
- NACE 11.05: Manufacture of beer (as above),
- NACE 11.06: Manufacture of malt,
- NACE 11.07: Manufacture of soft drinks, mineral and other bottled waters (exclude waters due to non-reference Reg. (EU) 2019/2157).

The Reg. (EU) 2019/2152 sets out what European business statistics refer to, together with the data sources and methods that may be used by MSs, and the technical specifications for data requirements. European business

Commission Implementing Regulation (EU) 2020/1197 as regards the coverage of the classification of products. http://data.europa.eu/eli/reg_impl/2022/2552/oj

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statistics comprise the following domains: (a) short-term business statistics; b) business statistics at national level; c) business statistics at regional level; (d) statistics on international activities.

The domains cover one or more of the following themes as further detailed in Annex I:

(a) population of enterprises;

(b) global value chains;

(c) Information and communication technology (ICT) usage and e-commerce;

(d) innovation;

(e) international trade in goods;

(f) international trade in services;

(g) investment;

(h) labour input;

(i) output and performance;

(j) prices;

(k) purchasing;

(l) real estate;

(m) R&D inputs.

The domains in Annex I are:

1) Short-term business statistics;

2) Business statistics at national level;

3) Business Statistics at regional level;

4) International Business Statistics.

For food production statistics, the following can be considered to be related to Annex IV of Decision (EU) 2019/1597:

- Business population;
- Purchasing;
- Production and performance;
- International trade in goods;
- Global value chains.

To date, PRODCOM data continue to be published on Eurostat[159], distinguishing between products sold, import and export[160], and total production[161]. The most updated data from 2021 can also be found on RAMON[162]. Manuals related to PRODCOM can be consulted in the 'Methodology' section[163].

159 https://ec.europa.eu/eurostat/web/prodcom/data/database
160 https://ec.europa.eu/eurostat/databrowser/view/DS-056120/default/table?lang=en
161 https://ec.europa.eu/eurostat/databrowser/view/DS-056121/default/table?lang=en
162 https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=PRD_2021&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC
163 https://ec.europa.eu/eurostat/web/prodcom/methodology

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RAMON is in the process of being closed. Therefore, all statistical data related to the described classifications and services can be found mainly on the 'Publications Office of the European Union' site[164]. As long as the RAMON platform continues to be active, it is possible to consult correspondence tables[165], which allow "converting" and equating different classification systems (e.g., CPA and CN).

The Main Industrial Grouping (MIG) and other special aggregates of NACE and CPA, used for the breakdowns required under Article 7(1)(d) of Reg. (EU) 2019/2152, are set out in Annex II of Reg. (EU) 2020/1197. Assignment of NACE groups and divisions into MIG are reported there (**Table 5**). For variables 130101, 130102 and 130103[166], approximations based on the allocation of NACE groups may be used for attribution of CPA groups to MIG.

Table 5. Allocation of interest for food of NACE headings to categories of aggregate classification

NACE description	Aggregate classification
10.6 Manufacture of grain, starch and starch products	Intermediate goods
10.9 Manufacture of prepared animal feeds	Intermediate goods
10.1 Processing and preserving of meat and production of meat products	Consumer non-durables
10.2 Processing and preserving of fish, crustaceans and molluscs	Consumer non-durables
10.3 Processing and preserving of fruit and vegetables	Consumer non-durables
10.4 Manufacture of vegetable and animal oils and fats	Consumer non-durables
10.5 Manufacture of milk and dairy products	Consumer non-durables
10.7 Manufacture of bakery and farinaceous products	Consumer non-durables
10.8 Manufacture of other food products	Consumer non-durables
11 Manufacture of beverages	Consumer non-durables

The Nomenclature of Territorial Units for Statistics (NUTS) is a hierarchical system for dividing the economic territory of the EU to:

- Collect, develop and harmonize European regional statistics,
- Conduct socio-economic analysis of NUTS 1 regions (main socio-economic regions), NUTS 2 (basic regions for the implementation of regional policies) and NUTS 3 (small regions for specific diagnoses),
- Frame EU regional policies (mainly at the NUTS 2 level).

164 https://op.europa.eu/en/web/eu-vocabularies/eurostat
165 https://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL
166 These are short term business statistics on import prices, being part of elements of data to be transmitted for the detailed topics in Annex I. 130101. Import prices (optional for non-euro area countries and countries applying the European sampling schemes); 130102. Import prices (euro area) (optional for non-euro area countries (and countries applying the European sample schemes); 130103. Import prices (non-euro area) (optional for non-euro area countries).

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The NUTS classification is governed by Reg. (EC) No. 1059/2003[167]. Classification criteria, for the definition of territorial units, are administrative units[168] (defined in its Annex II). To determine at what NUTS level a given class of administrative units in a Member State[169] is, the average size of the class from the point of view of population, according to the following scheme, is considered (**Table 7**):

Table 7. Hierarchical subdivision in the NUTS system

Level	Minimum	Maximum
NUTS 1	3 million	7 million
NUTS 2	800,000	3 million
NUTS 3	150,000	800,000

It is possible to identify breakdown in the three NUTS levels for the different MSs. Maps are also available[170], which make it possible to view this breakdown for each Member State.

To meet demand for statistics at the local level, Eurostat maintains a system of Local Administrative Units (LAUs) (defined in Annex III) compatible with NUTS. These LAUs are the building blocks of NUTS and include EU municipalities. Since 2017, only one level of LAUs has been maintained. Updated LAUs lists and relevant administrative data are available as required[171] .

The Geographic Information System of the Commission (GISCO) aims to stimulate the use of geographic information within the ESS and the EC. It leverages the Geographic Information System (GIS) integral hardware, software, and data to acquire, store, manipulate, analyse, manage, and present all types of georeferenced data (i.e., data associated with their geographical location) (**Figure 8**).

[167] Regulation (EC) No. 1059/2003 of the European Parliament and of the Council of May 26, 2003 on the establishment of a common classification of territorial units for statistics (NUTS). http://data.europa.eu/eli/reg/2003/1059/oj

[168] Geographical area where an administrative authority has the competence to make administrative or policy decisions for that area, within the legal and institutional framework of the Member State.

[169] If the population of an entire Member State is below the minimum limit for a given NUTS level, the entire Member State will constitute a NUTS territorial unit for that level. If, for a given NUTS level, there are no administrative units of an appropriate size in the Member State, the NUTS level will be formed by aggregating an appropriate number of existing smaller contiguous administrative units, based on relevant criteria (e.g., geographic, socioeconomic, historical, cultural, environmental circumstances). The resulting units are referred to as 'nonadministrative units.' In some cases (e.g., islands, outermost regions) they may receive derogation from the limits set for the NUTS classification.

[170] https://ec.europa.eu/eurostat/web/nuts/nuts-maps

[171] https://ec.europa.eu/eurostat/web/nuts/local-administrative-units

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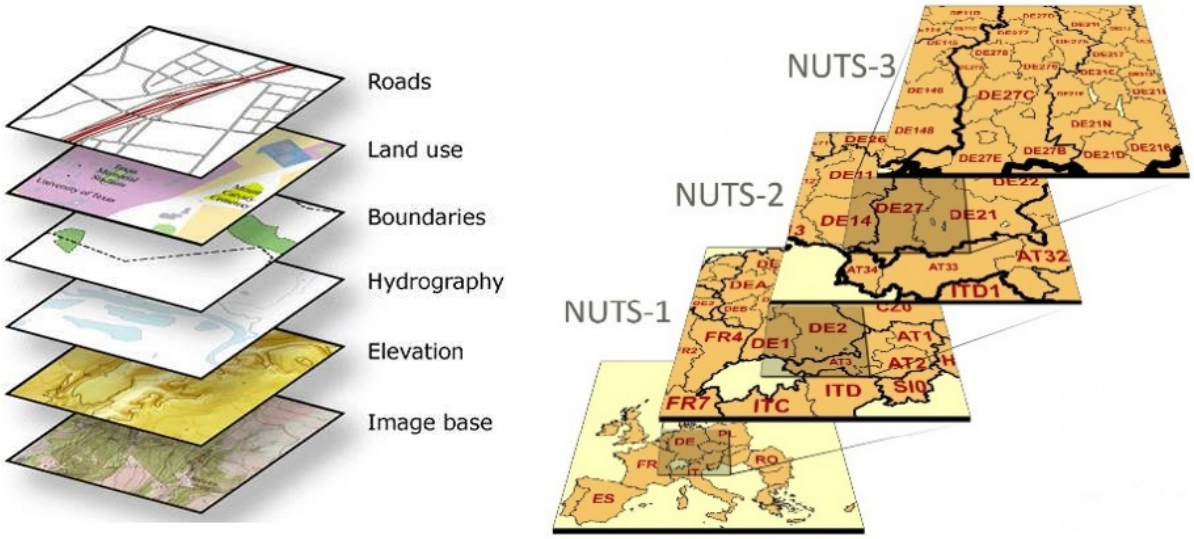

Figure 8. GISCO layers of georeferenced information and NUTS levels (source: Eurostat)

Georeferencing of statistical data was first used to create statistical maps for Eurostat publications and, more recently, for electronic products and websites. However, the combination of geographic and statistical information can generate information far beyond simply representing statistics on maps.

Geo-referenced data can be combined with numerical data for spatial analysis[172], producing information that allows relationships and patterns to be visually recognized, and making phenomena evident that would be more difficult to discover through statistical tables alone. In addition, the combination of computer processing power and GIS allows a multitude of different spatial-statistical analyses to be undertaken.

Geographic information can be used in a variety of applications. One of the most obvious examples is in relation to regional policy, which allows regional and local governments to follow policy initiatives more closely. Administrations are increasingly using spatial data to prepare strategic decisions in relation to transportation and regional planning. For example, analysis of infra-regional statistics can be used to create indicators.

Other areas where geographic information is of particular interest include agriculture and the environment. Both areas have benefited from advances in satellite imaging and remote sensing techniques using dedicated systems (e.g., Copernicus[173]). These allow alternative means of data collection in addition to in situ data. The combination of remote sensing techniques and existing geographic information allows for more effective monitoring as well as easier modelling of the impact of (environmental) changes, locally, nationally, internationally, and even globally.

An important element in spatial analysis is the spatial framework for thematic data. At the European level, NUTS with three regional levels are the standard spatial classification for statistical information. However, for phenomena related to surface area of a territory when distribution can vary greatly (e.g., population density), it is extremely difficult to apply spatial analysis techniques and obtain reliable results. GISCO is, therefore,

[172] So-called 'spatial analysis' techniques generate results in which the "whole is greater than the sum of the parts," leading to information that would be impossible to derive solely from contributing statistics or geographic information separately.

[173] https://www.copernicus.eu/en

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promoting population grids, as a complementary solution for the analysis of spatial phenomena, through the use of dedicated datasets (e.g., GEOSTAT 2011[174]) (**Figure 9**).

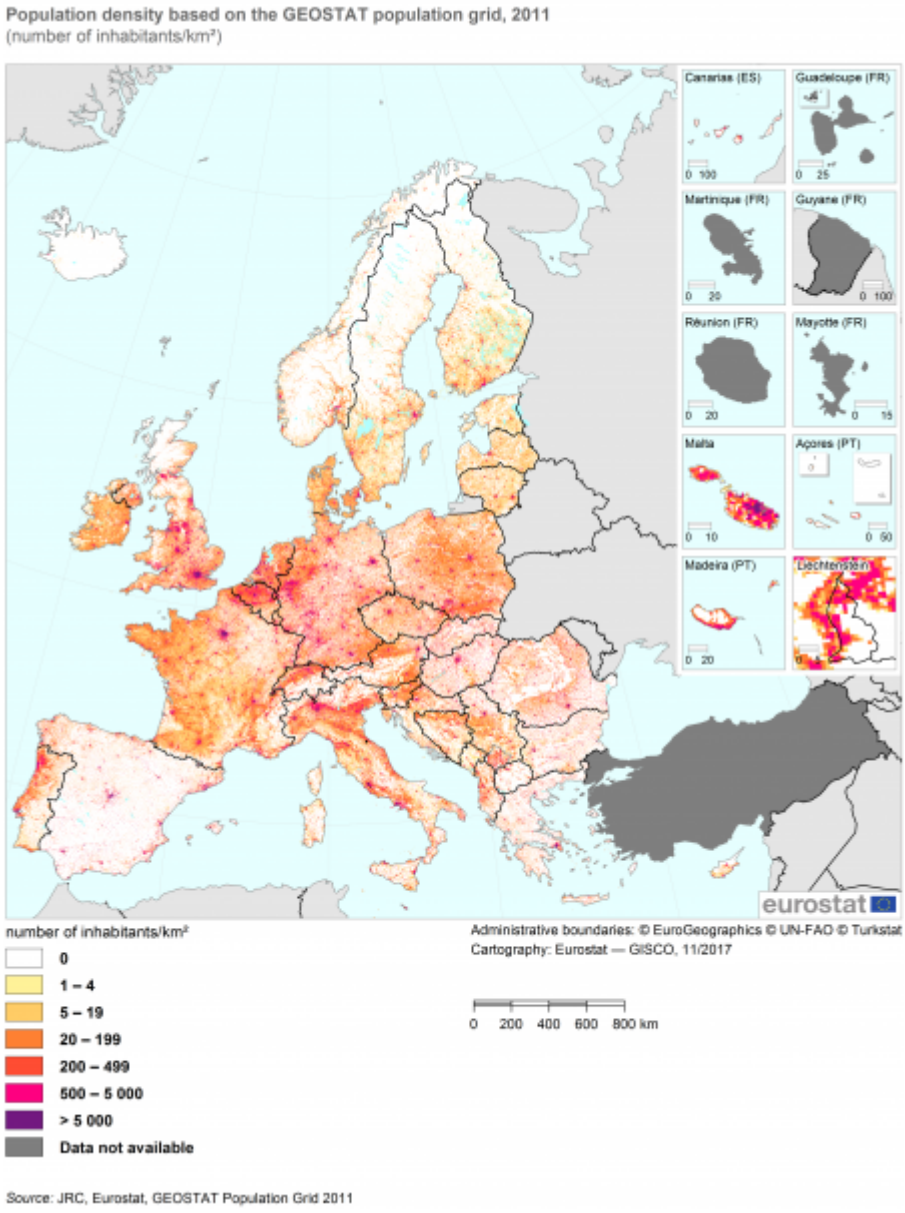

Figure 9. EU population density based on the GEOSTAT population grid (source: Eurostat)

Some GISCO data are publicly available and can be downloaded for non-commercial purposes[175]. At the statistical level, data obtained have been used to develop solutions such as the Statistical Atlas[176], which facilitates access to various data about MSs, such as those population, economy, health, environment, and urbanization.

[174] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Population_grids#Grid_statistics
[175] https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data
[176] https://ec.europa.eu/statistical-atlas/viewer/

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The reference legislation is Directive 2007/2/EC[177], which establishes Infrastructure for Spatial Information in the European Union (INSPIRE)[178]). Annex III lists production and industrial facilities, agricultural and aquaculture facilities, and statistical units for divulgation or use of statistics data among the spatial data themes.

Reg. (EU) No. 1089/2010[179] establishes requirements for technical arrangements for the interoperability and, where possible, harmonization of spatial datasets and spatial data services corresponding to the themes defined in the Annexes to Directive 2007/2/EC.

Statistics also cover agriculture[180], including agricultural production and organic farming for crops and animal production, and their derived products. European statistics for agricultural holdings are covered by Reg. (EU) 2018/1091[181], for information related to production methods, rural development measures, agro-environmental aspects, and other related information, acquired through surveys, administrative data from MSs, or other sources, methods and innovative approaches.

The Regulation applies to 98% of Utilised Agricultural Area (UAA) (excluding kitchen gardens) and 98% of the livestock units of each Member State[182] (indicated with the cell code of the INSPIRE statistical unit) but, for their regions (NUTS classification), only for agricultural holdings and common land agricultural units that meet at least one of the physical thresholds listed in Annex II with regard to the size of agricultural land or the number of livestock units[183] (**Table 8**).

Annex III includes variables for core structural data, which includes 'variables of land' and 'variables of livestock' that account for primary production quantity (e.g., crops, vegetables, pulses, livestock) distinguished for their number of ha/animals and the percentage of organic certification/conversion. These core data must be collected for the periods 2020, 2023 and 2026. For the first two years, the description of variables was specified with Commission Implementing Reg. (EU) 2018/1874[184], and Commission Implementing Regulation (EU) 2021/2286[185], introducing also specific codes that refers to the variables of land (e.g., CLND 010 – Triticale),

[177] Directive 2007/2/EC of the European Parliament and of the Council of March 14, 2007, establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). http://data.europa.eu/eli/dir/2007/2/oj

[178] https://inspire.ec.europa.eu

[179] Commission Regulation (EU) No. 1089/2010 of November 23, 2010, implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and spatial data services. http://data.europa.eu/eli/reg/2010/1089/oj

[180] https://ec.europa.eu/eurostat/web/agriculture/data/database

[181] Regulation (EU) 2018/1091 of the European Parliament and of the Council of 18 July 2018 on integrated farm statistics and repealing Regulations (EC) No. 1166/2008 and (EU) No. 1337/2011. http://data.europa.eu/eli/reg/2018/1091/oj

[182] With exceptions provided for samples representing more or less than 98 % of the UAA and livestock units.

[183] A standard measurement unit that allows for the aggregation of the various categories of livestock in order for them to be compared; the coefficients for establishing the livestock units for individual livestock categories are listed in its Annex I.

[184] Commission Implementing Regulation (EU) 2018/1874 of 29 November 2018 on the data to be provided for 2020 under Regulation (EU) 2018/1091 of the European Parliament and of the Council on integrated farm statistics and repealing Regulations (EC) No. 1166/2008 and (EU) No. 1337/2011, as regards the list of variables and their description. http://data.europa.eu/eli/reg_impl/2018/1874/oj

[185] Commission Implementing Regulation (EU) 2021/2286 of 16 December 2021 on the data to be provided for the reference year 2023 pursuant to Regulation (EU) 2018/1091 of the European

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livestock (e.g., CLVS 008 – Cows) and type of activities (e.g., MLFO 014 – Processing of farm products). To assure data quality transmitted by MS to Eurostat through their reports, measures are defined in Reg.(EU) 2020/405[186].

Table 8. Physical thresholds for the coverage of agricultural statistics

Item	Threshold
UAA	5 ha
Arable land	2 ha
Potatoes	0.5 ha
Fresh vegetables and strawberries	0.5 ha
Aromatic, medicinal and culinary plants, flowers and ornamental plants, seeds and seedlings, nurseries	0.2 ha
Fruit trees, berries, nut trees, citrus fruit trees, other permanent crops excluding nurseries, vineyards and olive trees	0.3 ha
Vineyards	0.1 ha
Olive trees	0.3 ha
Greenhouses	100 m^2
Cultivated mushrooms	100 m^2
Livestock	1,7 livestock units

Crops statistics to be realised by EU MSs for each harvest year (or in some cases for their regions, using NUTS classification), considering the production on their UAAs, are covered by Reg. (EC) No. 543/2009[187]. These statistics must be representative of at least 95% of:

a) total area under cultivation of crops from arable land;

b) total harvested area of vegetables, melons and strawberries;

c) total production area of permanent crops;

d) UAA.

Data must be reported for area under cultivation or harvested area (1,000 hectares), harvested production (1,000 tonnes) and yield (100 kg/ha).

Parliament and of the Council on integrated farm statistics as regards the list of variables and their description and repealing Commission Regulation (EC) No. 1200/2009. http://data.europa.eu/eli/reg_impl/2021/2286/oj

[186] Commission Implementing Regulation (EU) 2020/405 of 16 March 2020 specifying the arrangements for, and contents of, the quality reports to be transmitted under Regulation (EU) 2018/1091 of the European Parliament and of the Council on integrated farm statistics. http://data.europa.eu/eli/reg_impl/2020/405/oj

[187] Regulation (EC) No. 543/2009 of the European Parliament and of the Council of 18 June 2009 concerning crop statistics and repealing Council Regulations (EEC) No. 837/90 and (EEC) No. 959/93. http://data.europa.eu/eli/reg/2009/543/oj

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For products of animal origin, statistics are requested for a) milk and milk products; b) livestock and meat; and c) eggs and poultry.

Milk and milk products statistics are controlled by Council Directive 96/16/EC[188]. They must be produced through survey units for undertakings or agricultural holdings which purchase whole milk[189] or, in certain cases, milk products, either directly from agricultural holdings or from undertakings that collect milk or cream to transfer it, wholly or in part, without processing (latter is also covered for statistics purpose) with a view to transforming them into milk products. The information to be acquired by MSs has to cover three time periods (i.e., monthly, annually, triennially) (**Table 9**):

Table 9. Periodical surveys for milk and milk products

<table>
<tr><th colspan="3">Information from surveys for milk and milk products</th></tr>
<tr><th>Monthly</th><th>Annually</th><th>Triennially</th></tr>
<tr><td rowspan="3">quantity and fat content of the milk and cream collected and the protein content of the cows' milk collected</td><td>the quantity, fat content and protein content of the available milk and cream</td><td rowspan="5">the number of the survey units, broken down by size class.</td></tr>
<tr><td>the quantity of fresh milk products which have been processed and which are available for delivery, and of other manufactured dairy products, broken down by type</td></tr>
<tr><td>the use of raw materials in the form of whole milk and skimmed milk and the amount of fats used in the manufacture of dairy product</td></tr>
<tr><td rowspan="2">quantity of certain fresh milk products processed and available for delivery and of certain manufactured dairy products</td><td>the protein content of the main milk products, based on the measuring or estimating method most likely to guarantee reliable data</td></tr>
<tr><td>the quantity of cows' milk produced by agricultural holdings on a regional basis (territorial unit NUTS 2) according to the most appropriate measuring or estimating method for guaranteeing the reliability of the data</td></tr>
</table>

[188] Council Directive 96/16/EC of 19 March 1996 on statistical surveys of milk and milk products. http://data.europa.eu/eli/dir/1996/16/oj

[189] In this case, 'milk' means the milk of cows, ewes, goats and buffaloes. On the contrary of what provided in Regulation (EU) No. 1308/2013, where 'milk' is defined as the exclusively the normal mammary secretion obtained from one or more milkings without either addition thereto or extraction therefrom.

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Provisions for conducting these surveys are included in the Commission Decision 97/80/EC[190]. It includes a list of milk and milk products, distinguished by a product code (e.g., 1 for fresh products, 11 for drinking milk, 1121 for pasteurised whole milk). Each of these products needs to be reported for their monthly or yearly quantity production (1,000 tonnes) and other parameters (i.e., fat and protein content), together with its utilisation (i.e., milk) in dairies and in farms.

Livestock and meat statistics are part of Reg. (EC) No. 1165/2008[191] for (a) statistics on bovine, pig, sheep and goat livestock; (b) slaughtering statistics on bovine animals, pigs, sheep, goats and poultry; and (c) production forecasts of beef, veal, and pig, sheep and goat meats. Coverage and frequency of reporting are different for each category, and for different species, for livestock defined by Annexes of the Regulation.

Meat production forecasts are based on statistics produced for livestock and slaughtering, and other available information that help address forecasts of supplies for indicated animal species, expressed as 'gross indigenous production', which corresponds to the number of bovine animals, pigs, sheep and goats slaughtered plus the balance of intra-Community and external trade in these live animals.

Reg. (EC) No. 617/2008[192] set dispositions to provide statistics for eggs. The same production needs to be reported for organic production, in accordance with dispositions defined in Reg. (EU) 2018/848[193].

Regulations that sets requirements for statistics to be implemented for milk and milk products, livestock and meats, and crops, are going to be repealed from 1st January 2025, with disposition from Reg. (EU) 2022/2379[194] substituting and covering their application fields with only one specific regulation (which will be probably be implemented in the future with EC implementing and/or delegated acts).

2.2.2. EU indicators

Waste-related indicators are used to measure and track trends in waste generation and certain aspects of EU waste management. They provide information on progress towards EU policy objectives and help EU countries improve their environmental performance. Eurostat maintains the following sets of indicators[195]:

[190] 97/80/EC: Commission Decision of 18 December 1996 laying down provisions for the implementation of Council Directive 96/16/EC on statistical surveys of milk and milk products. http://data.europa.eu/eli/dec/1997/80(1)/oj

[191] Regulation (EC) No. 1165/2008 of the European Parliament and of the Council of 19 November 2008 concerning livestock and meat statistics and repealing Council Directives 93/23/EEC, 93/24/EEC and 93/25/EEC. http://data.europa.eu/eli/reg/2008/1165/oj

[192] Commission Regulation (EC) No. 617/2008 of 27 June 2008 laying down detailed rules for implementing Regulation (EC) No. 1234/2007 as regards marketing standards for eggs for hatching and farmyard poultry chicks. http://data.europa.eu/eli/reg/2008/617/oj

[193] Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No. 834/2007. http://data.europa.eu/eli/reg/2018/848/oj

[194] Regulation (EU) 2022/2379 of the European Parliament and of the Council of 23 November 2022 on statistics on agricultural input and output, amending Commission Regulation (EC) No. 617/2008 and repealing Regulations (EC) No. 1165/2008, (EC) No. 543/2009 and (EC) No. 1185/2009 of the European Parliament and of the Council and Council Directive 96/16/EC. http://data.europa.eu/eli/reg/2022/2379/oj

[195] https://ec.europa.eu/eurostat/web/waste/data/indicators

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- EU SDGs;
- Resource efficiency indicators (REIs);
- Circular Economy indicators (CEIs)

Waste management indicators cover[196]:

- Recycling,
- Backfilling,
- Energy recovery,
- Incineration,
- Other disposal modes,
- Landfilling.

This new set of waste management indicators provided by Eurostat is a way to monitor progress towards more recycling and less disposal. It reflects the treatment rates of the waste produced in a given country by type of treatment.

There is a combination between treatment data collected under Reg. (EC) No. 2150/2002 with import/export data from international trade statistics contained in COMEXT database[197], or from national sources. The total waste amount is defined as:

Amount of domestically generated waste treated = Waste treated in country (Reg. (EC) No. 2150/2002 data) + Waste exported for treatment (COMEXT data) - Waste imported for treatment (COMEXT data)

The indicators are expressed in volumes of treated waste by treatment category as a proportion of the total amount of domestically treated waste. The indicator set comprises treatment rates for the six treatment categories defined above.

The set of indicators covers waste from all economic sectors and from households but excludes some mineral waste types that arise in large quantities and originate mainly from the mining and the construction sector.

The waste management indicators are published by Eurostat as a pilot data set. They are considered as good approximations for the treatment of domestically generated waste but have some limitations, as follows:

[196] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_management_indicators
[197] https://ec.europa.eu/eurostat/comext/newxtweb/

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- CN used for international trade statistics does not consistently distinguish between wastes and goods, i.e., some CN-codes cover not only wastes but also non-wastes (by-) products,

- Trade statistics give information on the geographical destination of the waste but not on type of treatment at the place of destination. Hence, the type of treatment is based on assumptions,

- If calculated at country level, additional limitations result from the fact that the statistics on intra-EU trade do not cover 100 % of the traded goods/wastes because of reporting thresholds.

The need of FW indicators was addressed in JRC Report 'Food waste accounting[198]', for the necessity to monitor and show the compliance with SDG 12.3[199]. This task was assigned to the recently constituted EU Platform on Food Losses and Waste, to be used to effectively monitor implementation of FW prevention policies.

In the 2021, the new FW indicators were finally developed by the same JRC, and integrated in the EU Bioeconomy Monitoring System[200] after the publishing of their report 'Building a balancing system for food waste accounting at National Level[201]', where the new method for FW quantification that permits FW generation comparison at country level. The indicators set in the EU Bioeconomy Monitoring System dashboards (**Figure 10**) are included in a dedicated report[202], with the latest update.

Currently, there are 2 indicators available for FW, derived from the FW quantification method developed by JRC, included in the EU Bioeconomy Objectives 'Reducing Dependence on Non-renewable Unsustainable Resources' (other indicators are in their development phase and will be included):

- FW along supply chain – mass balance approach (**Figure 11**): it reports the amount of FW generated in EU27 and for single MS, divided for the primary production, processing and manufacturing, retail and distribution and consumption phases (in tonnes), also singularly or in combination.

- FW by food category – mass balance approach (**Figure 12**): FW amount is here reported for 10 food categories, namely 1) vegetables, 2) fruits, 3) sugarbeets, 4) fish, 5) potatoes, 6) eggs, 7) oilcrops, 8) dairy, 9) meat, and 10) cereals.

All geographical data is reported using GISCO and Map widget from the EC[203], on the base of NUTS classification.

198 Patinha Caldeira C. et al. (2017) Food waste accounting - Methodologies, challenges and opportunities. *Publications Office of the European Union*, ISBN 978-92-79-77888-9, https://doi.org/10.2760/54845

199 At the time, FAO had recently presented the 'Food Loss Index'.

200 https://knowledge4policy.ec.europa.eu/bioeconomy/monitoring_en

201 De Laurentiis V. et al. (2021) Building a balancing system for food waste accounting at national level. *Publications Office of the European Union*, ISBN 978-92-76-37275-2, https://doi.org/10.2760/316306

202 Kilsedar C. et al. (2023) EU Bioeconomy Monitoring System dashboards: extended with trade-related indicators. *Publications Office of the European Union*, ISBN 978-92-76-61625-2, https://doi.org/10.2760/217911

203 https://webgate.ec.europa.eu/fpfis/wikis/display/webtools/Map

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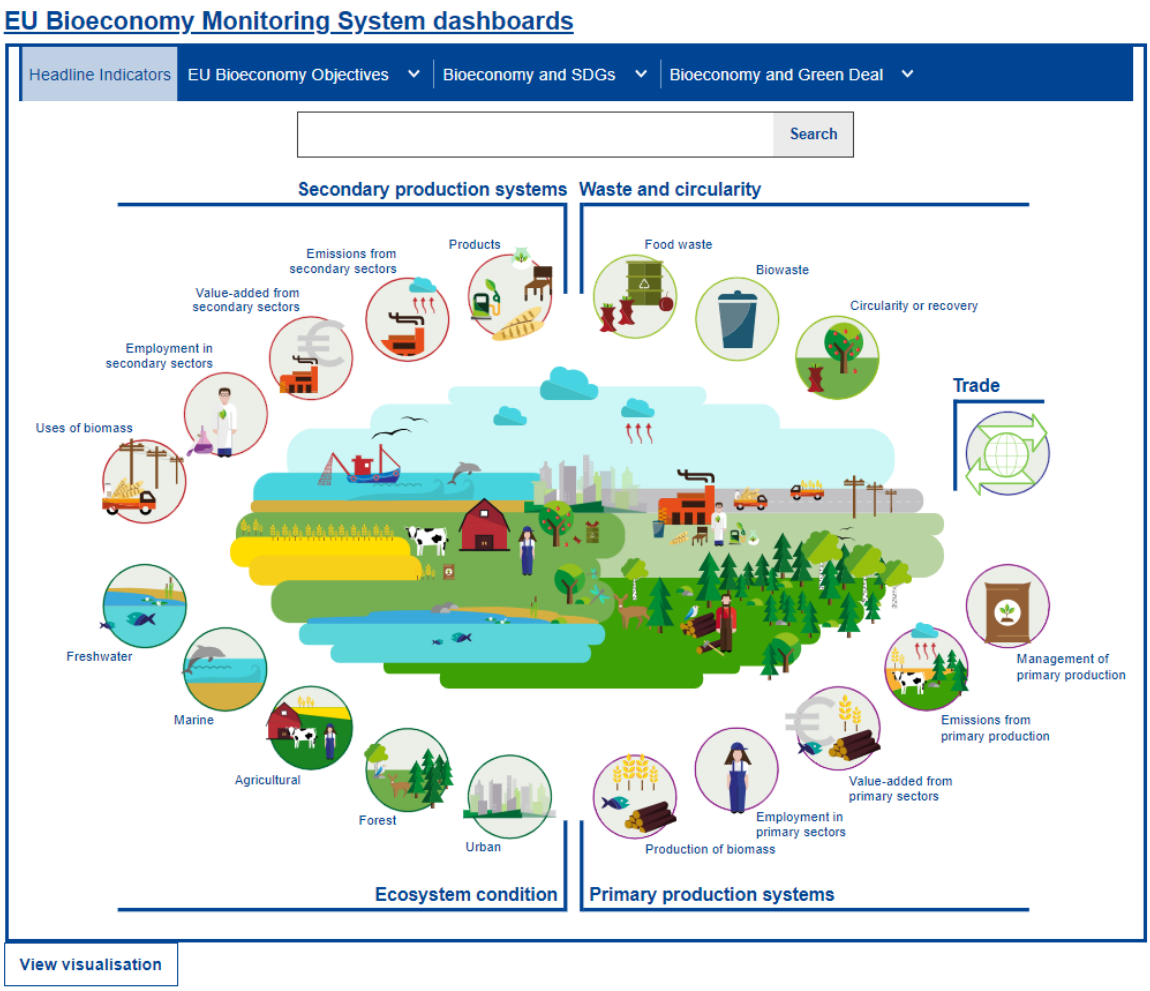

Figure 10. EU Bioeconomy Monitoring System dashboards, which includes also FW (source: EC)

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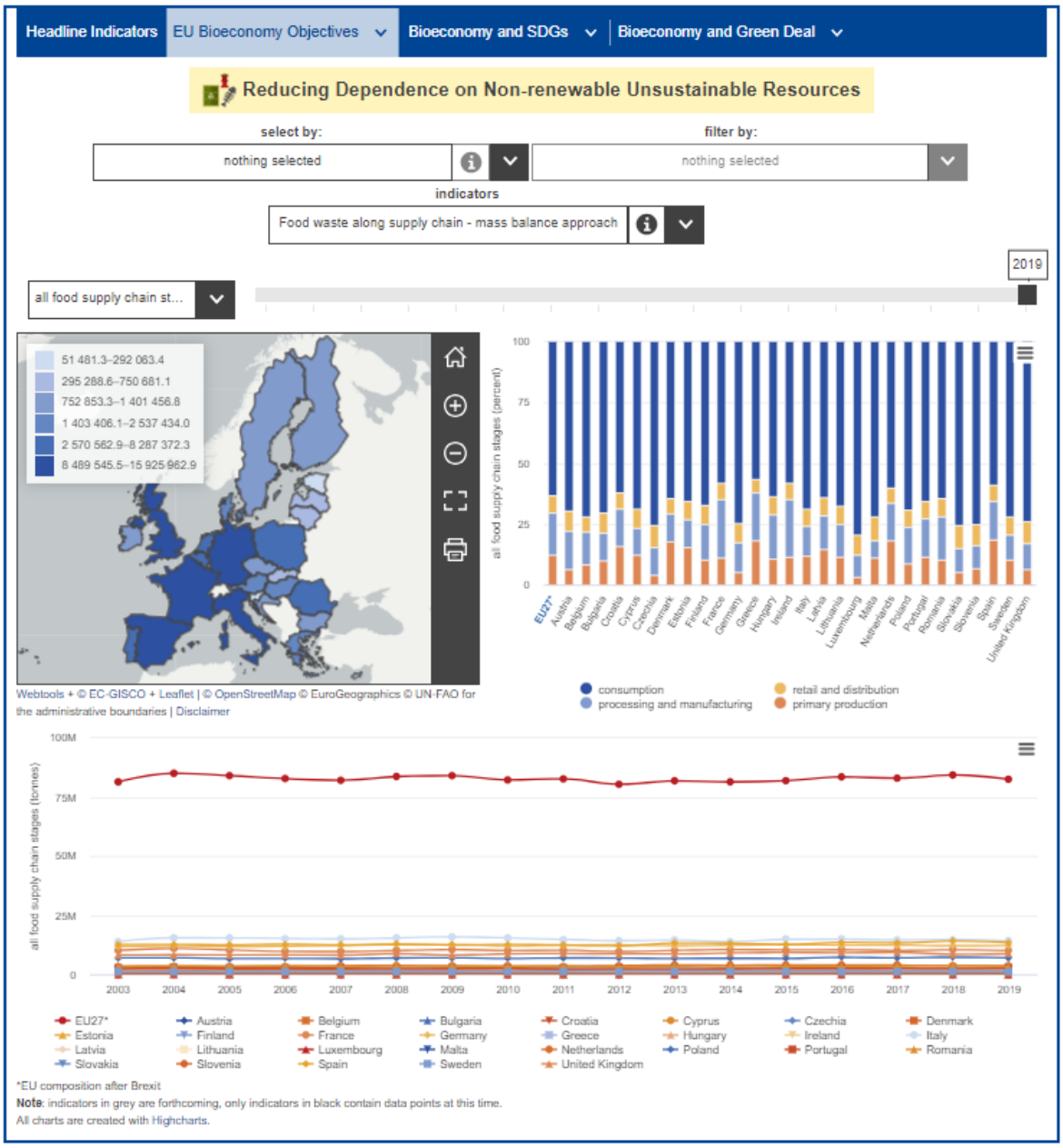

Figure 11. FW along supply chain – mass balance approach indicators (source: EC)

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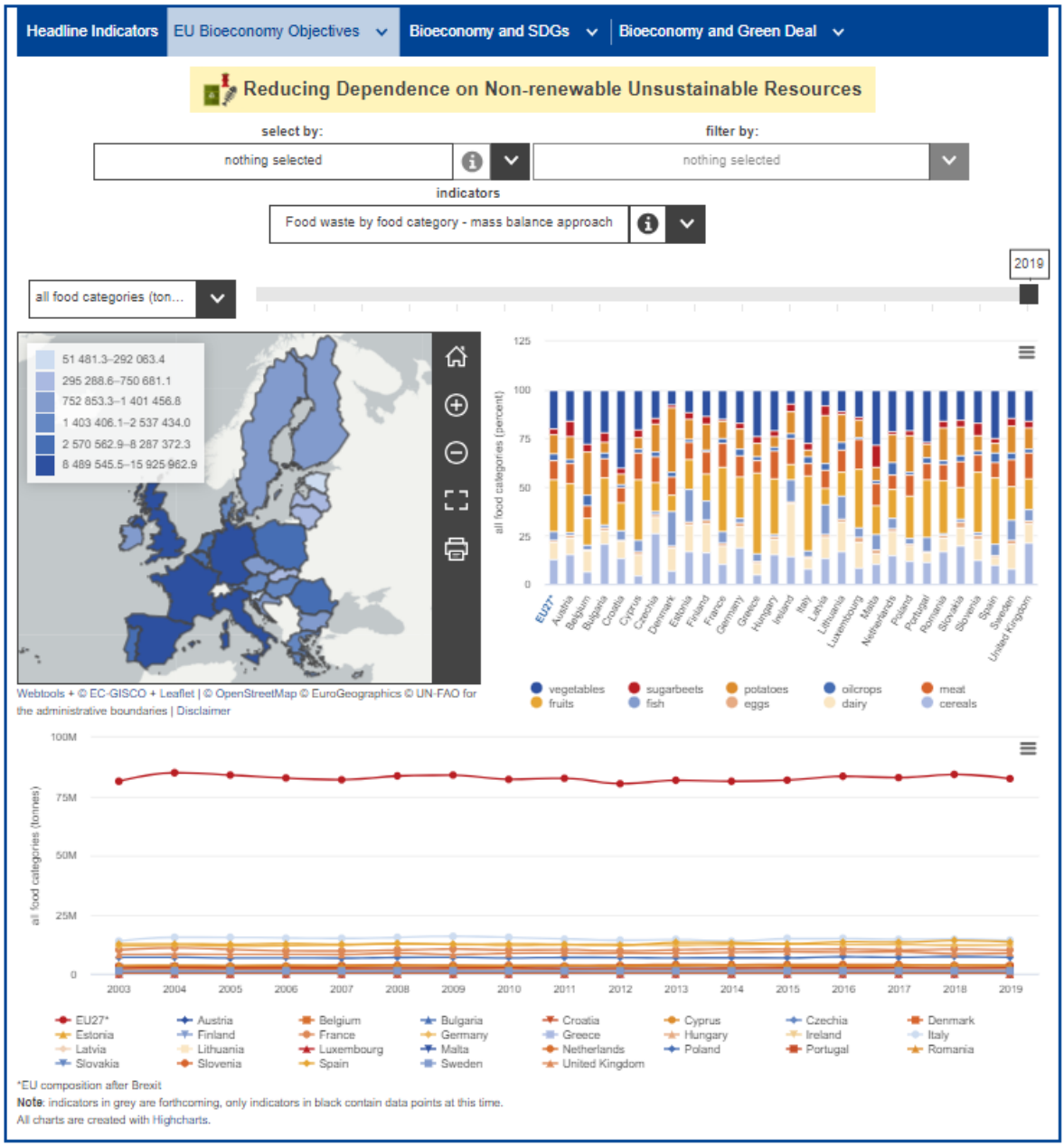

Figure 12. FW by food category – mass balance approach indicators (source: EC)

Regarding indicators, FAO is working on a FL Index and a FW Index[204,205], related to SDG 12.3, to be divided into two sub-indicators to distinguish between losses and waste. Progress on food and agriculture-related SDG indicators are included in a dedicated report[206]. These indicators are available also on FAOSTAT and UN websites[207,208].

[204] https://www.fao.org/sustainable-development-goals-data-portal/data/indicators/1231-global-food-losses/en
[205] https://sdg12hub.org/sites/default/files/2021-06/ca2640en.pdf
[206] https://www.fao.org/documents/card/en/c/cc1403en
[207] https://www.fao.org/faostat/en/#data/SDGB
[208] https://unstats.un.org/sdgs/dataportal

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An additional method has been developed by the International Food Policy Research Institute (IFPRI)[209,210], but it does not consider losses at the household level. It also considers the SDG 12.3.1[211]. There are also several datasets related to FLWs[212].

For feed, one of the most relevant stakeholders is Global Feed LCA Institute[213], which is developing a Life Cycle Assessment (LCA) database to assess environmental impact, including taking into account the destination of former food products in the feed chain.

2.2.3. EU food (waste) categories

Food categorisation topic is developing particularly for epidemiological purposes, especially to distinguish between different degree of food processing (e.g., non-processed, minimally processed, ultra-processed), leading to different international categorisations such as the International Agency for Research on Cancer (IARC), NOVA, IFPRI, International Food Information Council (IFIC) and University of North Carolina (UNC). Between these categorisations, and in the categorisations, there is still a lack of consensus between researchers, to define which food(s) has to be included in which category/ies[214].

In the EU, food categories are not harmonised. At the opposite, there are different categories and codes used in different regulations and contexts. Some example will be reported.

Old EU Categories and EU Category Codes for food are reported in a Guidance Note published by the Food Safety Authority of Ireland (FSAI) in the 2001[215], on the basis of 'Guidelines for the Harmonisation of the Conditions for the Submission of Statistics Concerning the Results of the Annual Inspection Programmes of the Member States' (Article 14 of Directive 89/397/EEC on the official control of foodstuffs[216]). This classification system comprises 21 items (foods and non-foods), for which some examples are reported in the guidance:

1) Dairy products;
2) Egg and egg products;
3) Meat and meat products;
4) Fish, shellfish and molluscs;
5) Fats and oils;
6) Soups, broths, and sauces;

209 https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/131530/filename/131741.pdf
210 https://pim.cgiar.org/2018/04/25/webinar-measuring-food-losses-a-new-methodology/
211 https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/134897/filename/135099.pdf
212 https://www.ifpri.org/topic/food-loss-and-waste
213 https://globalfeedlca.org
214 Pereira de Araujo et al. (2022) Food Processing: Comparison of Different Food Classification Systems. *Nutrients* 14(4):729, https://doi.org/10.3390/nu14040729
215 Food Safety Authority of Ireland (2001) Guidance Note on the EU Classification of Food – Guidance Note No. 2. ISBN 0-9539183-3-5, https://www.fsai.ie/getmedia/b753916a-dc95-47f7-9865-f74108e65dec/gn2.pdf?ext=.pdf
216 Abrogated by Regulation (EC) No. 882/2004, following abrogated by Regulation (EU) 2017/625.

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7) Cereals and bakery products;
8) Fruit and vegetables;
9) Herbs and spices;
10) Non-alcoholic beverages;
11) Wine;
12) Alcoholic beverages (other than wine);
13) Ices and desserts;
14) Cocoa and cocoa preparations, coffee and tea;
15) Confectionery;
16) Nuts and nut products, snacks;
17) Prepared dished;
18) Foodstuffs intended for special nutritional uses[217];
19) Additives;
20) Materials and articles intended to come into contact with foodstuffs (non-food);
21) Other (e.g. vitamins and minerals).

Considering the existence of multi-ingredient foods, a decision tree has been provided (**Figure 13**) to assist and support in the correct classification.

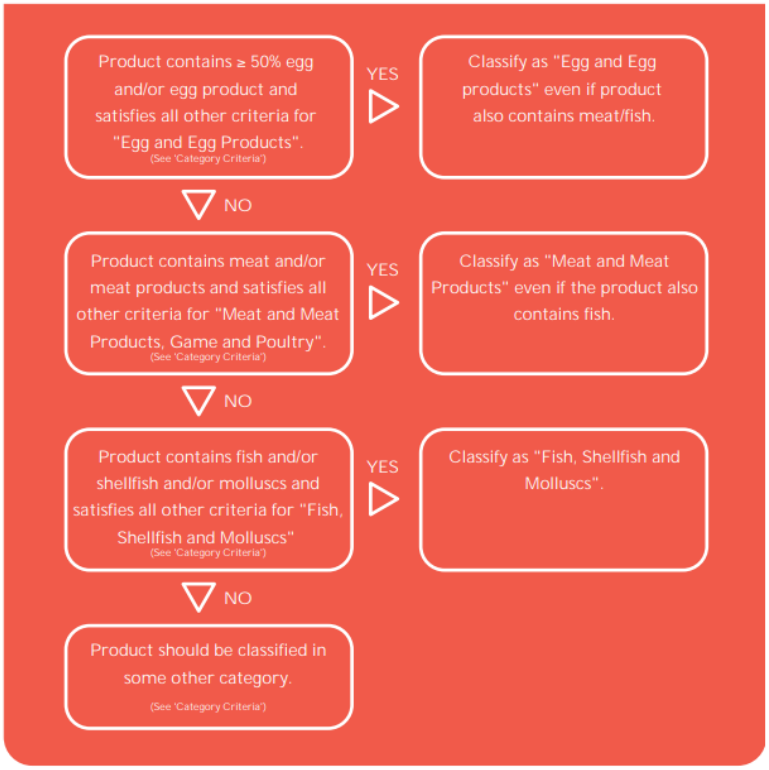

Figure 13. Decision tree for the determination of food category in case of multi-ingredient foods (source: FSAI)

A similar classification system is included in the Rapid Alert System for Food and Feed (RASFF) Window[218], in the 'product' drop down menu. Here, it is possible to select the following voices (also in this case there is a

[217] Now called 'Foods for specific groups'.
[218] https://webgate.ec.europa.eu/rasff-window/screen/search

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combination of food and non-food items):

1) Alcoholic beverages;
2) ABPs (non-food);
3) Bivalve molluscs and products thereof;
4) Cephalopods and products thereof;
5) Cereals and bakery products;
6) Cocoa and cocoa preparations, coffee and tea;
7) Compound feeds (non-food);
8) Confectionery;
9) Crustaceans and products thereof;
10) Dietetic foods, food supplements and fortified foods;
11) Eggs and egg products;
12) Fats and oils;
13) Feed additives (non-food);
14) Feed materials (non-food, but may be obtained by former foodstuffs);
15) Feed premixtures (non-food);
16) Fish and products thereof;
17) Food additives and flavourings;
18) Food contact materials (non-food);
19) Fruits and vegetables;
20) Gastropods;
21) Herbs and spices;
22) Honey and royal jelly;
23) Ices and desserts;
24) Live animals;
25) Meat and meat poultry (other than poultry);
26) Milk and milk products;
27) Natural mineral waters;
28) Non-alcoholic beverages;
29) Nuts, nut products and seeds;
30) Other food product/mixed;
31) Pet food (non-food, but may be obtained by former foodstuffs);
32) Poultry meat and poultry meat products;
33) Prepared dishes and snacks;
34) Soups, broths, sauces and condiments;
35) Water for human consumption (other);
36) Wine.

Another food category classification is included in the Annex II, Part E of Reg. (EC) No. 1333/2008[219,220], included also in the E-Submission Food Chain (ESFC) platform[221] used for the application of regulated products (e.g., novel foods, food additives). This classification comprises also a series of sub-categories, but only the main food

[219] Regulation (EC) No. 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives. http://data.europa.eu/eli/reg/2008/1333/oj
[220] Guidance document describing the food categories in Part E of Annex II to Regulation (EC) No. 1333/2008 on Food Additives. https://food.ec.europa.eu/system/files/2022-12/fs_food-improvement-agents_guidance_1333-2008_annex-2.pdf
[221] https://webgate.ec.europa.eu/esfc

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categories are here reported:

1) 0. All categories of food excluding foods for infants and young children, except where specifically provided for;
2) 1. Dairy products and analogues;
3) 2. Fats and oils and fat and oil emulsions;
4) 3. Edible ices;
5) 4. Fruit and vegetables;
6) 5. Confectionery;
7) 6. Cereals and cereal products;
8) 7. Bakery wares;
9) 8. Meat;
10) 9. Fish and fisheries products;
11) 10. Eggs and egg products;
12) 11. Sugars, syrups, honey and table-top sweeteners;
13) 12. Salts, spices, soups, sauces, salads and protein products;
14) 13. Foods intended for particular nutritional uses as defined by Directive 2009/39/EC;
15) 14. Beverages;
16) 15. Ready-to-eat savouries and snacks;
17) 16. Desserts excluding products covered in category 1, 3 and 4;
18) 17. Food supplements as defined in Directive 2002/46/EC excluding food supplements for infants and young children;
19) 18. Processed foods not covered by categories 1 to 17, excluding foods for infants and young children;

Only in the ESFC platform:

20) 19. Carriers and additives authorised for use in Food additives;
21) 20. N/A;
22) 21. Additives authorised for use in Food flavourings;
23) 22. Additives authorised for use in Nutrients;

Other food categories are provided in Reg. (EC) 2073/2005[222], distinguished between 'food safety criteria' and 'process hygiene criteria', with the latter divided into:

1) Meat and products thereof;
2) Milk and dairy products;
3) Egg products;
4) Fishery products;
5) Vegetables, fruits and products thereof.

[222] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. http://data.europa.eu/eli/reg/2005/2073/oj

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The European Food Safety Authority (EFSA) has developed its own food classification system named FoodEx2[223] (update of FoodEx1), consisting of descriptions of a large number of individual food items aggregated into food groups and broader food categories in a hierarchical parent-child relationship. Central to the system is a core list of food items or generic food descriptions that represent the minimum level of detail needed for intake or exposure assessments. More detailed terms can be found on the "extended list".[224]

The current version has eight hierarchies and 32 facets, used to add further detail to the information provided by the food list term. Facets are collections of additional terms describing properties and aspects of foods from various perspectives. EFSA has established a collaboration for the use of FoodEx2 with several institutions, including FAO.

The Standard Sample Description (SSD2) data model[225] is complemented by FoodEx2, to support the Authority in their risk assessment and management activities for food and feed. It specifies the data elements and data structure of samples for chemical contaminants and residues as well as microbiological contaminants, zoonotic agents and antimicrobial resistance data in food, feed, animals, environmental samples and food contact materials.

FoodEx2 food categories may be consulted through the use of the EFSA Catalogue browser[226] (**Figure 14**), which is a Java® based application directly connected with the Data Collection Framework (a platform through which data are submitted to EFSA), which allows the browsing, analysis and maintenance of EFSA's catalogues. Another system provided is the FoodEx2 Smart Coding App[227], working online.

223 EFSA (2015) The food classification and description system FoodEx 2 (revision 2). *EFSA Supporting Publication* 2015:EN-804, https://doi.org/10.2903/sp.efsa.2015.EN-804
224 https://www.efsa.europa.eu/en/data/data-standardisation
225 EFSA (2013) Standard Sample Description ver. 2.0. *EFSA Journal* 11(10):3424, https://doi.org/10.2903/j.efsa.2013.3424
226 https://github.com/openefsa/catalogue-browser/wiki
227 https://r4eu.efsa.europa.eu/app/FoodEx2-SCA

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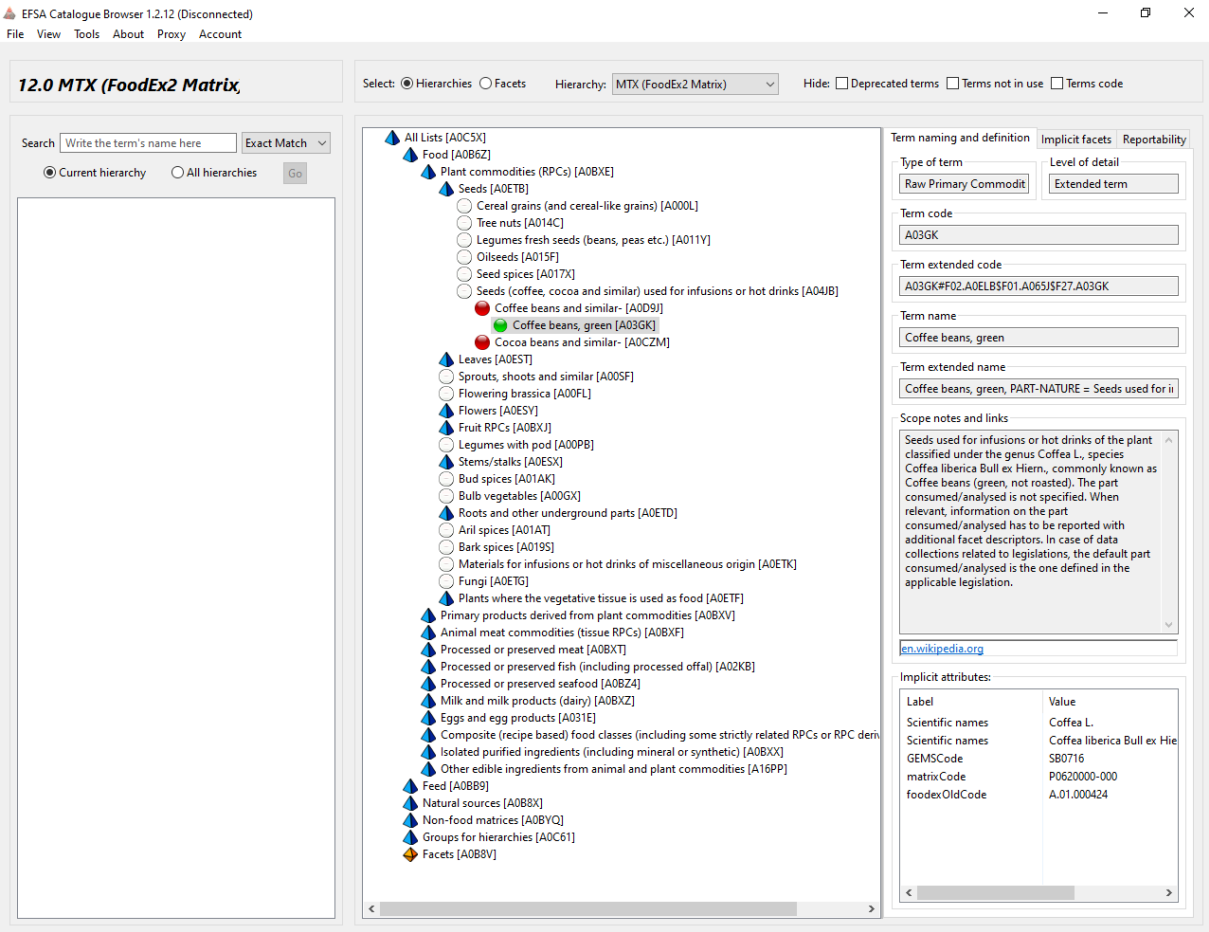

Figure 14. EFSA FoodEx2 Catalogue Browser search example for coffee beans, green (code A03GK). The hierarchy shown is the Master hierarchy MTX, with its different "food categories" (source: EFSA)

Each food (and other items) is provided with an alphanumeric code, consisting of a mandatory base term (e.g., A03GK for coffee beans, green) and optionally terms for facets codes. For the purpose of food categorisation, the base term is sufficient. However, the problem with FoodEx2 classification is that each hierarchy is constitute by different food categories (represented with the blue pyramids, also known as 'never use hierarchy terms. This lack of harmonisation hampers the use of FoodEx2 systems for the identification of proper food categories (unless it is determined that one of the hierarchies is fit for the purpose).

There is also inclusion of food categories covered by Reg. (EC) No. 1333/2008 and Reg. (EC) No. 2073/2005, showing how versatile the system is. Another feature of FoodEx2 is to distinguish between raw primary commodities, derivative ingredients, and composite foods. This is important to have a more precise distinction of the types of food groups.

As the Authority itself has declared, the FoodEx2 classification system is not immediate, and it requires time and practice to be fully managed. It may better serve as a complement for other food categorisations, to specify different food terms included.

The model presented by JRC report, and included in the EU Bioeconomy Monitoring System, includes only 10 food categories, but this is because they refer to primary production only. Foods included in these categories are

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taken from FAO classification, as follows:

1) Sugar beet: sugar beet only;
2) Oilcrops: olives; sunflower seed; rape and mustard seed; soybean; cotton seed;
3) Fruit: apples; bananas; citrus, other; dates; fruits, other; grapefruit; grapes; lemons, limes; oranges, mandarins; pineapple; plantains;
4) Vegetables: onions; tomatoes; vegetables, other; beans; peas; pulses, other
5) Potatoes: potatoes; sweet potatoes
6) Cereals: wheat; barley; rye; maize; oats; rice; other cereals;
7) Dairy: milk only;
8) Eggs: eggs only;
9) Meat: bovine; sheep; pig; poultry;
10) Fish: cephalopods; crustaceans; demersal fish; freshwater fish; marine fish; other molluscs; other pelagic fish.

From these food categories, and for each food item, the model further develops them in processed foods, by-products and FW differently, according to the production process and the specific FSC. For example, in the beer production process, barley is processed to obtain malt, but some inputs and outputs are destined to be wasted (e.g., mould) or sold as by-product (e.g., animal feed). After beer production, brewer's spent grain may also be destined to become waste or animal feed (lately the upcycling is commercially upscaling) (**Figure 15**).

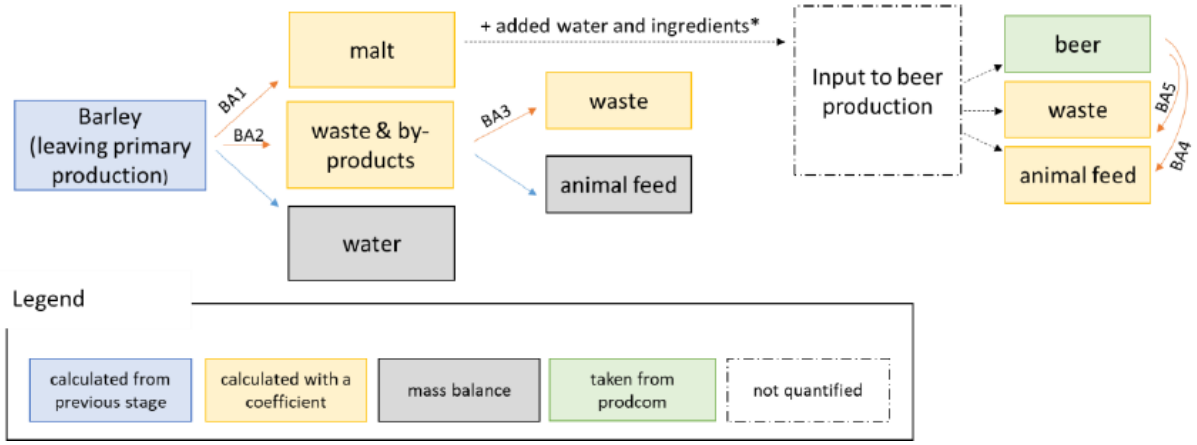

Figure 15. Classification of food products from JRC food categorisation (example of malt and beer production from barley). Each barley output destination is indicated with the code BA, followed by a serial number. It has to be noted the relevance of statistics to determine the production of beer, using PRODCOM data (source: JRC)

Other EU food categories were seen in different statistics regulations. NACE and CPA make possible to classify foods in each level, with a different degree of detail. An example is reported for tomatoes.

NACE and CPA

- First level (section): A – Products of agriculture, forestry and fishing;
- Second level (division): 01 - Products of agriculture, hunting and related services;

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- Third level (group): 01.1 – Non-perennial crops;
- Fourth level (class): 01.13 – Vegetables and melons, roots and tubers;

CPA only

- Fifth level (category): 01.13.3 - Other fruit-bearing vegetables;
- Sixth level (sub-category): 01.13.33 – Tomatoes.

Effective categories and sub-categories are present at CPA level only. For this reason, CPA should be used for a proper food categorisation[228].

CN sections consist of different Chapters, which may be referred as the food categories.

CN

- Section I - Live animals and products of the animal kingdom;

  1) Chapter I – Live animals;

  2) Chapter II – Meat and edible meat offal;

  3) Chapter III – Fish and crustaceans, molluscs and other aquatic invertebrates;

  4) Chapter IV - a) Dairy produce; b) birds' eggs; c) natural honey; d) edible products of animal origin, not elsewhere specified or included;

  5) Chapter V - Products of animal origin, not elsewhere specified or included;

- Section II - Products of the vegetable kingdom;

  6) Chapter VII – Edible vegetables and certain roots and tubers;

  7) Chapter VIII – Edible fruits and nuts; peel of citrus fruit or melons;

  8) Chapter IX – Coffee, tea, maté and spices;

  9) Chapter X – Cereals;

  10) Chapter XI – Products of the milling industry; malt; starches; inulin; wheat gluten;

[228] Article 4(1) of Regulation (EC) No 451/2008 states that '*Member States may use the CPA for aggregated or detailed, national, specific or functional adaptation based on the subcategories of the CPA*'.

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11) Chapter XII – Oil seeds and oleaginous fruits; miscellaneous grains; seeds and fruits; industrial or medicinal plants; straw and fodder;

12) Chapter XIII – Lac; gums; resins and other vegetable saps and extracts;

- Section III - Animal, vegetable and microbial fats and oils and their cleavage products; processed edible fats; waxes of animal or vegetable origin;

13) Chapter XV – Animal, vegetable or microbial fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes;

- Section IV - Products of the food industries; beverages, alcoholic liquids and vinegar; tobacco and manufactured tobacco substitutes; products, not containing or containing nicotine, intended for inhalation without combustion; other products containing nicotine intended for the intake of nicotine into the human body;

14) Chapter XVI - Preparations of meat, of fish, of crustaceans, molluscs or other aquatic invertebrates or insects;

15) Chapter XVII – Sugars and sugar confectionery;

16) Chapter XVIII – Cocoa and cocoa preparations;

17) Chapter XIX – Preparations of cereals, flour, starch or milk, pastry cooks' products;

18) Chapter XX - Preparations of vegetables, fruit, nuts or other parts of plants;

19) Chapter XXI – Miscellaneous edible preparations;

20) Chapter XXII – Beverages, spirits and vinegar;

21) Chapter XXIII – Residues and waste from the food industries; prepared animal fodder;

- Section VI - Products of the chemical or allied industries

22) Chapter XXXV – Albuminoidal substances; modified starches; glues; enzymes.

The latter chapter is an example to describe the possibility of CN (but also of NACE and CPA), to refer to other destination of uses for FW (e.g., starch from FW for the chemical industry).

Other food categories were seen, but they are sector specific, and they differ a lot between each other (e.g., code for milk and dairy products, variable of the land and of livestock).

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Since these food categories (from here called 'detailed food categories') are particular difficult to practically applicate, some 'simplified food categories' were developed, specifically to classify FW (along with FW classifications provided in the LoW and in the waste statistics). Two similar food categories were developed by University of Veterinary Medicine Budapest (UVMB)[229], on the basis of the results of FUSIONS project[230], and by partners of the INTERREG project STREFOWA[231], promoters of the initiative #REDUCEFOODWASTE[232], in which a waste management guideline[233] has been published to describe these food categories.

Both UVMB and STREFOWA partners have described not only 'simplified food categories', but they also have made a distinction between the avoidability/inavoidability of FW (e.g., edible, inedible parts); the consistency of the food (i.e., solid, liquid), and the disposal route (also connected to the food consistency). These categorisations are resumed in **Table 10**:

Table 10. UVMB and STREFOWA schemes for FW categorisation

	UVMB	STREFOWA
Avoidability	**Avoidable** (its generation could have been avoided, the root cause is consumer behaviour, e.g., spoiled milk in the fridge)	**Avoidable** (consumption residues, partially consumed food, entirely uneaten food as purchased, whole, unopened)
	Unavoidable (its generation cannot be avoided, e.g. chicken bone, eggshell)	**Unavoidable** (inedible parts and preparations residues, such as bones, skins)
	Potentially avoidable (its generation is influenced by individual taste or health issues, e.g., some people cannot chew certain food materials and they have to discard it)	
Consistency	**Solid state food**	**Solid state food** (it is part of the solid municipal waste streams, which includes biowaste within residual waste and separate food waste, and of home composting)
	Liquid state food	**Liquid state food** (as part of the sewer)
Disposal route	**Rubbish bin** (mixed waste)	**Rubbish bin** (mixed waste)

[229] Kasza G., Dorkó A., Kunszabó A., Szakos D. (2020) Quantification of Household Food Waste in Hungary: A Replication Study Using the FUSIONS Methodology. *Sustainability* 12(8):3069, https://doi.org/10.3390/su12083069

[230] https://www.eu-fusions.org/phocadownload/Publications/FUSIONS%20Food%20Waste%20Quantification%20Manual.pdf

[231] https://programme2014-20.interreg-central.eu/Content.Node/STREFOWA.html

[232] http://www.reducefoodwaste.eu/

[233] http://www.reducefoodwaste.eu/uploads/5/8/6/4/58648241/ce192_strefowa_d.t3.1.3_waste_management_guideline.pdf

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	Sewer (according to EU legislation this is not food waste, but our methodology allows us to measure this important material flow)	**Sewer**
	Composting	**Composting**
	Animal feeding (according to EU legislation this is not food waste, but our methodology allows us to measure this important material flow)	**Anaerobic digestion**
	Waste collection point (used frying oil)	**Waste collection point** (with different collection systems)
Food types (18 types)	1. Meals (home-made and ready-to-eat)	1. Sweet/cookies
	2. Bakery products	2. Pasta/rice
	3. Fresh vegetables	3. Frozen products
	4. Fresh fruits	
	5. Dairy products	4. Special diet
	6. Mineral water, soft drinks, coffee, tea	
	7. Raw meat	5. Alcohol
	8. Grain products (flour, semolina, oat)	
	9. Canned foods, pickles	6. Cooking additionals
	10. Processed animal products	
	11. Sauces, toppings (ketchup, mustard, salad dressings, mayonnaise)	7. Drinks
	12. Marmalades, jams	8. Meal
	13. Confectionery, snacks	
	14. Yeast, muesli, corn flakes, raisins, puffed rice, baking mixtures	9. Meat, fish, cold cuts
	15. Eggs	10. Dairy
	16. Frozen meats, vegetables	11. Vegetable and fruits
	17. Fats (butter, margarine, lard, etc)	
	18. Packed spices (rosemary, marjoram, parsley, etc)	12. Bakery

The use of 'simplified food categories' should be easier for FBOs and other operators that have to report FW generated amounts to EU MSs. The use of the food categories reported in EU statistics can also be used to facilitate the reporting duties of MSs to Eurostat (and in turn to the EC).

In order to maintain the facilitation to which the different operators could be subjected, and not to lose the possibility of obtaining statistically useful and meaningful information and data, a kind of association-conversion

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between 'simplified food categories' and 'detailed food categories' could be envisaged. In particular, the categories and sub-categories listed in the CPA might be the most suitable, as the NACE classification is already currently implemented to define the reference FSCs in which FWs are generated, within Decision (EU) 2019/1597. Eurostat itself stated that the CN classification has several limitations in effectively distinguishing goods and waste. Therefore, it may not be the best choice for this purpose.

Even if not correlated with FW quantification and measurement, the JRC study 'Grown and thrown: Exploring approaches to estimate food waste in EU countries[234]' (included in the JRC report 'Building a balancing system for food waste accounting at national level') stated that it is possible to estimate amount of food consumed in the EU, according to the following formula:

Food consumption in the EU = Food production in the EU – FW generation in the EU

This formula may be applied to every FSC. During their experimentation for the test of the MFA model for FW quantification, it was declared that this results in a more accurate way to determine food consumption in the EU, compared to statistics provided by EU MSs. This is particularly relevant, due to the following potential benefits: a) it is possible for EFSA and other national Authorities to perform a more accurate risk assessment and adopt better risk management decisions (or support EU MS and/or the EC in doing so); b) the knowledge of food consumption in the EU is helpful for a more precise food production and importation planning, reducing the possibilities to overproduce food destined to be wasted.

2.3. Blockchain

Blockchain is one of the tools and methodologies that are being developed within WASTELESS project. Its development will follow a Proof of Concept (PoC) (WP2), to finalise a WASTELESS public blockchain, to be tested in different FSCs case studies.

At the moment, there is no specific regulation for blockchain in the EU, but EC (on request from EP and EUCO) developed different policies and initiatives dedicated to this topic, which are linked with other EU policies and regulations, to increase the (blockchain) technological development and application in EU enterprises (especially SMEs) and EU public services and administrations, together with EU entrepreneurs and citizens digital skills.

Considering dedicated EU blockchain policies, initiatives and (other) regulations, the development and implementation of a blockchain system should follow them, to comply with the requirements and the intentions set by EU institutions (in particular EC). This alignment makes easier to ensure compliance with any future specific regulatory implementations, and to meet institutional needs and requirements with regard to this technology (without going against other regulatory requirements already in place - e.g., privacy).

To this purpose, a review of the blockchain technology has been presented, followed by the description of current EU policy in force. WASTELESS public blockchain development is taking into considerations the whole EU policy, with the aim of combine it with the current regulation related to FLW described in the previous sections.

[234] Caldeira C. et al. (2021) Grown and thrown: Exploring approaches to estimate food waste in EU countries. *Resources, Conservation and Recycling* 168:105426, https://doi.org/10.1016/j.resconrec.2021.105426

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To fulfil the objectives of task 1.3, specific information for documents (e.g., invoices, waste register, transport documents) and codification of materials are defined, and the framework of relevant (blockchain) policies are intended to guide the research activities of task 1.1 (SoA of current FLW policies and strategies), facilitate the achievement of the results of task 1.2 (Improved framework for FLW measurement & monitoring) to be exploited for the recommendations to be provided to task 1.4 (Recommendation for future regulatory framework for FLW measuring and monitoring). Together with WP2 and WP3 activities and results (see **Figure 16)**, other operators will have the opportunity to implement blockchain technology, following EU policy and regulations reported in this deliverable.

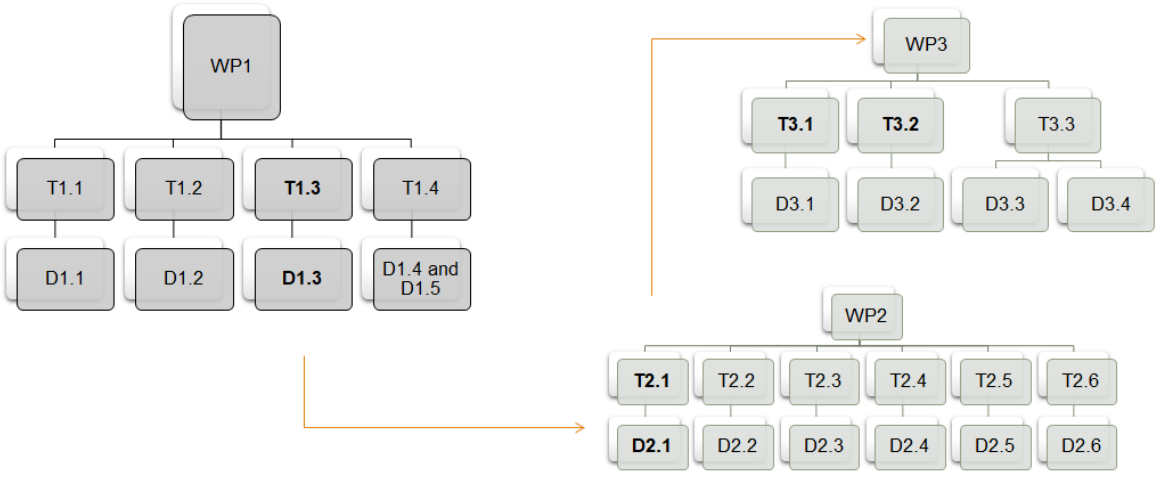

Figure 16. Interactions between WPs in WASTELESS project: T1.3 results support the development of the WASTELESS Public blockchain (T2.1), which is going to be tested in WP3 case studies (i.e., T3.1 and T3.2) (source: the author)

2.3.1 Blockchain technology

Blockchain is the technology initially implemented for storing and transmit digital cash (e.g., bitcoin) through dedicated peer-to-peer networks to authenticate transactions. The potential of blockchain system captured the attention of private and academia fields, for different uses in finance and economy, Internet of Things (IoT), energy, supply chains and other areas.[235]

Technically, blockchain is a decentralized, distributed and immutable ledger DLTs comprised of a cryptographically linked chain of record collection referred as blocks (**Figure 17**), and the records called transactions or events. The ledger is shared within all contributory members in the blockchain network, and transactions added to the ledger need verification and agreement between parties involved in the specific

[235] Wang G. et al. (2021) A Systematic Overview of Blockchain Research. *Journal of Systems Science and Information* 9(3):205-238, https://doi.org/10.21078/JSSI-2021-205-34

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blockchain. These features are the strong point of this system, being them associated with decentralisation, immutability and cryptographic link.[236]

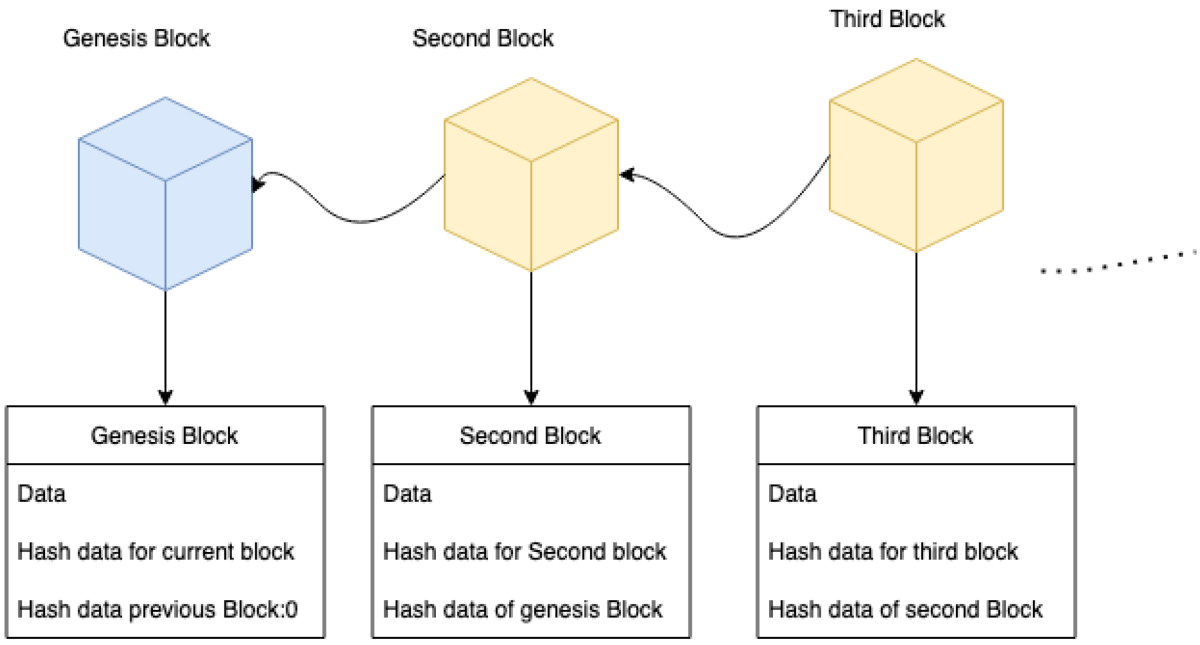

Figure 17. Blockchain layer architecture formed by blocks (source: Soltani et al., 2022)

Within the database where every written record is signed by a private key every record insertion and change can be traced back to specific public/private key pair and whose atomic operation is irrecoverably committed after the databases mathematically prove their validity and distributed consistency. The blockchain is based on statistical and cryptographic principles for improving security of data management enabling authorized and audited change and processing of data from its origin to the end of data usage.[237]

Through the blockchain, it is possible to develop 'smart contracts', considered as self-enforcing and self-executing programs to actuate the terms and conditions of a particular agreement or contract, using software codes and computational infrastructure. They may be considered as an extension of the utilisation of the distributed ledger, operating as decentralised programs, making available the peer-to-peer functionality, without the need of a centralised third party, and service availability without any centralised dependency, being autonomous. Blockchain smart contracts have different features, generally resumed as following:[238]

- Elimination of trusted third party: decentralisation eliminates the so-called single point of failure (i.e. centralisation), together with excessive data consumption and latency in operation, and the 'Black Box',

[236] Soltani R. et al. (2022) Distributed Ledger Technologies and Their Applications: A Review. *Applied Sciences* 12(15):7898, https://doi.org/10.3390/app12157898
[237] Kalafatic K. (2018) Using blockchain principles for improving AI research and security. *European AI Alliance* https://ec.europa.eu/futurium/en/system/files/ged/using_blockchain_principles_for_improving_ai_research_and_security.pdf
[238] Hewa T. et al. (2021) Survey on blockchain based smart contracts: Applications, opportunities and challenges. *Journal of Network and Computer Applications* 177:102857, https://doi.org/10.1016/j.jnca.2020.102857

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as the accountability is provided to all members of the blockchain system;

- Forge resistance: digital signatures permits to cryptographically verify the integrity of transactions and blocks in the distributed ledger, remaining persistently in the network;

- Transparency: transactions are visible to all parties, as the ledger and the smart contracts;

- Autonomous execution: once a triggering state is defined by blockchain members, the execution is carried out autonomously, and the service availability is guaranteed due to the absence of a centralised third party;

- Accuracy: smart contracts are immutable and verified, prior to the deployments in nodes in the blockchain network, without human or any other errors in the execution. This increase the trust, along with transparency.

Some important commercial smart contract platforms are shown in **Figure 18**.

Blockchain may also be distinguished in 3 types[239] (**Figure 19**):

- Public blockchain: the transaction can be checked and verified by everyone in the network, and the process of getting consensus is also available to public;

- Private blockchain: the blockchain is available for every node to participate, the node is restricted and has strict authority management to access the data;

- Federated/Consortium blockchain: an amalgamation of public and private blockchains, where the authorized node can be chosen in advance, and data can also be seen as partially decentralized. It usually has Business-to-business (B2B) partnerships.

Each one of them has its advantages and disadvantages. For example, public blockchain permits the access to anyone, and it is considered infeasible to tamper, but the consensus mechanism may hamper its transaction approval speed. Private blockchain is a closed system only for admitted (generally few) participants (which are supposed to know each other well), making the system faster. However, there is no possibility to prevent its control and manipulation (e.g., for fraud).

[239] Gad A.G. et al. (2022) Emerging Trends in Blockchain Technology and Applications: A Review and Outlook. *Journal of King Saud University – Computer and Information Sciences* 34(9):6719-6742, https://doi.org/10.1016/j.jksuci.2022.03.007

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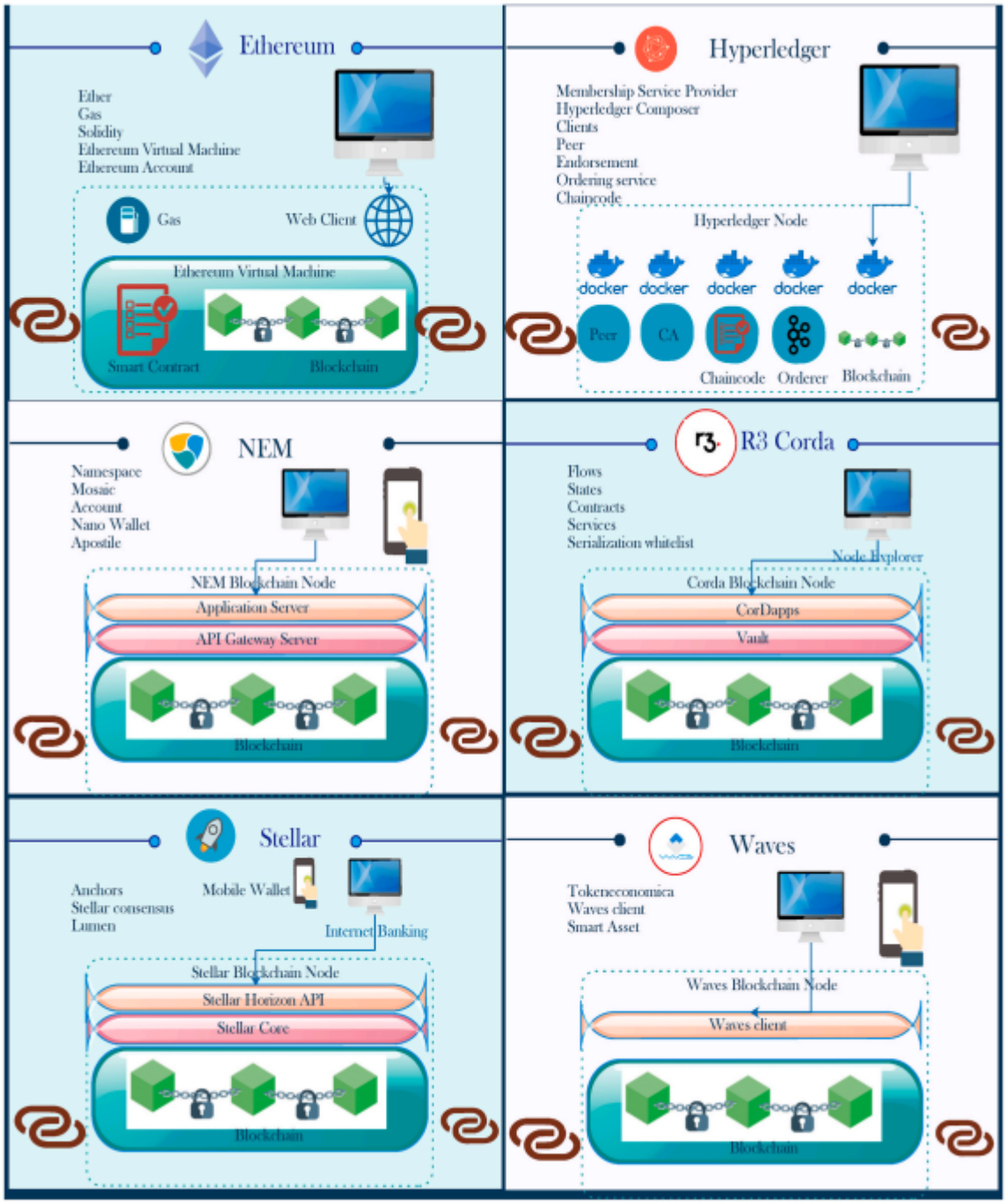

Figure 18. Example of smart contract platform (source: Hewa et al., 2021)

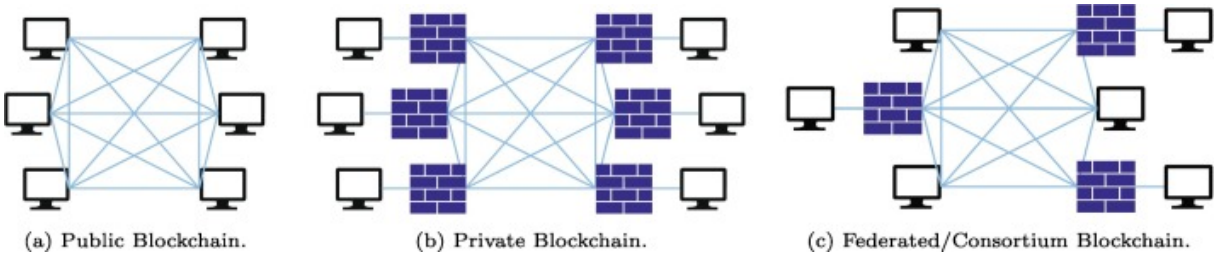

Figure 19. Different blockchain types (source: Gad et al., 2022)

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2.3.2 Blockchain implementation in the EU

EU is aiming to become a leader in blockchain technology, and a host to significant platforms, applications and companies, leading to the implementation of the 'Blockchain Strategy'[240]. The intention is to allow people and organisations that do not know or trust each other, to agree collectively and permanently record information without a third-party authority. To achieve these intended results, a 'gold standard' has been developed, which support EU legal and regulatory framework:

- Environmental sustainability: Blockchain technology should be sustainable and energy-efficient;
- Data protection: Blockchain technology should be compatible with, and where possible support, Europe's strong data protection and privacy regulations;
- Digital Identity: Blockchain technology should respect and enhance Europe's evolving digital Identity framework. This includes being compatible with e-signature regulations (e.g., eIDAS) and supporting a sensible, pragmatic decentralised and self-sovereign identity framework;
- Cybersecurity: Blockchain technology should be able to provide high levels of cybersecurity;
- Interoperability: Blockchains should be interoperable between themselves and with legacy systems in the outside world.

Blockchain is also part of 'A European strategy for data[241]', with the consideration that digital technologies are now an effective part of the economic and society, and 'data' is the pivot point to enable a proper transition and implementation in the EU. The collection of a huge amount of data has to be linked with fair use, to respect individual rights and compliance with EU regulatory requirements, especially when this data source derive from IoT devices and digital services.

Personal data protection from *General Data Protection Regulation* (i.e., Reg. (EU) 2016/679[242]) and Reg. (EU) 2018/1725[243] need tools to support consumers and other people to decide and monitor their data use. Blockchain is considered as one of these tools. Nonetheless, the continue flows of data exchange brings forth new challenges for data security (i.e., *cybersecurity*). DLTs as the decentralised blockchain is considered as '*possibility for both individuals and companies to manage data flows and usage, based on individual free choice and self-determination. Such technologies will make dynamic data portability in real time possible for individuals*

[240] https://digital-strategy.ec.europa.eu/en/policies/blockchain-strategy
[241] Communication from the Commission to the European Parliament, the European Council, The European and Social Committeee and the Committee of the Regions – A European strategy for data (COM/2020/66 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066
[242] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). http://data.europa.eu/eli/reg/2016/679/oj
[243] Regulation (EU) 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies and on the free movement of such data, and repealing Regulation (EC) No. 45/2001 and Decision No. 1247/2002/EC. http://data.europa.eu/eli/reg/2018/1725/oj

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and companies, along with various compensation models.'. This is a topic that has been discussed by the EU association European Law Institute (ELI)[244], to examine the practical application of blockchain-based solutions, and to verify its role and influence on consumer protection, and the presence of possible divergence with the current EU law, to assess the need for new regulation or amendments of already existing law, to complement better the technological innovation with consumer protection. A similar study has been published[245], related to 'smart contracts' and the effect of interaction between law and technology to develop solutions that promotes their evolution.

Blockchain has been considered by EC and MSs in other different communication documents. '2030 Digital Compass: the European way for the Digital Decade[246]' is aiming to achieve the same digital "sovereignty", also considering the COVID-19 pandemic, and the potential of digital technologies and solutions to face this and other similar crisis. The compass indicates 4 cardinal points, which are, in this case: a) the will to increase population and professionals' digital skills; b) develop secure and performant sustainable digital infrastructures; c) digital transformation of businesses; d) digitalisation of public services.

Different multi-country digital projects have been discussed between EU MSs, under the Recovery and Resilience Facility (RRF) (they have to be compliant with Reg.(EU) 2021/241[247]). Between them, there is the involvement of European Blockchain Service Infrastructure (EBSI)[248] (financed by Digital Europe programme[249]), to develop, deploy and operate a pan-European blockchain-based infrastructure that is green, secure, in full compliance with EU values and the EU legal framework, making cross-border and national/local public service provision more efficient and reliable and promoting new business models. To the Communication, the implementation of Decision (EU) 2022/2481[250] has followed, to establish the Digital Decade Policy Programme 2030, to favour digital innovation on basis of measurable indicators, and cooperation between EP, EUCO, EC and MSx. It promotes the implementation of multi-country activities, including EBSI (and blockchain solutions) in the areas of activity.

Blockchain has also been considered as one of the key technological innovations that may contribute in supporting EU citizens, investors and SMEs in their road toward sustainability.[251] New and higher investments

[244] ELI Principles on Blockchain Technology, Smart Contracts and Consumer Protection – Report of the European Law Institute. ISBN 978-3-9505318-1-7, https://www.europeanlawinstitute.eu/fileadmin/user_upload/p_eli/Publications/ELI_Principles_on_Blockchain_Technology_Smart_Contracts_and_Consumer_Protection.pdf

[245] Schrepel T. (2021) Smart contracts and the digital single market through the lens of a "law + technology" approach. *Publications Office of the European Union*, ISBN 978-92-76-41173-4, https://doi.org/10.2759/562748

[246] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions – 2030 Digital Compass: the European way for the Digital Decade (COM/2021/118 final). https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021DC0118

[247] Regulation (EU) 2021/241 of the European Parliament and of the Council of 12 February 2021 establishing the Recovery and Resilience Facility. http://data.europa.eu/eli/reg/2021/241/oj

[248] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Home

[249] Regulation (EU) 2021/694 of the European Parliament and of the Council of 29 April 2021 establishing the Digital Europe Programme and repealing Decision (EU) 2015/2240. http://data.europa.eu/eli/reg/2021/694/oj

[250] Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme 2030. http://data.europa.eu/eli/dec/2022/2481/oj

[251] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions – Strategy for

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are needed to support this transition, and the acquisition of competence and skills from all the relevant parties.[252] For example, Digital Crash Courses are intended to be developed for SME employees, to become proficient with blockchain and other digital areas (e.g., Artificial Intelligence (AI), cybersecurity), and other initiatives blockchain-related for this particular group.[253] Protection and innovation are considered two aspects that may obstacle each other, but need to cooperate to achieve the digital transition. EBSI has also the role to support the implementation of services, making possible, at the same time, the reciprocal approach between these two aspects.[254]

A lot of investment has been done by the EC, through the HORIZON programme, which has funded projects for an amount higher than 300 million €.[255,256] These funds are implemented also by the InvestEU Programme[257]. Some of these projects were also implemented by JRC, such as #Blockchain4EU[258], Blockchain Now And Tomorrow[259], and Blockchain for digital government[260]. Other forms of investments are prizes (5 million €), such as the 'Blockchains for social good[261]' funded by the European Innovation Council (EIC). The prize wants to recognise and support the efforts made by developers and civil society in exploring the decentralised applications of blockchains for social innovation. It covers areas such as traceability and fair trade, financial inclusion, decentralised circular economy, transparency of public processes, participation in democratic decision-making, and management of public records.

For the development of blockchain technology in the EU, the implementation of standards is considered necessary, to ensure interoperability, generate trust and help ensure the easy use of the technology. Identity,

Financing the Transition to a Sustainable Economy (COM/2021/390 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0390&qid=1681179505095

[252] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions – Towards a green, digital and resilient economy: our European Growth Model (COM/2022/83 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0083&qid=1681179505095

[253] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions – An SME Strategy for a sustainable and digital Europe (COM/2020/103 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A103%3AFIN

[254] Communication from the Commission to the European Parliament, the European Council, The European and Social Committee and the Committee of the Regions – A New European Innovation Agenda (COM/2022/332 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0332&qid=1681179505095

[255] https://digital-strategy.ec.europa.eu/en/news/eu-funded-projects-blockchain-technology

[256]https://digital-strategy.ec.europa.eu/en/news/overview-eu-funded-blockchain-related-projects

[257] Regulation (EU) 2021/523 of the European Parliament and of the Council of 24 March 2021 establishing the InvestEU Programme and amending Regulation (EU) 2015/1017. http://data.europa.eu/eli/reg/2021/523/oj

[258] Nascimento S. et al. (2018) #Blockchain4EU - Blockchain for industrial transformations. *Publications Office of the European Union*, ISBN 978-92-79-85719-5, https://doi.org/10.2760/204920

[259] Anderberg et al. (2019) Blockchain now and tomorrow - Assessing multidimensional impacts of distributed ledger technologies. *Publications Office of the European Union*, ISBN 978-92-76-08977-3, https://doi.org/10.2760/901029

[260] Alessie D. et al. (2019) Blockchain for digital government - An assessment of pioneering implementations in public services. *Publications Office of the European Union*, ISBN 978-92-76-00581-0, https://doi.org/10.2760/942739

[261] https://eic.ec.europa.eu/blockchains-social-good_en

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security, governance and smart contracts are topics considered relevant to be included in blockchain standards. Different international, national and industrial organisations (e.g., StandICT) are involved for the development of these standards.[262]

To further support the blockchain implementation, the EC has promoted three initiatives: the European Blockchain Regulatory Sandbox[263], the EU Blockchain Observatory and Forum[264], and the European Blockchain Platform (EBP)[265]:

- The Regulatory Sandbox aims to establish a pan-European framework for regulatory dialogues to increase legal certainty for innovative blockchain solutions, with and between regulators and supervisors on the one hand, and companies or public authorities on the other hand (with the help of a facilitator). Lessons learned will be shared between participating regulators, helping the EC to identify best practices. The European Blockchain Regulatory Sandbox will operate for 3 years with three annual cohorts of 20 use cases each. A team has been developed to support the design, organisation and management of the European Blockchain regulatory Sandbox[266];

- The EU Blockchain Observatory and Forum's goal is to create a community to discuss and highlight key developments of blockchain technology and strengthen partnerships in Europe and beyond. It is committed to enhancing the understanding of the blockchain technology, its applications and the larger economic ecosystems in which it can play an important role;

- The EBP is an initiative to develop an EU strategy on blockchain and build a blockchain infrastructure for public services. It supports interoperability and the broad deployment of blockchain-based services, and it offers a regulatory-compliant environment in full compliance with EU laws and with clear governance structures and models to help blockchain grow and flourish all across Europe. It has been involved for the development of EBSI and the Regulatory Sandbox. The Declaration between 21 MSs and Norway has been signed in 2018, and 8 more countries (for a total of 30) have joined[267].

The European Blockchain Convention[268] is the main European event born in 2018, intended to accelerate the growth and development of the blockchain system. It hosts attendees, speakers and start-ups operating in the blockchain field, while founders, investors, regulators, developers, corporations, and many more come together every year to learn, get inspired, and connect.

Other considerations were provided also by EP, EUCO and the European Economic and Social Committee (EESC). They are summarised as follows (**Table 11**):

Table 11. Collection of EP resolutions, EUCO conclusions and EESC opinions on blockchain

262 https://digital-strategy.ec.europa.eu/en/policies/blockchain-standards
263 https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Sandbox+Project
264 https://www.eublockchainforum.eu/
265 https://digital-strategy.ec.europa.eu/en/policies/blockchain-partnership
266 https://ec.europa.eu/digital-building-blocks/wikis/display/EBSISANDCOLLAB/EBSI+SANDBOXCollab
267 https://digital-strategy.ec.europa.eu/en/news/european-countries-join-blockchain-partnership
268 https://eblockchainconvention.com/

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EP	EUCO	EESC
2017/2772(RSP)[269] Blockchain (and DLT) is a tool that may enforce citizens autonomy and strengthen their data control, together with verification of check from other people. Private (particularly SMEs) and public sector will benefit from blockchain implementation. So, the EC should monitor this implementation, and promote different initiatives and research activities.	2020/C 447/01[270] Regulatory sandboxes are used in different sectors (e.g. n finance, health, legal services, aviation, transport and logistics, energy) and also for new emerging technologies (e.g., blockchain). Calls the EC to present a progress report on this exchange of information and good practices regarding regulatory sandboxes, including European Blockchain Regulatory Sandbox.	EESC 2019/00522[271] EESC supports for development of EBP and EU Blockchain and Observatory Forum and civil society organisations to render digital infrastructures as a disruptive social innovation. The practical application of blockchain can significantly improve the performance of social economy organisations, benefiting them, their members and, above all, their end-users. It recalls also the EP resolutions. Waste reduction is considered to benefit from implementation of decentralised distributed ledgers, which can be used to improve services provided to the public by environmental associations and social enterprises.
2018/2085(INI)[272] Different calls to the EC, including: - ongoing developments of pilots/initiatives in the international supply chain, and the external aspects of customs and		EESC 2019/02261[273] It describes the opportunity from the blockchain implementation (e.g., achieving of SDGs, empowering citizens, developing public and private services, standardisation processes, transparency improvement through smart contracts,

[269] European Parliament resolution of 3 October 2018 on distributed ledger technologies and blockchains: building trust with disintermediation (2017/2772(RSP)). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018IP0373&qid=1681178120828

[270] Council Conclusions on Regulatory Sandboxes and Experimentation Clauses as tools for an innovation-friendly, future-proof and resilient regulatory framework that masters disruptive challenges in the digital age (2020/C 447/01). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020XG1223%2801%29&qid=1681216998592

[271] Opinion of the European Economic and Social Committee on 'Blockchain and distributed ledger technology as an ideal infrastructure for the social economy' (own-initiative opinion) (EESC 2019/00522). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019IE0522&qid=1681178120828

[272] European Parliament resolution of 13 December 2018 on Blockchain: a forward-looking trade policy (2018/2085(INI)). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018IP0528&qid=1681178120828

[273] Opinion of the European Economic and Social Committee on Blockchain and the EU single market: what next? (own-initiative opinion) (EESC 2019/02261). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019IE2261&qid=1681178120828

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regulatory processes; - Invitation to produce a horizontal strategy document involving relevant Directorate-General (DGs) on adopting blockchain technologies in trade and supply-chain management, and other areas; - optimisation of blockchain architecture for EU policies and (international) market trade; - analysis of blockchain role in the achievement of SDGs.		reinventing socioeconomic models). There are, however, still some challenge to tackle, such as personal data protection, implementation costs, and interoperability.

EP's Science and Technology Options Assessment (STOA) has published a dedicated study[274] to analyse blockchain technology in the context of international trade and supply chains, and its impact in 8 use cases. Between them, three were of particular interest:

- Case #5 – Shipping documents and event tracking system: to reduce the amount of administrative burden (manual, time-consuming, paper-based process), needed for goods exchange, and the potential derived time delays. The connection of all parties in a trade ecosystem, where they are able to interact and access these documents on real time via a distributed ledger, helps to speed up the exchange of goods, automate shipping processes, and reduce paper work and human error(s);

- Case #6 – Blockchain-based electronic Certificate of Origin (CO): COs are essential trade documents, and may be often subjected to manipulation/misinterpretation by different operators. It also requires time, since it has to be manually filled and physically transmitted when goods are delivered. There is also uncertainty relative to the true origin of goods purchased. Electronic COs, included in a blockchain distributed ledger, may serve as an authentication system for trade documents. It may also speed up the process;

- Case #8 – Tracking ethical sourcing in the food industry: some practices in the food industry are considered compromising for the environment and for the people (e.g., wildlife menace, human rights abuses, unfair trade practices). The implementation of blockchain technology may help to provide traceability of the food (e.g., fish) served to the consumers, adding information related to the fishing method, fish origin, vessel type and other information, without possibility to change and modify them.

[274] European Parliament (2020) Blockchain for supply chains and international trade. *European Parliamentary Research Service* PE 641.544, https://www.europarl.europa.eu/RegData/etudes/STUD/2020/641544/EPRS_STU(2020)641544_EN.pdf

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For the food sector, different other examples were provided, especially for transparency and traceability assurance (e.g., International Business Machines Corporation (IBM) Food Trust adopted by Walmart and Carrefour), but also to tackle and manage cases of food contamination and food fraud.

From regulatory point of view, blockchain (as DLT) is included in the scope of application of Reg. (EU) 2022/858[275], introducing the DLT Pilot Regime. However, this is related only to the infrastructure market. This regulatory implementation is a test that may be considered to assess the impact of DLT technologies, and some potential issues (e.g., personal data protection, compliance with climate policy).

2.3.3 Food (waste) management with blockchain solutions

Blockchain application to the agri-food system is not new, and it has been object of an extensive research. The traceability and transparency, that it can offer, may support food producers (e.g., farmers, processing industries) to transparently displaying the process of food products from the soil to the end-user, both easily determining the exorbitant prices of food products, deriving from environmental problems (e.g. climate change, water scarcity) and food demand increase from the increasing population, and determining the origin of the products correctly. Different other advantages are considered in different FSC stages[276]:

- Raw material purchase: Information such as product type, amount of chemical, which is the shopping information between the supplier and the manufacturer, is recorded in the blockchain structure. QR codes can be used to automate these processes,

- Planting the crop: The producer records the number and type of seeds used during planting in the blockchain structure. With a smart contract to be used here, it can be checked that no more seeds are planted from the seed taken in the previous transaction;

- Cultivation: With the networked microcontrollers to be used here, information about the growing place of the product, how much water or sun it receives can be added to the blockchain. Again, when there is an anomaly with smart contracts, it can be recorded;

- Harvest: During the harvest of the planted product, adding the obtained amount to the blockchain with IoT devices can be automated and it can be determined whether the product is organic through the process from seed to harvest;

- Delivery of the product to the fabricator: Using GPS technology, the delivery process of the product to the fabricator can also be monitored with IoT devices;

- Production: The amount delivered to the manufacturer can be added to the blockchain. In this way, it is possible to monitor how much loss is incurred in the transfer phase of the goods from the manufacturer to the manufacturer;

[275] Regulation (EU) 2022/858 of the European Parliament and of the Council of 30 May 2022 on a pilot regime for market infrastructures based on distributed ledger technology, and amending Regulations (EU) No 600/2014 and (EU) No 909/2014 and Directive 2014/65/EU. http://data.europa.eu/eli/reg/2022/858/oj

[276] Mendi A.F. (2022) Blockchain for Food Tracking. *Electronics* 11(16):2491, https://doi.org/10.3390/electronics11162491

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- Delivery of the product to the retailer: Using GPS technology, the delivery process of the product to the retailer can also be monitored with IoT devices. The quantity and freshness of the delivered product can be recorded on the blockchain;

- Consumption: The consumer can view the entire life cycle of this product, all data collected, with the help of a QR code. They can also observe how the pricing is conducted in all the above transactions.

JRC has also considered blockchain use in food systems, to guarantee geographical traceability and prevent food frauds, especially for food products such as PDO and PGI, defined in Reg. (EU) No. 1151/2012[277]. It is also possible to combine acquired data with audit schemes and product testing.[278]

In the animal field, blockchain has been tested in combination with Copernicus for earth observation, under the ESA funded project AquaLedger[279]. This permitted to collect information about the marine environment and aquaculture management, with the integration with a blockchain/DLT based platform towards improved and sustainable supply chain management in the fisheries and aquaculture sector. The main application was the control of water quality parameters (e.g., dissolved oxygen, salinity, pH, turbidity).[280]

In the United States of America (USA), blockchain technology is part of the 'New Era of Smarter Food Safety[281]' launched by the FDA, with the intention to incorporate the use of new technologies, tools and approaches to implement the science and risk-based requirements of the FSMA. Former Deputy Commissioner for Food Policy and Response Frank Yiannas was one of the proponents, having joined the FDA after its experience in the Walmart retail company, where he succeeded to implement a traceability system that permit to identify the suppliers in less than 3 seconds[282]. The same smartness was considered necessary in the USA. FSCs, and blockchain has been considered by him as the 'holy grail of digital food traceability solutions' thanks to its '*distributed and decentralized nature that aligns more closely with a decentralized and distributed food system, has enabled food system stakeholders to imagine being able to have full end-to-end traceability. An ability to deliver accurate, real-time information about food, how it's produced, and how it flows from farm to table is a game-changer for food safety.*'[283]

TRUSTyFOOD[284] is another EU funder project aimed at implementing blockchain into agri-food systems. From past experiences, it wants to review the different results obtained from its implementation, and understand the

[277] Regulation (EU) No. 1151/2012 of the European Parliament and of the Council of 21 November 2012 on quality schemes for agricultural products and foodstuffs. http://data.europa.eu/eli/reg/2012/1151/oj

[278] De La Calle Guntinas M.B. (2023) Geographical origin authentication via elemental fingerprint of food. *European Commission*, JRC132521, https://publications.jrc.ec.europa.eu/repository/handle/JRC132521

[279] https://www.aqualedger.eu/

[280] https://www.copernicus.eu/en/use-cases/improving-traceability-aquaculture-and-fisheries-blockchain-and-earth-observation

[281] https://www.fda.gov/food/new-era-smarter-food-safety

[282] Yiannas F. (2018) A New Era of Food Transparency Powered by Blockchain. *Innovations: Technology, Governance, Globalization* 12(1-2):46–56, https://doi.org/10.1162/inov_a_00266

[283] https://www.fda.gov/food/conversations-experts-food-topics/deputy-commissioner-champions-more-digital-transparent-food-safety-system

[284] https://www.trustyfood.eu/

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reason for acceptation or refusal by (potential) users. It is important to avoid past mistakes and find the best solutions to be implemented for the use in FSCs. The project structure is reported in **Figure 20**:

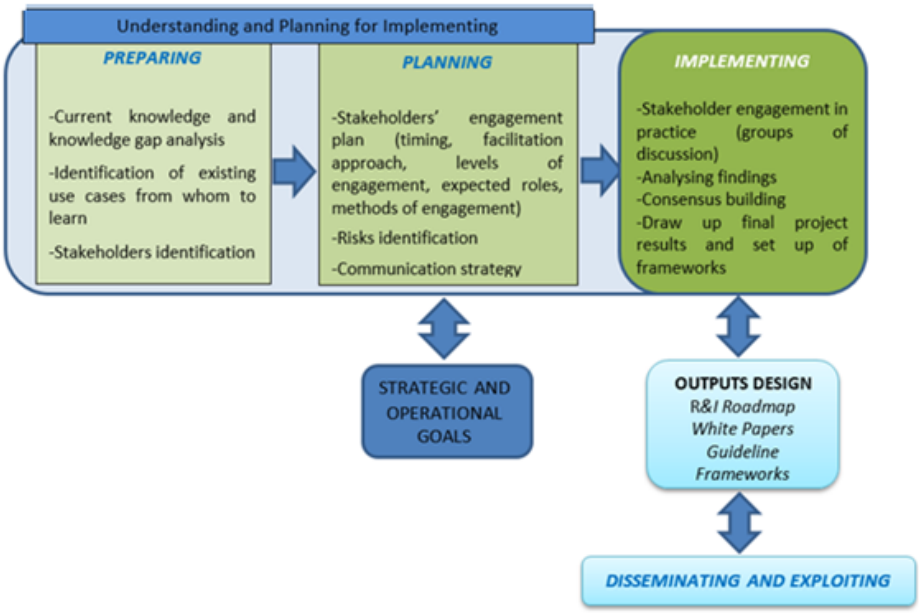

Figure 20. TRUSTyFOOD project implementation (source: TRUSTyFOOD)

Other case studies in the agri-food sector were collected by the EU Blockchain Observatory & Forum for the event 'Use of blockchain applications in the agri-food sector' organised by the Directorate-General for Communications, Networks, Content and Technology (DG CNECT), together with Directorate-General for Agriculture and Rural Development (DG AGRI) and the EU Blockchain Observatory & Forum cooperation[285], bringing together experts in blockchain technologies with actors along the agri-food supply chain to discuss how to further exploit the potential of blockchain within the agri-food sector.

Blockchain has the potentiality to be implemented also in 'waste management'. Current applications of blockchain typically focus on[286]:

- payment or rewards facilitation: the remuneration system provides, for example, digital token that is exchangeable with goods or other currencies. The case of Plastic Bank[287] is described, to incentivise individuals to become plastic collectors, reducing amount of plastic waste (especially in developing countries);

285 https://www.eublockchainforum.eu/sites/default/files/reports/EUBOF2.0_AgriFoodWorkshopReport_Final_0.pdf

286 Taylor P. et al. (2020) Blockchain Technology for Sustainable Waste Management. *Front. Polit. Sci.* 2:590923, https://doi.org/10.3389/fpos.2020.590923

287 https://plasticbank.com/

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- monitoring and tracking of waste: data on the type of wastes collected and waste transfers is recorded on the blockchain

Some issues are considered from these applications. For example, recording the waste chain requires individual or groups of waste items to be repeatedly identified at defined FSCs. Physical objects can be stored on the blockchain via their digital identities, but generating reliable digital identities is challenging. It also becomes infeasible to both join waste streams and retain identities for individual waste components. A solution to resolve this is that material waste from an industrial process may be handled in batches per ton from the beginning, and stored as such on the blockchain with a digital identity for the batch rather than the individual pieces. Some other problems are that 1) data inserted in the blockchain must be correct from the beginning, since editing is difficult; 2) it does not help to define the waste responsibility in a chain of ownership; 3) it is needed that terms and definitions are clear and unanimous.

Recording the generation and transfer of resource and waste streams on the blockchain provides a record of provenance for wastes, useful to confirm the transfer/discarding of a waste, and identify the organisation responsible for the waste. For example, ownership of waste W can be transferred from organization O to individual I and recorded on the blockchain using their digital identities. If this is also the last blockchain record that contains W, we can also discern that I is responsible for the waste if responsibility transfers with ownership. Simultaneously, this record also enables identification for future uses of waste, such as who has the available wastes for the formation of new markets where they are reused, recycled, and recovered (e.g., to transition toward circular economies). Such records on the blockchain are clearly useful for auditing resource and waste streams (which may aid regulatory compliance), but requires a number of assumptions.

The 'innovation resistance theory' explains barriers and challenges in the practical application of blockchain in FSCs[288], which it may be considered as a Sustainability-Oriented Innovation (SOI) (i.e., a combination of technological, organisational, and institutional/social innovation). It is defined as '*the rejection, postponement or opposition to new products, services or process innovations based on potential changes from a satisfactory status quo or because it conflicts with their belief structure*'. Incredibly, this resistance is also considered as a necessary step to achieve the innovation implementation, as researchers and other stakeholders may put a strong focus in analysing what is needed for that innovation to be accepted and implemented. There are two form of 'innovation resistance', named a) passive innovation resistance, deriving from a general inclination to resist change, and/or satisfaction with the current *status quo*, and b) active innovation resistance, formed by a combination of functional and psychological barriers. To advance sustainability and overcome blockchain resistance as a SOI, 5 opportunities were found:

1) Address fraud and human rights violations;

2) Ensure fairer supply chains;

3) Enhance food traceability;

[288] Friedman N. & Ormiston J. (2022) Blockchain as a sustainability-oriented innovation?: Opportunities for and resistance to Blockchain technology as a driver of sustainability in global food supply chains. *Technological Forecasting and Social Change* 175:121403, https://doi.org/10.1016/j.techfore.2021.121403

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4) Deliver environmental benefits, including the reduction of FLW. However, this is now considered more a path to reduce costs, more than ensure the reach of environmental benefits. At the same time, the system enables to better manage and save resources, time and, finally, waste generation;

5) Generate shared economic value.

For 'resistance innovation' 4 main forms were identified:

1) Active resistance through protecting the *status quo*: it is the most dominant form of resistance to a blockchain technology, with 'transparency' being the main issues considered by operators (it may prevent fraud and other opaque operations), to prevent higher economic returns for their companies, or they fear higher cost from the implementation of sustainable practices, and a lack of their privacy (for the needed opaqueness, and/or for commercial secrets);

2) Cooperative barriers, simply shown as a lack or difficulty in stimulate and incentivise the cooperation between different actors in the FSCs;

3) Functional barriers: there are general perceptions that blockchain is not so convenient or functional to achieve sustainability, and that it is overestimated (value barriers). It is difficult to use for most of FBOs, and there is a complexity from their legal point of view (complexity barriers). Different FBOs do not even know what are the challenges of sustainability that they are going to face, and how blockchain is able to cope with them (communicability barriers);

4) Psychological barriers are, for example, the belief that it is needed a particular effort to understands norms that able the use of blockchain in FSCs, or that the technology is not really an innovation (only its implementation is new), or that it is not really capable to achieve sustainability goals as promised.

Blockchain is generally considered as a tool that may drive to innovation and achievement of sustainability in FSCs, but the different forms of active and passive innovation resistance are usually not taken into consideration, damping its full implementation. Different point of views related to blockchain in FSCS are collected in **Figure 21**.

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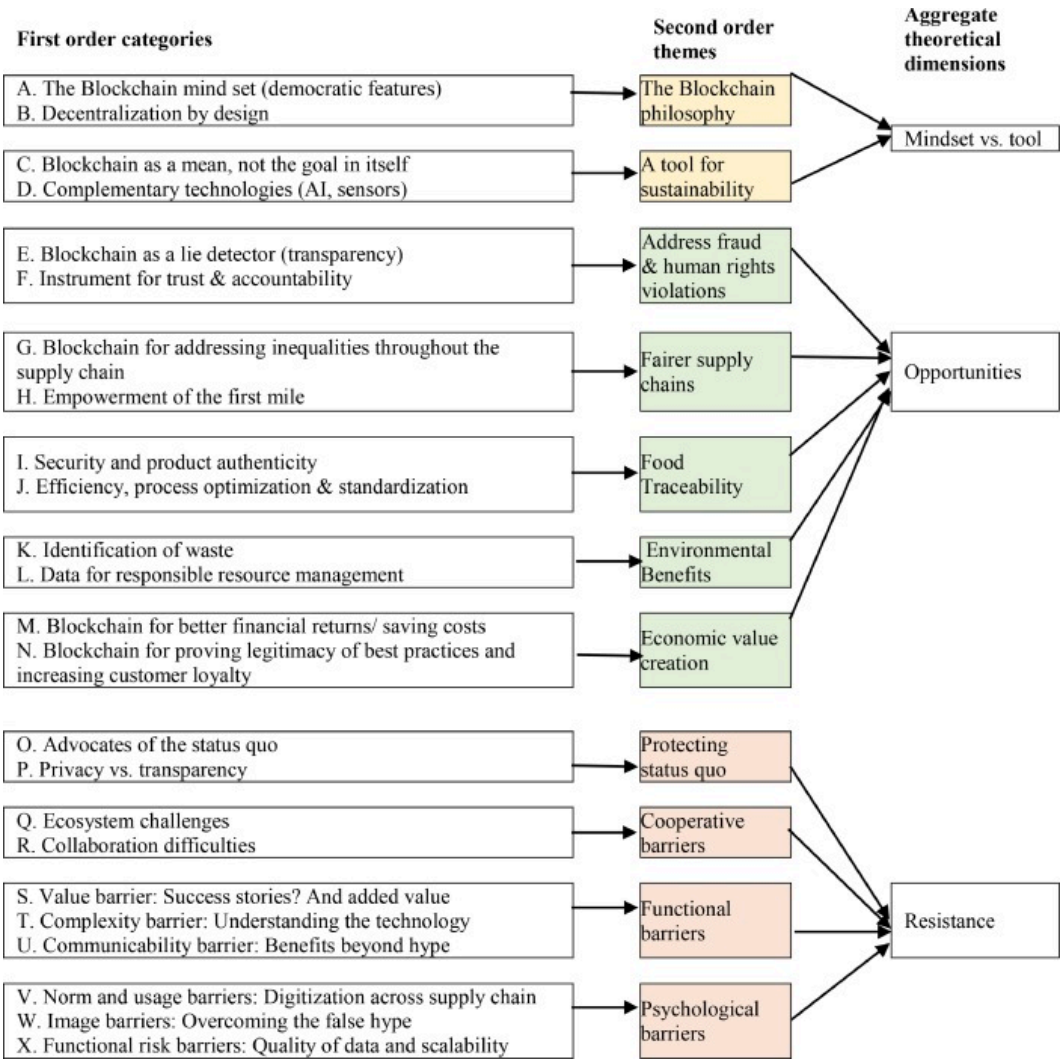

Figure 21. Opportunities and resistance in the implementation of blockchain in FSCs (source: Friedmand and Orniston, 2022)

The ERASMUS+ project BlockWaste[289] is aiming to provide training for the waste management, through the use of blockchain technology. For this purpose, it also has developed a free interactive tool to offer users several keys to achieve Blockchain-based integration of municipal solid Waste. One for its reports has analysed blockchain case studies in waste management, and it provides also guidance to start blockchain projects for this use[290]. For FW management, 2 specific use cases were reported (from USA):

1) Naturipe: products produced by Naturipe will be equipped with a QR code on the packaging. When customers scan the code, they will be able to see the certification of origin of e.g., fruit along with information on where the fruit was grown, picked, packed and how it was stored at any point along the supply chain;

289 https://blockwasteproject.eu/

290 Blockchain Applications for Waste Management - Analysis of Blockchain use cases in waste management and general guidance for starting Blockchain project. https://blockwasteproject.eu/wp-content/uploads/2021/10/O1.A2.2-Blockchain-Applications-for-Waste-Management.pdf

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2) Food Trust: IBM partnership with Nestlé and Carrefour has developed the Food Trust Network, aiming for a sustainable and smart food industry. The technology based on blockchain tracks individual food items, giving authorized users access to information on the whole food supply chain, data on the origin and current location of individual food items, as well as certifications, test data and temperature data. Initially tested with only one food products, it has been extended of a wider range of food products.

Both blockchain systems were based on documentation (use of blockchain technology as a more or less static database for documentation), certification and registration (blockchain technology is used as a tool for the public registration of producers or products and the certification of public institutions. Private or civil society organizations use the blockchain for issuing product labels and certificates), trace and track flows (blockchain technology as a database for recording transactions in chronological order with a timestamp and for recording material and payment, within the supply and waste management), and process automation (by smart contracts through blockchain technology).

As the guidelines for starting blockchain implementation in waste management, blockchain itself has been considered to play a "marginal" role, while it is fundamental to adopt intensive communication, understand stakeholders' interests, and explain in a simple way the technical possibilities of blockchain in order to convince them. A scheme has been developed to explain this (**Figure 22**):

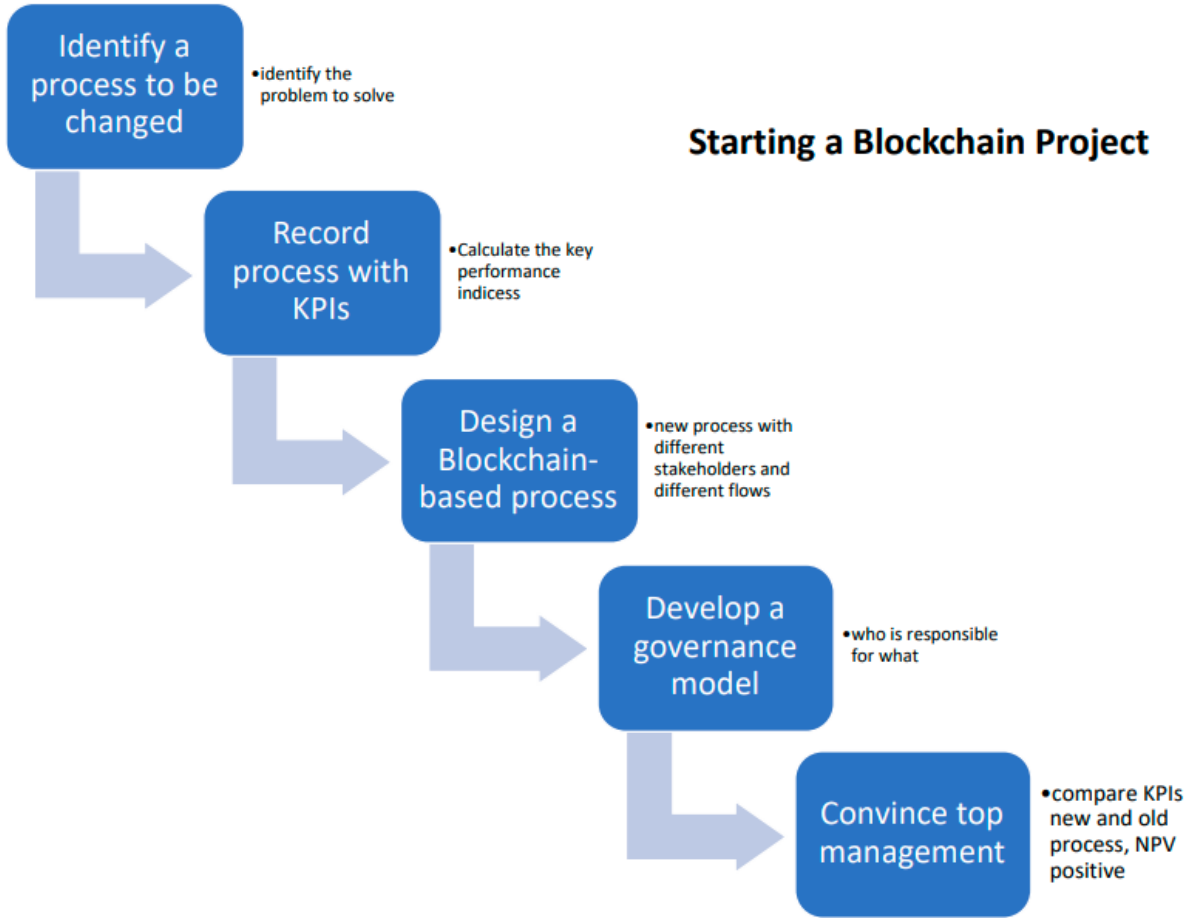

Figure 22. Process of starting a blockchain project (source: BlockWaste)

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1) Blockchain processes are suitable for decentralized processes with a larger number of external participants, for whom it is absolutely essential to obtain reliable information about the status of a project or process at all times. To avoid failures, it is suggested to change from a 'intra-organisation view' to a 'inter-organisational view', understanding stakeholders' interests;

2) The workflow and key performance indicators (KPIs) must be recorded. This usually requires the cooperation of all blockchain participants. It is recommended to record the process with a simple software without a high degree of detail and to limit the selection of indicators to the most important ones, so that the coordination process and the amount of work remain manageable;

3) The design of a blockchain-based process is considered as the main challenge. Three flows have to be considered: information flow, material flow, and payment flow. All participants have the same information about the progress of the project at the same time;

4) A governance structure must be created and shared by all stakeholders, and the definition of hierarchies and power distribution must be defined. Ideally, all participants should have the same rights and same decisional power. In general, there are some questions to be addressed (e.g., Who decide the participation? Who distributes rights to participant in the blockchain database? How is a new entry validated? Changes are decided democratically or hierarchically? How is the process monitored? How are disputes resolved?);

5) To convince the top management to adopt a blockchain solution is also particularly difficult. Arguments in favour are considered considerable cost savings and higher profits (even after implementing costs). Also, current KPIs have to be confronted before and after blockchain implementation in the companies. To reduce the unsuccess, it is suggested to start with small projects, to be scaled successively after first positive results.

Another case study that combines the application of blockchain in food production and FW management is given by the combination of Italian projects Track Chain 4.0 and Re-Waste[291], also to support FW recovery in an optic of circular economy. Blockchain has also been combined with GIS, for georeferencing the flows of FW generated in FSCs.[292]

From a preliminary literature review, it has been identified that there are no established applications in the FW sector, and that scientific literature is quite fragmented across interdisciplinary fields. As for georeferencing with GIS (known as 'Geospatial Blockchain' or 'Geoblockchain'), it allows to track geographical and spatial behaviours within the blockchain, with the first objective to verify the geographic origin of blockchain transactions, rather than share geospatial information as data. Also, this implementation is very limited for FSCs application, and none has been found for FW management. It can also be used to create more effective food waste recycling programs by tracking the movement of food waste through the recycling process.

For example, a geoblockchain can be used to monitor FW movement from collection points to processing facilities and the quality and quantity of food waste processed at each stage of the recycling process. This could help to ensure that FW is being recycled efficiently and effectively and that it is being used to its full potential.

[291] https://www.unitus.it/it/unitus/gruppi-di-ricerca-2020/articolo/progetto-re-waste

[292] Madonna M. (2023) Blockchain Application to the CE: the recycling of agri-food waste. https://www.researchgate.net/publication/369649826_Blockchain_Application_to_the_CE_the_recycling_of_agri-food_waste

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To integrate blockchain, it is possible to couple open source Application Programming Interfaces (APIs) (e.g., Quantum Geographic Information System (QGIS), Geographic Resources Analysis Support System Geographic Information System (GRASS GIS), Google GIS) to visualize and manage cartographic data within a geoblockchain, and simplify the exchange of information between different systems and platforms (e.g., using eXtensible Markup Language (XML)). To improve the performances, cloud-based services, file security packet (IFSP) and Intelligent Decision Support System (IDSS) may be implemented to store and share geospatial data and other large files, increasing the performance, reliability, and security, of services, or developing data pattern and trends, developing algorithms and machine learning models to prevent FW, or analyse data to enable their exchange between a blockchain system and other systems, such as supply chain management or logistics systems. If efficiently implemented, they may also permit to develop predictive models, optimising FW cycles (for improvement and cost reduction), and assist with a decision support model, through recommendation and guidance based on predictive and data analyses, to make better informed decision.

For this reason, the project Re-Waste, utilising the Track Chain 4.0 model, is considered as one of the few case studies applications (if not the only one) that applies Geoblockchain for FW management. As FW recovery and reuse, it aimed to create low-impact products from FLW from canteens and agriculture, to be used as fertilizers, soil improvers, and biostimulants in agriculture after molecule extraction made by mushrooms and other agents, improving plants' natural defences and enhancing growth and productivity. It also increases the added value of FLW by promoting the deployment of digital and blockchain-based infrastructure for improving agricultural data sharing and scaling up a sustainable agricultural recycling program.

The implementation of Track Chain 4.0 model could also help farms and companies to receive tax advantages and (re)organise their production processes to implement blockchain. Also, a model has been developed with the main components and actors of a blockchain-based FW management system (**Figure 23**).

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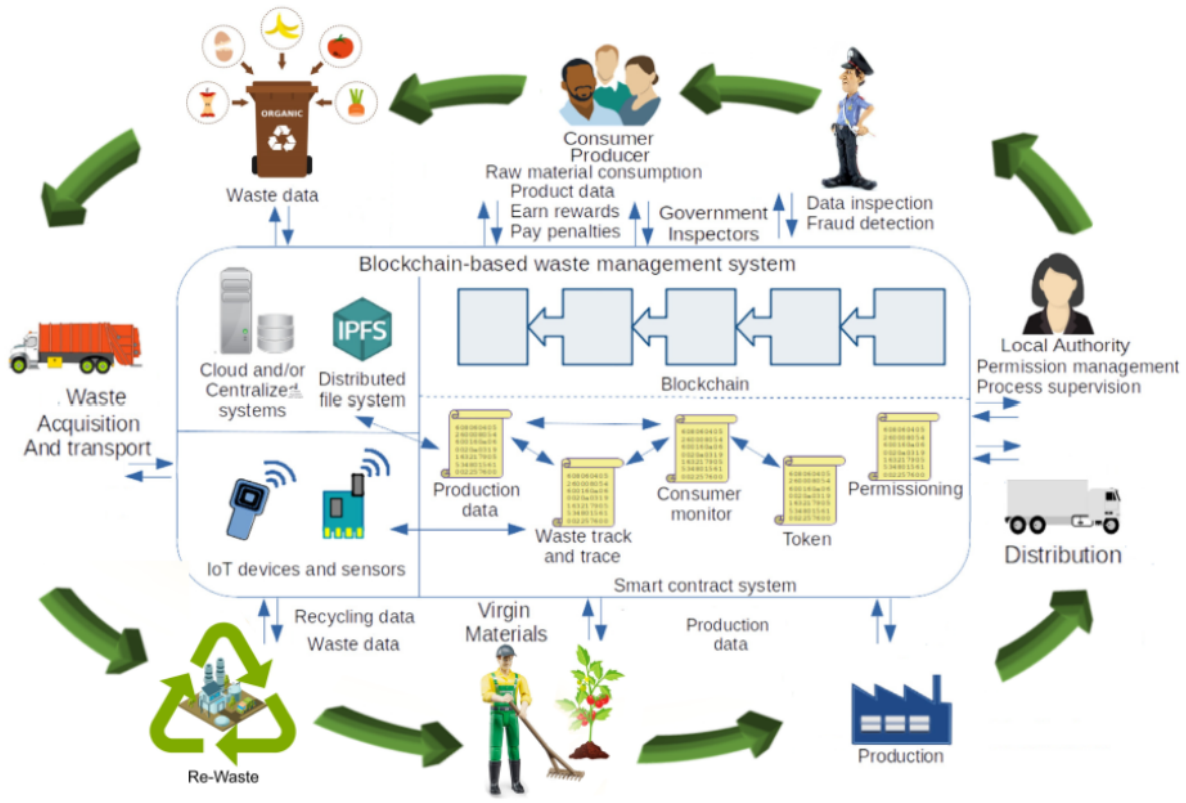

Figure 23. Blockchain-based FW management system in a circular economy model (source: Madonna, 2023)

For different phases of FSCs, the following contributions from blockchain applications are considered:

- Production phase: considered crucial for FLW prevention, data are here recorded on the food composition through smart contracts. Competent authorities may also be a part of the system, enforcing access rules or extended producer responsibility through rewards or penalties;

- Consumption phase: consumers have access to food information prior to buying, leading to a change of food ownership in the FSC. Not only FBOs, but also competent authorities may directly operate to predict FW, and policy makers may eventually decide to adopt incentive measures to avoid FW;

- Waste collection phase: it may involve smart bins coupled with Radio Frequency Identification (RFID) and IoT sensors, after properly FLW sorting, automatically recording data on the type and quantity of waste produced by producers and consumers. This data is, thereafter, transmitted through a transaction to a specific smart contract. Also, in this case, the system can be used to incentivise citizens' engagement, or track and prevent waste frauds by competent authorities;

- Waste Acquisition and Transport Phase: waste collectors may automatically acquire and certify data on the weights and types of waste transported and the truck route through IoT scales and GPS devices. Smart contracts can verify this data without human intervention, and the waste collector can use blockchain data in route optimization software to optimize collection routes and times;

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- Sorting and treatment phase: FLW can be treated directly at production centres or at eco-centres. The latter can access data on the composition and amount of waste from previous phases to operate efficiently and securely and can record data on the amount and type of waste treated and the quantity and type of processed products through a specific smart contract. Governments can access this data to prevent waste mismanagement and implement Circular Economy policies;

- Recycling phase: if not processed, FLW may be used or delivered directly in farms or other facilities where it is destined for intended uses (e.g., fertilisers). The farms, the recycling company or other companies can access data on the type of process from previous phases to optimize the recycling process and can record data on the amount and type of recycled material through a specific smart contract. Governments can access this data to verify the accuracy of recycling claims and implement CE policies.

In the context of Re-Waste project, blockchain has played an Important role in ensuring identity and data integrity of various nodes in the FW supply chain and to create a decentralized and immutable record of the entire food supply chain, including recycling (leading to tax benefits and facilitating transparency and accountability). This is also possible through georeferencing (i.e., geoblockchain) combining blockchain with GIS, and eventually other technologies (e.g., IoT, RFID, AI), enhancing traceability and compliance with EU legislation for FW management.

An agreement of blockchain capability to better manage FW generation in FSCs also derive from the EU project FIT4FOOD2030[293]. Blockchain systems are considered important to design a trusted, self-organized, open and ecological food traceability system which involves inputs from all parties of the food chain. Reducing market inefficiencies, it is possible to reduce FW. Another challenge for its full implementation is considered the general complexity of food systems, along with blockchain systems itself[294].

2.3.4 WASTELESS Public blockchain solution

WIISE Chain[295] is the blockchain platform intended to be applicated for the management of FLW measurement and quantification in the WASTELESS project. It is based on OpenTimestamps[296], which is an open source standard format for blockchain timestamping.

Timestamps permits to identify the date and the time when a piece of data existed. In a blockchain system, it makes possible to verify proof of existence of documents without the need to rely on a (thrusted) third party, excluding also the possibility of a voluntary (i.e., malicious) or involuntary (i.e., careleness) compromission of the

293 https://fit4food2030.eu/
294 Emiliani T. et al. (2020) D3.3 In-depth analysis of 10 pathway areas for food systems transformation. *FIT4FOOD2030,* *https://fit4food2030.eu/wp-content/uploads/2020/12/FIT4FOOD2030_D.3.3_Report-on-pathways-for-action-towards-food-systems-transformation.pdf*
295 https://wiisechain.com/
296 https://opentimestamps.org/

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timestamp (and of the associated information and document(s))., while usually timestamps require the presence of this third party (i.e., timestamp authority).[297]

In the OpenTimestamps, a web server aggregates data items from users by using a Merkle tree, and inserts the tree root value into a blockchain transaction. The transaction record and the time-stamp in the block become the proof of existence of data items. It makes use of hash functions and digital signature schemes to build a blockchain, and also uses hash functions to hash users' data.[298] One other advantage of Opentimestamps is that it is a service free of charge, reducing the usually high costs for the implementation of a blockchain system, making it more competitive and accessible to a wider number of enterprises (especially SMEs).

WIISE Chain ables FBOs (buyers and suppliers) to exploit OpenTimestamps to verify the correspondence between the proof and the original file.[299] This is helpful to have certainty of the information declared in a specific document(s), since it is not possible to exchange this information or document without notifying the other actors (or stakeholders, considering end consumers) in the FSC.

For the scope of WASTELESS project, WIISE Chain intends to operate as a (distributed) ledger that permits FBOs and other operators to declare information about FW generate in their processes. This information is request in the form of a survey, where the FW responsible figure will provide all the relevant information to FW. To support the truthfulness of their declarations, different documents may be attached. The use of OpenTimestamps ables the verification of data and time inclusion.

In the food industry, is necessary to make a clear distinction between food provenance (i.e., geographic origin) with data provenance. The former is guaranteed through the use of scientific analytical methods (e.g. Carbon-13 (13C) analysis), while the latter is related to the data origin, where the results of these analyses are indicated. This is the example of certification documents, which may be associated to the indication of a specific origin (determined through a specific analytical method), or to other information (e.g., certification of products such as organic farming)[300]. In the case of FW, these documents have to certify its provenance along the whole FSC for the specific FBO or operator.

It is necessary to prior establish the kind of document and information required to the implementation of a blockchain system in the food (waste) sector, that follows the FW flow. Before that, it is necessary to establish and classify the requirements, to assign consequently information (as possible) to stakeholders, documents and existing systems. These requirements are defined as[301]:

- Usage requirements: focused on applicability and contain generally formulated user needs without software-specific features. It has to indicate the capability of a tool or instrument (blockchain in this

[297] Estevam G, et al. (2021) Accurate and decentralized timestamping using smart contracts on the Ethereum blockchain. *Information Processing & Management* 58(3):102471, https://doi.org/10.1016/j.ipm.2020.102471

[298] Long M. & Liqun C. (2022) A Blockchain-based Long-term Time-Stamping Scheme. https://eprint.iacr.org/2022/319.pdf

[299] https://wiisechain.com/blockchain

[300] Rejeb A. et al. (2020) Blockchain Technology in the Food Industry: A Review of Potentials, Challenges and Future Research Directions. *Logistics* 4(4):27, https://doi.org/10.3390/logistics4040027

[301] Thume M. et al. (2021) Blockchain-based traceability in the food industry: requirements analysis along the food supply chain. *OSF Preprints*, https://doi.org/10.31219/osf.io/uyb64

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case);

- Technical requirements: all challenges for the functionality of the solution for the problem intended to be solved;

- Interoperability requirements: include methods and standardization needs for the information and communication structure.

The first information that should be included is the one relating to the compliance with legal requirements for FBOs or other operators working in the food field (e.g. *General Food Law*, *Food Hygiene Regulation*) and voluntary standards, if applied (e.g., ISO 9001, ISO 22000, ISO 14001, British Retail Consortium (BRC), International Food Standard (IFS)). The compliance with these requirements is relevant not only for the interested actors, but also for all the associated relevant stakeholders (i.e., suppliers, producers, retailers, (logistic) service providers, end consumers, food authorities, certification organisms). A series of 58 data classes have been identified, to provide information (generally in the form of documents) to assure the compliance with these requirements. These are divided in 6 data categories (**Figure 24**):

The direct participants in the supply chain (supplier, producer, wholesaler/retailer, logistics service provider) are especially interested in transport and delivery data, as they ensure trouble-free communication during normal operations and in the event of breakdowns. Product and packaging data are particularly important for the end consumer, as important data can be derived (shelf life, compliance with the cold chain, origin of raw materials, etc). Local and national food authorities are mainly interested in product and company data. In case of food safety problems, for example, it is of crucial importance for authorities to know all partners involved, the upstream and downstream flow of raw materials used, as well as batch numbers and quantity proportions. End consumers and food authorities, as exclusive output actors, may be excluded from this analysis. The two main input actors are suppliers and producers.

Besides data requirements, the willingness to share data is a decisive point in the development of a blockchain system. There is a very heterogeneous opinion on which data should be shared with whom in the supply chain. This creates the need for an individual possibility of sharing information in the digital system and a strong interrelation between identified usage requirements and technical requirements. This applies to the food sector and also to the determination of the FW produced in it.

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Product data	Process data
• Product (name) • Quantities of the ingredients used • Internal and external batch number(s) • Best before date / Expiry date • Raw materials used • Product temperature • Results of quality controls (internal) • Information on returned goods • Origin / Country of origin / Location	• Process type • Location of the process step • Process date / Time • Use of animal feed • Use of biocides and pesticides • Data for measuring device monitoring • Recording of in-process controls and results • Food control results
Company data	**Transport & Delivery data**

• Process owner / Company
• Company address
• Company registration number
• Origin / Country of origin / Location
• Stock register
• Internal company hygiene regulations
• Results of internal and external company controls
	• Load carrier temperature
	• Cargo location temperature
	• Shipping / Transfer date (delivery date)
	• Shipping object / Product
	• Location of the goods (truck, warehouse, plant)
	• Place of departure
	• Departure time
	• Transport unit / Means of transport
	• Transport packaging
	• Transport marking:
	  ○ Storage / Stacking ability
	  ○ Marking: Fragile
	  ○ Labelling: Cooling requirements
	  ○ Other warehouse / Transportation marking
	• Transport loads:
	  ○ Static, mechanical (stack dipping pressure)
	  ○ Dynamic mechanical (vibrations, shocks)
	  ○ Climatic (humidity, temperature)
	  ○ Biotic (pest infestation, germ contamination)
	  ○ Other charges
	• Consignor / Consignee
	• Carrier
	• Supplier information
	• Manufacturer information
	• Packer information

Qualities & Grades	
• Certificates • Label (organic / conventional labelling) • Labelling of GMO goods	
Packaging data	
• Nutrition labelling • Big 7 (calorific value, fat, saturated fatty acids, carbohydrates, sugar, protein, salt) • Vitamins / Minerals • Instruction for use • Allergen labelling • Storage advice • Preservation and use of packaging materials • Marking of the packaging • Other information on the goods	

Figure 24. 6 data categories and associated 58 data classes to be provided in a FSC (source Thume et al., 2021)

After the identification of legal requirements, related stakeholders and associated documents, it is important to determine the technical requirements of the blockchain platform. They are collected in **Table 12**.

Table 12. Technical requirements for a blockchain implemented in a FSC, according to Thume et al., 2021

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Technical requirements	
Access	Access to information for everyone: traceability data and product information (e.g., food, FW) should always be accessible by everyone, especially by the consumer (e.g., via a website) and by other participants (e.g., via a software).
	Dynamically adaptable access to submitted data for other participants: Access to information should be generally limitable and dynamically activatable for different stakeholders according to individual permissions and data shares set by the input actors.
	Access to specific information for food authorities: From their point of view, in case of a control or food safety/waste issue, specific information regarding the source and the buyer of a product/manager of waste should be accessible.
	Visual representation of data: It should be possible to visualize the data so that complex supply chain information can be easily read by any user. For example, a supply chain of a specific product is depicted as a graph for the end consumer.
Data storage	High availability: The storage service should be highly available so as not to block other information systems and processes.
	Retrieval of non-product-specific information: It should be possible to share participant related information as well as information on assets used by the participant in manufacturing process, including supporting activities (cleaning, maintenance, repair of a machine etc).
	Handling of measured values and sensor data: It should be possible to record measured values and sensor data (e.g., temperature data), both manually and automatically.
	Authenticity of data: It should be possible to efficiently prove the authenticity of information to ensure forgery protection, even for large data sets or high-frequency data.
Data processing	Extensive evaluation options: There should be extensive evaluation options (for product batches, events, etc) for the participants of the supply chain, for instance, a product search function to be able to evaluate batches of a certain company for a certain time period.
	Visual representation of measured data trends: The temporal course of measured values should be visually displayed. The representation of target and tolerance values is also desirable to indicate critical deviations.
Notification	Active notification of supply chain participants: As soon as events occur, potentially negatively affected supply chain participants should be actively notified so that they can either act themselves or anticipate future supply bottlenecks.
	Issue of (product-specific) warnings: In case of extraordinary events, such as the discovery of spoiled food (contaminated or hazardous FW), it should be possible to issue warnings to participants, end consumers and legal institutions that are linked to a specific product.
	Monitoring of objects and activities: It should be possible to monitor products and activities, detect the status of a product (location, timestamp, temperature etc.) and save it. The user will be notified when a certain state of an object (e.g., critical temperature) occurs and when a certain activity takes place.
Process mapping	Assignments to higher-level units: Traceability should be eased and facilitated by assigning products to higher-level units.
	Passing on the responsibility / accountability for a product or object: It should be obvious who is currently responsible for an object or who was responsible for an object at a respective time (it is valid also for FW management).

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	Creating or removing objects: It should be possible to register new resources and new localities of companies. In addition, it should be possible to remove products or objects so that their further use is no longer valid.
	Food controls: It should be possible to report and view food (waste) control results.
	Role and rights management: It should be possible to define different roles and rights for participants of the supply chain, consumers and legal institutions. Not every participant in the supply chain needs or requires the same rights (e.g., reading and writing rights).
	Filing of documents: It should be possible to store, view and share documents such as certificates.

Finally, interoperability must be guaranteed for operators and consumers, and special attention should be paid to solutions that remedy (temporary) disruptive events (e.g., Internet failures, lack of identifiers on products).

Interfaces must always be precisely and explicitly defined and information must be retrievable and interpretable without further queries (as explained for 'simplified food categories'). The use of codes with different digits is discouraged, especially for the retrieval of these data. Data can be entered serially (e.g., once an hour), instead of in individual entries, and readability must be easy for users. To increase this, information can be combined with graphical interfaces.

The blockchain system must also be able to function offline and it must be possible to download aggregated data for its intended uses, either in real time or configured for later transmission. Transactions should be reported independently of each other and manual operations for searching or correcting/adding information should be allowed (it should be remembered that in a blockchain system there is a tracking of transactions performed).

Other considerations are that different data should be possible (e.g., the generation of FW points in the FSC) and that not all information should be visible to all actors (also considering relative interest). The management of roles and rights should be determined in advance. This should not exclude full access rights, where it is decided to provide them as such. A uniform data transmission framework is needed for all participants. This can be achieved by the application of specific standards (e.g., GS1[302]).

In order to stimulate participation by FBOs and other interested parties, the structure of the survey is as straightforward and simplified as possible. Nevertheless, the data and information collected is intended to be as in line as possible with current FW legislation (e.g., Decision (EU) 2019/1597; FW statistics; LoW FW classification).

The food categories defined by UVMB have been considered, but we would like to implement a system whereby the categories chosen by the operators can be automatically coded and translated against the categories already defined in EU statistics (especially CPA). We would also like to try already to define a measurement system for the reduction of food waste with respect to certain time reference periods (e.g. yearly, six-monthly, four-monthly, quarterly), and to combine it with the objectives already set by the WFD, and with those potentially implemented with its revision, as proposed by the EC.

302 https://www.gs1.org/standards/blockchain

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The layout of the survey and the operation of the blockchain can be found in **Annex 3**.

3. Conclusion

The WASTELESS Public Blockchain has several EU policies, which support its improvement and implementation within EU business.

Through the results of previous projects (e.g., FUSIONS, STREFOWA), it was possible to define the main food categories to be considered in the implementation of measurement and quantification by FBOs. It is possible to associate or correlate them with the food categories already defined at EU level for statistics (especially those related to products), so as to facilitate the identification of a common framework to be presented at EU level.

In the subsequent WASTELESS project activities, the blockchain will be tested to ensure compliance with the defined framework, and the possible application within food companies, in order to measure and quantify and, indirectly, the ability to prevent FW.

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4. Bibliography

See the notes.

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5. Annexes

Annex 1 – Definitions

The definitions included in this Annex are provided by EU laws. Where not available, other official sources will be used.

- Animal by-product: entire bodies or parts of animals, products of animal origin or other products obtained from animals, which are not intended for human consumption, including oocytes, embryos and semen;

- Backfilling: any recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Waste used for backfilling must substitute non-waste materials, be suitable for the aforementioned purposes, and be limited to the amount strictly necessary to achieve those purposes;

- Bio-waste: biodegradable garden and park waste, food and kitchen waste from households, offices, restaurants, wholesale, canteens, caterers and retail premises and comparable waste from food processing plants;

- Broker: any undertaking arranging the recovery or disposal of waste on behalf of others, including such brokers who do not take physical possession of the waste;

- By-product: an incidental product deriving from a manufacturing process or chemical reaction, and not the primary product or service being produced;

- Collection: the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility;

- Dealer: any undertaking which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste;

- Derived products (animal by-products): products obtained from one or more treatments, transformations or steps of processing of animal by-products;

- Disposal: any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy;

- Feed: any substance or product, including additives, whether processed, partially processed or unprocessed, intended to be used for oral feeding to animals;

- Feed business: any undertaking whether for profit or not and whether public or private, carrying out any operation of production, manufacture, processing, storage, transport or distribution of feed including any producer producing, processing or storing feed for feeding to animals on his own holding;

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- Feed business operator: the natural or legal persons responsible for ensuring that the requirements of food law are met within the feed business under their control;

- Final consumer (or end consumer): the ultimate consumer of a foodstuff who will not use the food as part of any food business operation or activity;

- Food (or foodstuff): any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans. 'Food' includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment. It includes water after the point of compliance as defined in Article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC[303,304];

- Food business: any undertaking, whether for profit or not and whether public or private, carrying out any of the activities related to any stage of production, processing and distribution of food;

- Food business operator: the natural or legal persons responsible for ensuring that the requirements of food law are met within the food business under their control;

- Food law: the laws, regulations and administrative provisions governing food in general, and food safety in particular, whether at Community or national level; it covers any stage of production, processing and distribution of food, and also of feed produced for, or fed to, food-producing animals;

- Food loss: food crops left on field and ploughed in, mortality of the animals ready for slaughter, both during transport to slaughterhouse and rejects at slaughterhouse[305];

- Food waste: all food as defined in Article 2 of Reg. (EC) No. 178/2002 of the European Parliament and of the Council (see 'food' definition) that has become waste;

- Hazard: a biological, chemical or physical agent in, or condition of, food or feed with the potential to cause an adverse health effect;

- Material recovery: any recovery operation, other than energy recovery and the reprocessing into materials that are to be used as fuels or other means to generate energy. It includes, *inter alia*, preparing for re-use, recycling and backfilling;

- Municipal waste: a) mixed waste and separately collected waste from households, including paper and cardboard, glass, metals, plastics, biowaste, wood, textiles, packaging, waste electrical and electronic equipment, waste batteries and accumulators, and bulky waste, including mattresses and furniture; b)

[303] Both abrogated by Directive (EU) 2020/2184.
[304] Food' shall not include: (a) feed; (b) live animals unless they are prepared for placing on the market for human consumption; (c) plants prior to harvesting; (d) medicinal products; (e) cosmetics (f) tobacco and tobacco products; (g) narcotic or psychotropic substances (h) residues and contaminants; (i) medical devices.
[305] JRC definition.

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mixed waste and separately collected waste from other sources, where such waste is similar in nature and composition to waste from households[306];

- Preparing for reuse: checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing;

- Primary production: the production, rearing or growing of primary products including harvesting, milking and farmed animal production prior to slaughter. It also includes hunting and fishing and the harvesting of wild products;

- Recovery: any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy;

- Recycling: any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;

- Retail: the handling and/or processing of food and its storage at the point of sale or delivery to the final consumer, and includes distribution terminals, catering operations, factory canteens, institutional catering, restaurants and other similar food service operations, shops, supermarket distribution centres and wholesale outlets;

- Reuse: any operation by which products or components that are not waste are used again for the same purpose for which they were conceived;

- Separate collection: the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment;

- Stages of production, processing and distribution: any stage, including import, from and including the primary production of a food, up to and including its storage, transport, sale or supply to the final consumer and, where relevant, the importation, production, manufacture, storage, transport, distribution, sale and supply of feed;

- Traceability: the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution;

- Waste: any substance or object which the holder discards or intends or is required to discard;

- Waste holder: the waste producer or the natural or legal person who is in possession of the waste;

[306] Municipal waste does not include waste from production, agriculture, forestry, fishing, septic tanks and sewage network and treatment, including sewage sludge, end-of-life vehicles or construction and demolition waste.

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- Waste management: the collection, transport, recovery (including sorting), and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker;

- Waste producer: anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste.

Annex 2 – Food waste categories

Table 12. LoW list (Decision 2000/532/EC)

LoW Code	Food waste	Entry type
02 01	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing	
02 01 01 [(b)]	Sludges from washing and cleaning	ANH
02 01 02 [(a)]	Animal tissue waste	ANH
02 01 03 [(a)]	Plant tissue waste	ANH
02 02 [(a)]	Wastes from the preparation and processing of meat, fish and other foods of animal origin	
02 02 01 [(b)]	Sludges from washing and cleaning	ANH
02 02 02 [(b)]	Animal-tissue waste	ANH
02 02 03 [(b)]	Materials unsuitable for consumption and processing	ANH
02 03 [(a)]	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 [(b)]	Sludges from washing, cleaning, peeling, centrifuging and separation	ANH
02 03 02 [(b)]	Wastes from preserving agents	ANH
02 03 03 [(b)]	Wastes from solvent extraction	ANH
02 03 04 [(b)]	Materials unsuitable for consumption and processing	ANH
02 04 [(a)]	Wastes from sugar processing	ANH
02 05 [(a)]	Wastes from the dairy products industry	
02 05 01 [(b)]	Materials unsuitable for consumption and processing	ANH

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02 06 [a]	Wastes from the baking and confectionery industry	
02 06 01 [b]	Materials unsuitable for consumption or processing	ANH
02 06 02 [b]	Wastes from preserving agents	ANH
02 07 [a]	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)	ANH
02 07 01 [b]	Wastes from washing, cleaning and mechanical reduction of raw materials	ANH
02 07 02 [b]	Wastes from spirits distillation	ANH
02 07 04 [b]	Materials unsuitable for consumption or processing	ANH
16 03	Off-specification batches and unused products	
16 03 06 [a]	Organic wastes other than those mentioned in 16 03 05	MNH
19 05	Wastes from aerobic treatment of solid wastes	
19 05 01 [b]	Non-composted fraction of municipal and similar wastes	ANH
19 05 02 [b]	Non-composted fraction of animal and vegetable waste	ANH
19 08	Wastes from waste water treatment plants not otherwise specified	
19 08 09 [b]	Grease and oil mixture from oil/water separation containing only edible oil and fats	MNH
19 09	Wastes from the preparation of water intended for human consumption or water for industrial use	
19 09 02 [b]	Sludges from water clarification	ANH
20 01	Separately collected fractions (except 15 01[307])	
20 01 08 [a]	Biodegradable kitchen and canteen waste	ANH
20 01 25 [a]	Edible oil and fat	MNH
20 03	Other municipal waste	
20 03 01 [a]	Mixed municipal waste	ANH
20 03 02 [a]	Waste from markets	ANH

(a) Codes included in Annex II of Decision (EU) 2019/1597; (b) Codes included only in Annex III of Regulation (EC) No. 2150/2002.

[307] Packaging (including separately collected municipal packaging waste)

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Table 13 EWC-Stat Ver. 4 list (Regulation (EC) No. 2150/2002)

EWC-Stat Code	Food waste	Entry type
09.1	Animal and mixed food waste	Non-hazardous
09.2	Vegetal wastes	Non-hazardous
10.1	Household and similar waste	Non-hazardous
10.2	Mixed and undifferentiated materials	Non-hazardous
10.3	Sorting residues	Non-hazardous

Annex 3 – WASTELESS Public Blockchain operative settings

The model of the survey[308] to be submitted to FBOs is available here: https://forms.gle/2358ooxdEu2oMvVB7

In addition to the amount of FW produced by FBOs, the survey aims to define the types of food wasted, why food is wasted, where it is generated and where it ends up. For each information provided, FBOs have the possibility to upload a document (as determined by Thume et al., 2021) that will be included in the blockchain system, as a proof of their declaration.

Other information related to food company are intended to be requested, to understand different factors that may influence the generation and management of FW in food companies (e.g., implementation of voluntary standards such as ISO[309]).

Information for food categories are required according to UVMB food categories, while other questions were set on the basis of JRC Report 'Review of studies on food waste accounting at MSs level[310]' and the Decision (EU) 2019/1597.

From the information provided by FBOs, it is intended to develop a distribution of the destiny of raw materials used to realise the processed products, according to the Lansink' scale determined by the 'waste hierarchy' (**Figure 25**). In this way, it is possible to estimate the amount of food produced and wasted at the same time, and indirectly determine the amount of food produced by the specific FBO, that it is consumed. This classification is helpful to define the valorisation of FW in the best way possible.

[308] The format does not necessarily represent the final version that is going to be submitted to FBOs in the context of WASTELESS project. Some amendments are still possible.

[309] ISO/TC 34/SC 20 – Food loss and waste is preparing a working draft to define standardisation of procedure to mitigate FLW (i.e. ISO/WD 20001). It is currently cooperating with International Food Waste Coalition.

[310] Patinha Caldeira C. et al. (2019) Review of studies on food waste accounting at Member State level. *Publications Office of the European Union*, ISBN 978-92-76-09512-5, https://doi.org/10.2760/340637

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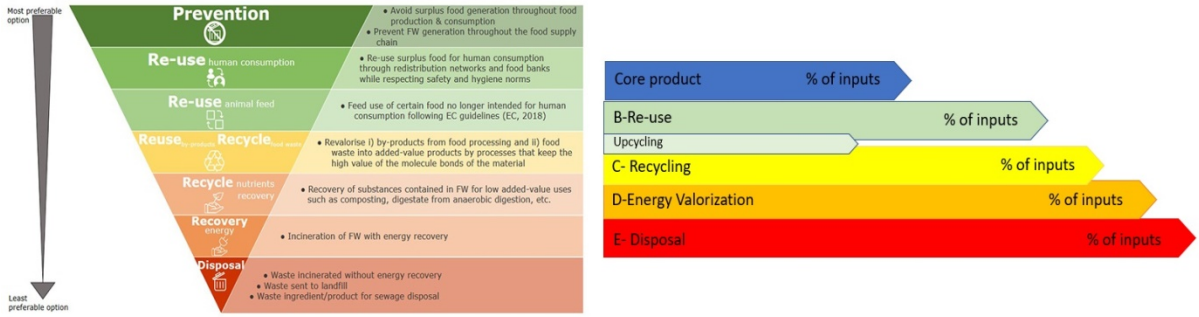

Figure 25. Left: the waste hierarchy as presented by JRC (source: EC); right: proposed waste hierarchy, including the definition of % of inputs destined to each category (and a proposal of inclusion of upcycling) (source: the author).

It will be tried to develop an automatic conversion system that permits to associate the 'simplified food category' chosen for FBOs, with one of the 'detailed food categories' from EU Statistics (probably CPA). This trial intends to define the possibility to exploit EU statistics for the categorisation of food (waste) products, and implement better the use of NACE, which is related to economic activities only.

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