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Food Waste Drivers in Europe, from Identification to Possible Interventions

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Abstract: The growing volumes of food globally lost or wasted and implications for food security and sustainability have raised the concern of researchers, governments, international organizations and grass-root movements. Much research and experiences investigating food waste causes and drivers focus on one specific segment of the food supply chain and limit the analysis to the situation of one or few countries, while the few studies of wider geographical scope also target other relevant and diversified objectives (e.g., food waste definition, quantification, environmental and economic impacts, and recommendations for interventions). This study, carried out by a network of European institutions involved in research and initiatives against food waste, focuses on the analysis of a broad area, Europe, through a wide and systematic literature review and consultation with stakeholders in international focus groups. The food supply chain was divided into seven segments and three main contexts were defined for the examination of food waste sources: Technological, Institutional (related to organisational factors, i.e., business management, economy, legislation, and policy), and Social (related to consumers' behaviours and lifestyles). Results suggest a wide and multifaceted problem, interconnected across all stages of the food supply chain, from primary production, to final consumption. Within each context, the identified drivers have been grouped according to the possibilities and the type of interventions for food waste reduction. A final cross-contextual prioritization distinguished food waste sources related to (A) inherent characteristics of food; (B) social and economic factors; (C) individual non-readily changeable behaviours; (D) other priorities targeted by private and public stakeholders; (E) diversified factors, such as mismanagement, inefficient legislation, lack of awareness or information; and sub-optimal use of available technologies, which could be more promptly changed. Such diversification of causes calls for specific monitoring systems, targeted policy measures, and actions of individual stakeholders at each stage of the food supply chain.

Keywords: food waste; food waste drivers; food sustainability; food policy

1. Introduction

In recent years, many studies and initiatives launched by governmental and international organisations have raised public attention on food waste (FW) and its implications in terms of nutrition security, sustainable development, environmental impact, and spoiled resources. It has been estimated, that nearly one-third of the total food mass [1] and about one-quarter of the total food calories [2] globally produced would be lost or wasted. This equals to a green-house gas (GHG) impact of 3.3 Gtonnes of CO_2 equivalent—not including emissions due to land-use changes, which would increase the total estimation by between 25% and 40%—an amount which exceeds the total GHG emission of every country in the world except China and the United States [3]. In the European Union (EU), an average FW annual production of 180 kg per inhabitant has been estimated, excluding waste from the agricultural sector, which corresponds to 25% of the food purchased by households [4].

Such figures call for identifying FW causes along the food supply chain (FSC) and which policies should be undertaken for FW prevention and reduction. In 2011, the European Commission (EC) invited the EU Member States to address food wastage in their national waste prevention programmes [5]. In January 2012, a Resolution of the European Parliament [6] called for urgent measures to halve FW by 2025 through a co-ordinated strategy, combining European and national measures that improve the efficiency of the FSC, sector by sector. In September 2015, the United Nations (UN) 2030 Agenda for Sustainable Development introduced the target of halving, by the year 2030, the amount of FW per capita globally produced at the retail and consumer levels (Sustainable Development Goal No. 12.5) [7]. In December 2015, the EC identified FW among the priority areas of the EU Action Plan for Circular Economy [8], in order to develop a common methodology to measure FW and define relevant indicators, create a stakeholder platform to share best practices, clarify food legislation, facilitate food donations and recycling, and improve date labelling.

Much research and experiences investigating FW causes and drivers focus on some specific segments of the FSC. The most targeted are the final segments, i.e., retail, food services and consumers/households, where most of post-harvest FW is generated in developed countries. Additionally, many studies limit the analysis to a single country, while the analyses of international scope aiming at identifying the main FW determinants for the whole FSC are not frequent and in general are included in wider studies targeting other relevant objectives such as FW definition, quantification, environmental impact, economic impact, current legislation, actions of social engagement, and policy recommendations [1,4,9,10] (see Table 1).

Table 1. Selection of recent studies analysing food waste causes.

Reference	Author	Segments of the FSC Addressed	Description and Methods	Geographical Coverage	Classifying FW Causes or Drivers
[11]	Lanfranchi et al. (2016)	Consumers/ households	Questionnaire survey on a large sample of the population of the Province of Messina (Sicily–Italy) investigating households' food purchase behaviours, reasons for wasting food and attitudes towards preventive actions	Italy	NO
[12]	Mondejar-Jimenez et al. (2016)	Consumers/ households	Exploratory study, based on a survey involving 380 youths in Italy and Spain, investigating food waste behaviours in the framework of the Theory of Planned Behaviour.	Italy and Spain	NO
[13]	Thyberg and Tonjes (2016)	The whole FSC	Large review of historical premises and current main drivers of FW: modernisation of food systems, cultural, socio-demographic, and behavioural factors, and policies causing generation of FW	Mostly the USA	YES

Table 1. *Cont.*

Reference	Author	Segments of the FSC Addressed	Description and Methods	Geographical Coverage	Classifying FW Causes or Drivers
[14]	Visschers et al. (2016)	Consumers/ households	Investigation on the causes of self-declared FW in household through an e-mail survey (796 questionnaires)	Switzerland	NO
[15]	Secondi et al. (2015)	Consumers/ households	Multilevel analysis on household food waste behaviour in the European countries based on the results of a Flash Survey of Eurobarometer	Europe	NO
[16]	Girotto et al. (2015)	Various	Analysis of FW generation in different FSC sectors under the perspective of recovery for industrial uses (literature review)	Unspecified	NO
[17]	Aschemann-Witzel et al. (2015)	Consumers/ households	Results of a review of literature and 11 expert interviews on FW causes in households	Unspecified	NO
[18]	Neff et al. (2015)	Consumers/ households	On-line survey to a representative sample of US consumers (1010 respondents) investigating awareness, attitudes, and behaviours about the waste of food	USA	NO
[19]	Parizeau et al. (2015)	Consumers/ households	Survey of 68 households in a Canadian middle-sized town and measure of the FW produced.	Canada	NO
[20]	Adams (2015)	The whole FSC	Study investigating the role of retailers in the generation of FW across the food supply chain and assessing policy recommendations with respect to its reduction	Europe	YES
[21]	Principato et al. (2015)	Consumers/ households	Assessment of the awareness on FW issues in a non-probabilistic sample of 233 Italian university students in Rome	Italy	NO
[22]	Stancu et al. (2015)	Consumers/ households	Analysis of behavioural attitudes towards self-reported household FW in a sample of 1062 Danish consumers	Denmark	NO
[23]	Betz et al. (2015)	Food services	Quantification of FW produced by the food services of two big companies operating respectively in the education and in the business sectors	Switzerland	NO
[24]	Lebersorger and Schneider (2014)	Retail and markets	Quantification of waste for different categories of food products and investigation of related causes based on FW data collected from 612 Austrian food retail outlets and on a sorting analysis of discarded food in a small sample of the surveyed outlets	Austria	NO
[10]	High Level Panel of Experts (2014)	The whole FSC	Report by the High Level Panel of Experts of the Committee on World Food Security (HLPE) reviewing a wide range of causes of FW, and identifying broad categories and levels of causes	Global	YES
[25]	Graham-Rowe et al. (2014)	Consumers/ households	Qualitative study based on semi-structured interviews to 15 UK households identifying motivations and barriers for FW minimisation	UK	NO
[26]	Abeliotis et al. (2014)	Consumers/ households	Face-to-face interviews on the FW attitudes and the presence of behavioural good practices preventing FW of 231 Greek consumers	Greece	NO
[27]	Quested et al. (2013)	Consumers/ households	Analysis on the results of studies on the behaviours of UK consumers towards FW, on how they have been used in public-awareness campaigns, and how they fit the main behavioural theories	UK	NO

Table 1. *Cont.*

Reference	Author	Segments of the FSC Addressed	Description and Methods	Geographical Coverage	Classifying FW Causes or Drivers
[28]	Schneider (2013)	The whole FSC	Summary of international research on FW prevention with respect to different continents and food supply chain segments (literature review)	Global	NO
[29]	Oelofse and Nahman (2012)	The whole FSC	Estimation of total FW in South Africa based on available food supply data for the country and on estimates of average FW generation at each step of the food supply chain for sub-Saharan Africa	South Africa	NO
[30]	Koivupuro et al. (2012).	Consumers/ households	Investigation, based on a questionnaire and on a FW diary study, about the influence of socio-demographical, behavioural, and attitudinal factors on the generation of FW in 380 Finnish households	Finland	NO
[31]	Williams et al. (2012)	Consumers/ households	Study on FW causes in the Swedish household, especially related to packaging, based on the record of self-measured FW produced by 61 families along seven days	Sweden	NO
[32]	Baptista et al. (2012)	The whole FSC	Outcomes of a national research project (PERDA) aimed at estimating the total amount of FW in the Portuguese FSC through mass flow analysis, on line questionnaires, and interviews to experts	Portugal	NO
[33]	Mena et al. (2011)	Food processing, wholesale and retail	Based on data collected through 43 interviews with managers in food manufacturing, wholesaling and retailing in the UK and Spain, the study discusses the identified root causes of FW and good practices.	Spain, UK	YES
[1]	Gustavsson et al. (2011)	The whole FSC	Quantification of global losses occurring along the food supply chain and identification of causes and possible ways of FW prevention	Global	YES
[34]	Waarts et al. (2011)	The whole FSC	Investigation on legislation obstacles to food waste reduction based on interviews and two workshops with experts and stakeholders from different FSC segments	Netherlands	YES
[4]	Bio Intelligence Service (2010)	The whole FSC	Based on expert interviews and literature and data analysis, the study covers all main aspects of the FW issue in the EU (causes, quantification, environmental impacts, existing policies, and recommendations)	European Union	YES
[9]	Parfitt et al. (2010)	The whole FSC	Study based on an international literature review and interviews to food supply chain experts analysing FW definitions, estimates, and causes.	Global	YES

Source: own elaboration.

This study was conceived within the European Project FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies—http://www.eu-fusions.org/) and aimed at identifying, classifying, and analysing the main causes of FW generation along the entire FSC and the impacts of current developments in technology, FSC management, and consumers' behaviours and lifestyles. The countries included in the European Economic Area (EEA) were the main geographical reference of the analysis, which was based on a wide review of existing documents, scientific literature, and results of previous research, and was implemented by investigating FW sources in the different segments of the FSC through three categories of drivers: Technological, Institutional (i.e., related to organisational factors), and Social (i.e., related to behavioural factors). The international network of

research, academic and government institutions, non-governmental organisations, private businesses, and individual experts involved at different levels in the FUSIONS Project provided a fundamental support to carry out the study, through consultations and discussions organised in the framework of the Project's activities.

2. Materials and Methods

2.1. Setting Up the Structure of the Analysis

The first step of the work consisted in the identification of specific domains (contexts) characterizing FW drivers and the different FSC levels at which FW can be generated. Three contexts for the classification of FW drivers were deduced from a first analysis of literature and consultations of experts involved in the FUSIONS project:

i The Technological context is intended to gather the FW drivers related to misuse, failures, and limits of current FSC technologies;

ii The Institutional context refers to the organizational aspects of food production and consumption in the perspective of both the private and the public sector. This implied the definition of two sub-contexts:

   a. The Business management and economy sub-context is related to the FW drivers depending on organization of food businesses and their integration along the FSC, and on management choices determined by economic variables;
   b. The Legislation and policy sub-context is concerned with FW caused by inefficient legislation in the food sector and in other connected fields, and by policy measures that may subordinate potential generation of FW to other priorities (e.g., food security, food safety, consumer information, low cost of waste disposal, etc.).

iii The Social context refers to FW drivers related to consumer behaviours and lifestyles.

The FSC was divided into seven segments, which define the different stages of the whole from-farm-to-fork process:

(1) The primary production segment includes the production of food staples destined to processing or directly to final consumption;
(2) The processing of agricultural staples segment refers to the first processing of agricultural staples producing ingredients mainly destined to further processing in the food industry;
(3) The food processing and packaging segment is concerned with production and packaging of food products for consumers;
(4) The wholesale and logistics segment relates to the activities of wholesaling of food products, including storage and transportation;
(5) The retail and markets segment embraces the selling of food to consumers in supermarkets, shops and marketplaces;
(6) The food services segment is related to the preparation of meals and dishes consumed outside the home;
(7) The households segment refers to the preparation and consumption of food at home.

On this basis, the information on FW causes collected for the analysis was organized in a matrix, whose rows and columns were respectively the seven FSC segments and the three context/driver categories (Figure 1). This type of structure allowed a bi-dimensional analysis of the information on FW causes: "horizontal", i.e., by FSC segment, and "vertical", i.e., by type of drivers (or context category), as respectively indicated by blue and green arrows in Figure 1.

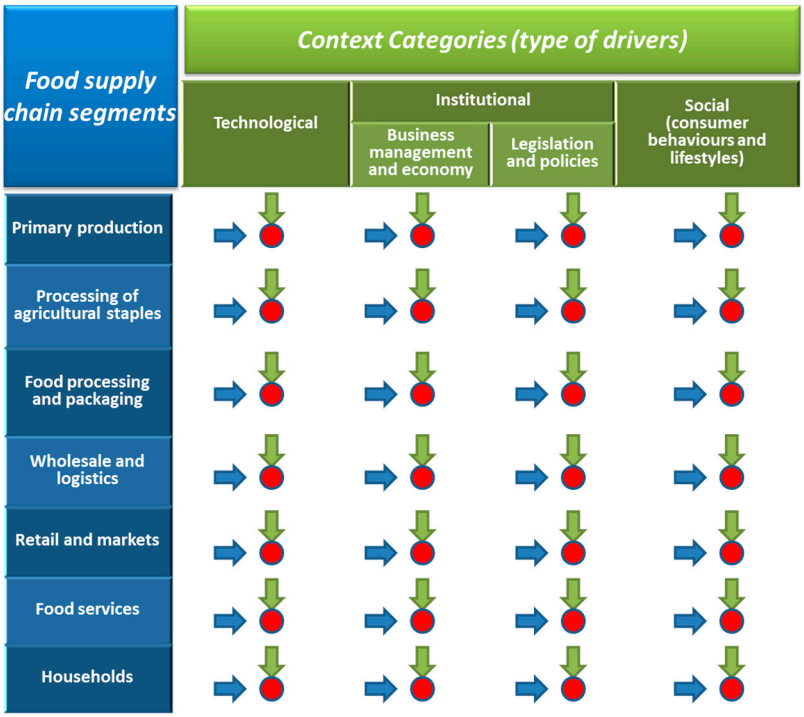

Figure 1. Representation of the matrix structure of the analysis: the small red disks, the blue arrows, and the green arrows respectively symbolise the information collected, the horizontal analysis by FSC segment, and the vertical analysis by context category (own elaboration).

2.2. Inventory of Food Waste Causes and Identification of Drivers

The basis of the analysis was an inventory of FW causes developed on the information collected through a questionnaire submitted to 13 institutions involved in the FUSIONS project from different EEA countries. For each FSC segment, the questionnaire requested the experts of the institutions involved to indicate the current causes of FW generation and the respective information sources from the scientific literature or other source. The returned questionnaires indicated a total of 286 causes of FW generation based on 171 literature references and on the direct experience of the interviewees [35]. The information collected was also integrated by consultation and discussion in focus groups at nine meetings organized by the FUSIONS project between 2013 and 2014, which involved more than 150 European stakeholders operating in different FSC segments (see Appendix A).

After the inventory, the identified FW causes were analysed to define the respective originating drivers and classify them into the three contexts. The whole supply chain was then analysed vertically under the perspective of the drivers' categories, as set by the matrix structure of the study (Figure 1). This exercise, which also took into consideration the focus groups' consultations, led to distinguish, within each context category, three groups of drivers. The clustering criteria were specific for each context, but followed the general principle of differentiating the drivers by possible interventions for FW reduction (Table 2).

Based on drivers' grouping, the final part of the work was a transversal analysis across the drivers' contexts, which led to prioritisation of the drivers based on the type of actions to be undertaken by stakeholders at different levels. The development of the whole study is summarised in Figure 2.

Table 2. Grouping of identified food waste drivers by context and sub-context.

Contexts and Sub-Contexts	Clustering Criteria for the Identified Food Waste Drivers
Technological	T1—drivers inherent to the characteristics of food, and of its production and consumption, where technology has become limited; T2—drivers related to collateral effects of modern technologies; T3—drivers related to the suboptimal use of, and mistakes in the use of modern technology;
Institutional—(A) Business management and economy	IBE1—drivers addressable by management solutions operated within one single business unit; IBE2—drivers addressable by management solutions coordinated among different operators of the food supply chain; IBE3—drivers depending on broader economic and structural variables, not readily addressable by management solutions at the level of single business units or the supply chain;
Institutional—(B) Legislation and policy	ILP1—drivers related to the agricultural policy and to food quality and marketing standards; ILP2—drivers related to food safety, consumer health and information, and animal welfare policies; ILP3—drivers related to the waste and taxation policies and to other policies;
Social	S1—drivers related to wide social dynamics that are not readily changeable; S2—drivers related to consumers' individual behaviours that are not readily changeable; S3—drivers related to consumers' individual behaviours modifiable through information and improved awareness;

Source: own elaboration.

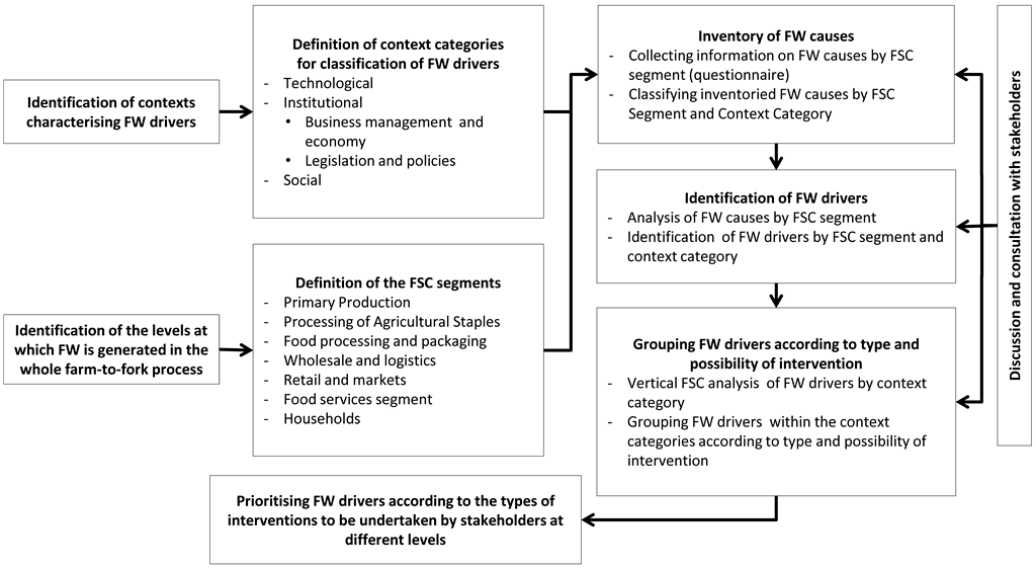

Figure 2. The development of the study (own elaboration).

3. Results: Food Waste Drivers in Context

3.1. The Technological Context

The identified technological FW drivers have been divided into three broad groups as described in the following Sub-Sections.

3.1.1. FW Drivers Inherent to the Characteristics of Food, and of Its Production and Consumption, Where Technology Has Become Limited (T1)

T1 drivers are related to the limits of available technologies with respect to certain characteristics of food staples (e.g., perishability) and the modes of their production and consumption. These types of drivers are mostly seen in the primary production and processing of farm staples segments of the FSC, where storage and microbiological issues related to perishability of farm products may occur [36–39] and also changing environmental and weather conditions may affect significantly product quality

and possibilities of conservation, with impacts in terms of FW [40]. An example is given by losses of oilseeds caused by pod shatter or during harvest [41,42], which cannot be readily addressed by technology, but require research and plant breeding solutions. Climate change was also identified as a driver contributing to increased losses due to moisture and moulds, as well as increased contamination in harvested crops [43]. Perishability is however a factor of great concern in all the FSC segments, which available technologies are not always able to manage, especially for fresh products and in adverse conditions of storage and transportation, and may also lead to insufficient product life at the household [36,40,44–52].

Some characteristics of food production reduce the possibility to predict the volumes of supply and demand by hindering the capacity of FSC operators to adapt to changing market settings with consequences on FW generation. At the farm level, crop production is affected by variability factors, such as weather, pests, phytopathogens, and alternate bearing characters [53,54]. These factors may directly cause overproduction or induce farmers to overplant in order to avoid risks of not fulfilling contract conditions for deliveries in terms of final products' quantities and grading characteristics. Waste of unsold and unharvested products is the consequence, particularly evident for the more perishable products such as fruit and vegetables [55–57]. More generally, crops and livestock production always implies considerable time gaps between the planning of production volumes and when the products can be marketed: an example is the time gap between the first investments for planting tree crops and the first possible harvest, which in general covers several years. For these types of motivations, the technical capacity to avoid crop-shrink wastage due to overplanting, grading, and market price falls may be limited [56,58]. Similarly, consumer demand of food products may be extremely volatile due to unusual weather conditions, food scares, and several other causes (see Section 3.4.2): forecasting these events often is technically impossible and the whole FSC is involved in the market imbalances they create, with impacts in terms of FW increase.

3.1.2. FW Drivers Related to Collateral Effects of Modern Technologies (T2)

T2 grouping relates to the fact that FSC technologies evolve by optimising not only the use of food staples in the different FSC segments, but also other economically relevant factors of production: e.g., energy, land, buildings, equipment, workforce, etc. Therefore, the implementation of new technologies that potentially cause an increase in the waste of food staples, but reduce the use of other more costly factors and compensate additional losses with scaling production, may be perfectly rational for both the agri-food businesses and consumers: especially if they do not pay for the full environmental damages caused by FW [59].

Examples of these drivers (T2) are non-selective fishing, where trawl fishing and non-selective gears imply by-catches which are not utilised [60–63]; and automation of tasks related to harvesting, handling, processing, and transportation of food staples. Processing methods for potatoes, tubers and vegetables, such as mechanical peeling and handling, can cause very high amounts of waste [64,65] and this may reflect the advanced technology of European food production systems. The soft nature of many fruits and vegetables makes them susceptible to damage during automated harvest and handling, although much research has been undertaken in this area in recent decades [56].

Animals' conditions in industrial livestock farming implies different types of stresses and impacts on animal welfare, with consequent losses of production, deaths of animals, and discard of carcasses after slaughtering. This waste may be reduced by improving animal welfare, which however trades off production costs [66,67] and current practices of industrial livestock farming in general cannot avoid a certain level of losses, even when the minimum legal standards on protection of animals are fulfilled [68–72].

3.1.3. FW Drivers Related to the Suboptimal Use of, and Mistakes in the Use of Modern Technology (T3)

Most technological drivers identified in the literature reside in the T3 group. These drivers are also predominant in all the sectors of the food chain post farm-gate and have often strict connections

and overlaps with problems of organisation and mismanagement within the business units that are treated as IBE1 institutional drivers in Section 3.2.1.

Inadequate systems of control in production and processing are one of the most frequently cited drivers leading to FW. This occurs across all sectors of the food processing industry. Examples include slaughtering and processing losses in the meat industry [47], cutting and trimming losses [73], losses due to production errors and rudimentary control measures [9,74,75], processing waste (e.g., pastry trimmings, overfilling losses) [76], and failure of the heat seal on packaged food [47].

Closely related to inadequate production and processing control are suboptimal operation and ease of use of equipment, which can result in losses due to production errors [33,77]. Spoilage caused by poor storage handling and conditions, and damage created during transport [10,40,58,78] along with cold chain inefficiencies [79] occur during passage of materials throughout the FSC.

Suboptimal use of packaging and labelling is also a key driver in creating FW, while appropriate use will help in the reduction of FW by maintaining product quality. Packaging defects and errors can lead to broken and damaged food items and the food cannot be sold if the packaging is mismarked or mislabelled [33]. The packet size and material must also be optimal to avoid waste in the households [31]. FW at home can also be alleviated through improved technology such as fridge and freezer temperature and door open alerts [79], suitable storage containers and systems [80,81], and internet and mobile applications.

Table 3 shows a summary of the FW drivers identified in the Technological context.

Table 3. Summary of identified FW drivers in the Technological context.

Groupings of FW Drivers (Technology)	Identified FW Drivers (Technology)
T1—FW drivers inherent to the characteristics of food, and of its production and consumption, where technology has become limited	• Perishability of food staples; • Changing environmental and weather conditions; • Climate change; • Unpredictability of supply and demand volumes and consequent overproduction and demand volatility;
T2—FW drivers related to collateral effects of modern technologies	• Fish by-catches; • Automation of tasks related to harvesting, grading, handling, processing, and transportation of food staples; • Animal stresses in industrial livestock farming;
T3—FW drivers related to the suboptimal use of, and mistakes in the use of modern technology	• Inadequate systems of control in production and processing; • Suboptimal operation and ease of use of equipment; • Poor storage handling and conditions; • Damages during transport; • Cold chain inefficiencies; • Suboptimal use of packaging and labelling; • Packaging defects and errors; • Inappropriate packet size and material; • Inappropriate use of fridges and storage systems in households;

Source: own elaboration.

3.2. The Institutional Context—(A) Business Management and Economy

The drivers related to the Business management and economy context relate to FW caused by operational or strategic decisions undertaken within the FSC business units. However, the grouping of these drivers, described in the below sub-sections, considers that the decisions assumed by one unit may also affect the amount of FW produced by other FSC operators.

3.2.1. FW Drivers Addressable by Management Solutions within One Single Business Unit (IBE1)

Most business management and economy drivers belong to the IBE1 group and it is highly probable that a considerable amount of FW created along the FSC could be avoided by management

and organisational improvements operable at the level of the single business units. In fact, a better management of production processes could avoid many technical errors and misuses of FSC technologies, which are primary FW causes treated in Section 3.1.3.

The drivers identified in the food processing and packaging segment are generally related to poor management that causes technical errors, such as production of sub-standard food, food contamination, damages to packaging or errors in labelling, which are important FW determinants. Other examples can be found in the practices related to grading and sorting of food products, in the overfilling of food containers, and in imperfect products resulting from changes in food preparations [1,4,9,34–36,55,58,73,82–86].

Likewise, poor management and lack of training in the business units cause FW in the wholesale and logistics segment, where common FW drivers are mishandling, improper conditions of storage and transportation, damage to packaging during transportation and incorrect application of inventory turnover that can cause excessive prolongation of product storage and consequent rejection by retailers [1,4,84–89].

Similar drivers affect also the retail and market segment including inaccurate storage and incorrect stock turnover [1,50,78,84,85]. Products with a low turnover rate are more often wasted than products with a high turnover and failures in sales forecasts of seasonal products lead to FW increase [90–92]. Other IBE1 FW drivers identified in the retail and markets segment are packaging renewals due to marketing campaigns [35,84], delisting of products [56], and trade-off between the need to maintain fresh products on the stores' shelves and the upward trend to prolong the opening hours of food shops [90].

Major challenges in the food service segment are given by incorrect forecast of servings [85,93–98] which may cause overproduction [99,100] or that products in stock pass expiration or best-before dates [34]; increasingly varied menus, which augment difficulties in accurate forecasts and preparation of meals [4,34,85,101–103]; inflexibility in portion size and assortment, which may induce plate waste by customers [23,94,98,104–107]. In addition, the fact that customers pay for served meals does not stimulate food service providers to undertake actions for reducing plate waste [94]. Poor information on menus has been identified as a FW driver in canteens, and also too short lunch breaks in schools, which stress service users and induce to leave uneaten food on dishes [94,102,105,107] while it has been found that improvement of meal ordering and menu choices may reduce trolley waste in hospitals [98,108].

3.2.2. FW Drivers Addressable through Management Solutions Coordinated among Different FSC Operators (IBE2)

IBE2 drivers are related to a lack of coordination along the FSC and have been mostly found in the wholesale and logistics and in the retail and markets segments. However, food processors are also affected, especially when they deal directly with big retailers through various forms of contracts and agreements that, in general, impose very strict conditions for deliveries and returning of unsold products [33,34,109]. In fact, FW prevention may be constrained by contracts and agreements between FSC operators, for example, when suppliers must agree to deliver orders in too short time, they tend to overstock to avoid penalties and this may cause FW; similarly, big retailers accept only products with a high proportion of shelf-life remaining (usually over 70%), which is particularly problematic for producers who are unable to sell through alternative channels [33], and when the products are sold under the retailers' brand labels and trademarks. In the latter case, tolerance for errors in delivering is further reduced since unsold products cannot be redirected, with increased FW impacts [33,34,109].

In this framework, we can also include the tendency of the FSC operators that have more bargaining power to transfer to suppliers or to customers the risks of unsold products and related costs of disposal: e.g., big retailers tend to impose to suppliers the return of unsold or damaged products for free or the possibility of last-minute cancelations of orders [4,55,85,86,110]. This way to exercise market power may have various consequences in terms of FW: it does not encourage the stronger FSC operators to accurately order and manage stock; causes FW increase by the weaker FSC operators [1,4,41,55,84,85,90,91,111]; and may instigate marketing practices suspected to boost FW

generation and even illegal FW disposal in some circumstances, as indicated, for example, by press reporting related to the bakery sector [112,113].

More generally, market power imbalances and lack of trust, transparency, communication, and information sharing in the FSC are seen as a root FW cause by several authors pointing out that better coordination between retailers, distributors, wholesalers, and manufacturers can reduce FW and avoid it being shifted across the supply chain [4,36,55]. Also, forecasting failures in stocks and orders often depends on scarce FSC coordination causing, for example, misjudgements of the demand volumes, especially related to seasonal changes [34,85,91,114,115]. There are also marketing practices deemed to have FW impacts that could be regulated through an increased cooperation between FSC operators; examples are the fixing of best-before dating according to consumer expectations and not to the actual quality of products [84], the selling of products in too large packages [58,89,91,116], "buy one, get one free" (BOGOF) promotions [12,116,117], and the so-called "cannibalisation" effects of certain sales campaigns, which destabilize the demand structure and reduce predictability of market forecast with impacts on FW [45,84,89].

3.2.3. FW Drivers Depending on Broader Economic and Structural Variables, Not Readily Addressable by Management Solutions at the Level of Single Business Units or of the FSC (IBE3)

The drivers of the IBE3 group are predominantly found in the primary production segment. In developed countries, these drivers are related with low market prices which may induce farmers to leave crops unharvested or even to destroy products [93,118]. Lack of infrastructure and facilities for proper conservation are drivers of FW and food quality losses in the early FSC stages of developing countries [1,119]. Although these drivers are mainly attributed to low income regions, they need to be considered by the FSC operators of developed countries involved in international trade. In the food processing segment, IBE3 drivers relate to limited access to finance, which hinders technological progress [1] and the implementation of good practices for FW reduction. In the household segment, the perceived cheap price of food is recognised as a possible FW driver [10,58,104,118,120].

Table 4 shows a summary of the FW drivers identified in the Institutional sub-context related to Business management and economy.

Table 4. Summary of identified FW drivers in the Institutional context—Business management and economy sub-context.

Groupings of FW Drivers (Business Management and Economy)	Identified FW Drivers (Business Management and Economy)
IBE1—drivers addressable by management solutions operated within one single business unit	• Production of sub-standard food; • Food contamination; • Damages to packaging • Errors in labelling • Errors in grading and sorting of food products; • Overfilling of food containers; • Imperfect products from changes in food preparations; • Mishandling of food products; • Improper conditions of storage and transportation; • Damages to packaging during transportation; • Incorrect application of inventory turnover; • Inaccurate storage and incorrect stock turnover; • Failures in sales forecasts of seasonal products; • Packaging renewals due to marketing campaigns; • Delisting of products; • Prolongation of food shops' opening hours; • Incorrect forecast of servings in food services; • Increasingly varied menus; • Inflexibility in portion size and assortment; • Insufficient information in menus; • Inadequacy of menus to consumers' preferences; • Too short lunch breaks in schools; • Poor meal ordering systems;

Table 4. *Cont.*

Groupings of FW Drivers (Business Management and Economy)	Identified FW Drivers (Business Management and Economy)
IBE2—drivers addressable through management solutions coordinated among different FSC operators	• Overproduction and overstock due to short time imposed to deliver orders; • Retailers want products with a too high proportion of shelf-life remaining; • Reduced tolerance of retailers for errors in delivering; • Tendency to transfer to suppliers or to customers the risks of unsold products and related costs of disposal; • Return of unsold or damaged products for free; • Possibility of last-minute cancelations of orders; • Market power imbalances; • Failures in stocks and orders forecasting depending on scarce FSC coordination; • Market destabilisation effects of certain sales campaigns and other marketing practices;
IBE3—drivers depending on broader economic and structural variables, not readily addressable by management solutions at the level of single business units or of the FSC	• Low prices of farm products stimulating unharvesting and product destruction in the farm sector of developed countries; • Lack of finance in developing countries, hindering the setting of facilities for proper conservation and processing of food staples; • Cheap price of food in households of developed countries;

Source: own elaboration.

3.3. The Institutional Context—(B) Legislation and Policy

The drivers related to the Legislation and policy sub-context have been grouped according to the type of policy measures that are deemed to imply the generation of FW. The three groups identified are described in the below Sub-Sections.

3.3.1. FW Drivers Related to the Agricultural Policy and to Food Quality and Marketing Standards (ILP1)

The drivers of the ILP1 group are chiefly related to marketing standards. Strict cosmetic standards required by the retail industry for fruit and vegetables are deemed to cause an important amount of farm waste for products with imperfect shape or appearance [33,51,60,84,96,97,101,102,121,122]. The European legislation currently applies specific marketing standards to ten fruits and vegetables products—apples, citrus fruit, kiwifruit, lettuces, curled leaved and broad-leaved endives, peaches and nectarines, pears, strawberries, sweet peppers, table grapes, and tomatoes [123]—leading to sorting out of products at the farm level and among trading parties in other downstream FSC segments [34]. Products which deviate from the marketing standard may not be treated as fresh products along the FSC, but they can be used for processing and animal feeding [34,45]. In 2011, specific marketing standards for 26 fruit and vegetables products were abolished in the EU [122], but it seems that it did not impact significantly for FW reduction, because FSC operators continued to require them as private standards [34].

Some authors blame the agricultural policies and government subsidies of stimulating farmers to oversupply certain commodities by causing huge FW impacts [93,118,122,124,125]. However, there is lack of specific research in this field and, as regards the EU, it must be said that the traditional picture of agricultural policies inducing overproduction is mostly related to the former framework of the European Common Agricultural Policy, which was radically reformed in 1992, as noted by some researchers [122].

The European Common Fishery Policy is also indicated as a FW cause, mainly in connection with the practice of discarding unwanted catches into the seas [60,84,115]. Fish are discarded for different reasons: they are under the minimum size allowed for fishing the species; the fisherman has no fishing quota for the caught species or because of certain catch composition rules, the caught species have no market, the fisherman does not have enough room on board, etc. [62]. In 2014, a ban on discarding,

with obligation of landing all the unwanted catches was introduced in the EU. The application of the measure is progressive between 2015 and 2019, and takes place fishery by fishery [126].

3.3.2. FW Drivers Related to Food Safety, Consumer Health and Information, and Animal Welfare Policies (ILP2)

Most legislation and policy drivers reside in the ILP2 group, which is also predominant in all the FSC segments following primary production. Food hygiene and safety regulations are among the most frequently cited ILP2 FW drivers in various FSC segments, such as processing of farm staples, wholesale and logistics, retail and markets, and food services. They oblige FSC operators to discard considerable amounts of food on the basis of safety standards that are often perceived as too strict, and frequently make the recovery or the alternative valorisation of discarded food legally or technically impossible [34].

Many FSC operators consider the so-called EU "hygiene package" [127] an important FW generator, because of too strict safety standards, especially regarding time limits on storing opened packaging, prepared food and unrefrigerated products, temperature of frozen meat, the setting of hygiene codes that may be even stricter than the legislation, and because of differences in law implementation and enforcement among countries, even inside the EU, and among food sectors, companies of different size, and product codes [33,97]. EU regulations on food contamination by microorganisms, pesticides, or pharmaceuticals are blamed as FW causes, because of increasingly strict tolerance for residuals—especially pesticides for fruit and vegetables, and antibiotics and hormones for animal products—and the augmented efficacy of detection methods, differences in tolerance with respect to the EU's third countries and among food products, and prohibition of decontamination practices.

Controls on import for certain fresh products are accused of taking too much time and often of taking place in improper conditions with the consequence of shortening the time useful for consumption, thus contributing to FW. If phytosanitary controls find a batch of fruit or vegetables to be contaminated, the protocols impose that it must be fully destroyed or sent back to the country of origin, even in the case that contamination affects only a small or marginal part of the entire batch [34,127]. The European legislation on novel foods is accused of requiring—because of its rigidity and overlapping between EU and national regulations—an excessively heavy bureaucratic effort from FSC operators, especially if compared with the United States' rules. This prevents the import of food products that have been eaten for centuries outside Europe, that are wasted or sent back, and hinders the possibility of food innovations that could be useful in terms of FW reduction [34].

Food safety legislation sets restrictions on the use of animal residuals for food and animal feed preparations that are often perceived as hindrances to FW prevention and reduction [34,75]. The EU measures for prevention of transmissible spongiform encephalopathies [127,128] have forbidden the use of proteins from animals to feed ruminants, with a ban extension to feed all animals other than ruminants. The EU regulation for animal by-products [127,129] has set the prohibition of feeding terrestrial animals and farmed fish of a given species with by-products obtained from animals or farmed fish of the same species, feeding farmed animals with catering waste and its derivatives, and with forages obtained from land where organic fertilizers other than manure have been applied.

All these restrictions constrain the possibility to make use, in Europe, of residuals and waste from food processing and retail activities and from kitchens and food services for livestock production, while such practices are widespread in third countries from which the EU imports meat, farmed fish and other livestock and aquaculture products [34]. The EU limitations are deemed to make residuals and waste containing even very small quantities of animal derivatives unusable for such purposes and the procedures that would allow their usage, such as traceability and separation of the animal fraction, are often complex and costly for FSC operators [34,75]. Consequently, these potential resources frequently do not find better use than co-fermentation in bio-digesters for energy production.

In general, this usage is easy and also supported by government subsidies, which may also make it financially preferable for the waste that has already been separated [33].

Food products accompanied by labelling with erroneous or misleading information should be removed from the market and are often discarded due to impracticability of relabelling or reprocessing. European legislation in this field is considered complex and fragmented and for this reason is indicated as a potential cause of errors and consequently of FW [34,84,85], even if efforts for integration and simplification have been made with the progressive implementation of Regulation (EU) No. 1169/2011 [34,130]. Date labelling rules, and in particular the "best before"/"use by" dating scheme, are accused of being a source of avoidable FW, because they may be confusing for many consumers who would avoid purchasing or directly discard food approaching or passing the "best before" date, with the conviction that it could soon become or already be unsafe, or simply have lost some quality [57,85,131–135]. The possibility of indicating other types of dating such as "sell-by" and "not to be used after", "display until" may add confusion [57,85,136,137] and consumer surveys have confirmed the existence of a remarkable level of misunderstanding as regards date labelling [57,132–134]. The European Commission, in its action plan for the Circular Economy, announced initiatives to examine ways of improving the use of date marking and its understanding by consumers, in particular the "best before" label [8]. However, consumer associations are opposed to proposals of reducing the food items subject to obligation of minimum durability dating and consider that such a measure could be even counterproductive in terms of FW impact [138].

Food safety policy and related measures impact on food product liability, which in the EU is set under the so-called European General Food Law [139]. Food product liability is widely considered a hindrance for donation of food destined to be wasted [13,20,55,58,78,95,140,141]. The European regulation attributes FSC operators with the same level of responsibility for both the food they sell to customers and for the food they donate to charities for redistribution to needy people [140]. This makes FSC operators reluctant to donate, not only due to the risk of being legally pursued in the case that food-related health problems to beneficiaries arise, but also due to the consequent reputational damage [34,140]. The general principle established by the European regulation finds different applications in the EU Member States. Some of them (e.g., France, Greece, Italy) have set provisions to facilitate donations by transferring the product liability from the donors to the charities that receive and redistribute the food, but there is uncertainty about possibilities to incorporate such experiences in the legislation of all the EU member States [140].

3.3.3. FW Drivers Related to the Waste and Taxation Policies and to Other Policies (ILP3)

Among the ILP3 drivers, the analysis found out the relevance of waste management, energy and taxation policies as FW drivers. Waste management policies are indicated among the causes of FW when the environmental and operational costs of disposal are not adequately compensated with corresponding taxation and fees imposed by responsible authorities. In fact, too low disposal fees are not only a disincentive to good practices for FW reduction by consumers and FSC operators [4,142,143], they also contribute to hide the various "external" costs of FW, related to over-exploitation of environmental resources, by increasing the future burden of resource depletion. In the United Kingdom, the increase of landfill taxation since the end of the 1990s has played an important role in the activation of measures by public and private operators to reduce the landfill disposal of organic waste, including FW [142].

Waste management and FW have implications in terms of energy policies. In Europe, there is a lack of a FW hierarchy scheme with juridical value indicating priorities for FW utilisation and this has consequences in terms of optimal distribution of State incentives to initiatives for FW prevention and reduction [140]. We have already seen that, because of renewable energy incentives, it may be more profitable to co-ferment for energy production FW that has been already separated, than to direct it to the animal feeding industry [34]. Similarly, co-fermentation of safe food destined to waste may be more profitable than to donate it for redistribution, especially in countries that have developed a good

infrastructure for bio-gas production [140]. This inversion of priorities in resource utilisation may be considered as a waste, and the misaddressed incentive system which supports it as a FW driver.

Lack of tax breaks and fiscal incentives on food donations is seen as an important obstacle to the recovery and redistribution of food destined to be wasted. The European Directive on the common system of value added tax (VAT) [144] sets a principle of taxability of donated goods. Therefore, to create a VAT exemption system for food donations in the EU Member States, it is necessary that national legislations interpret the Directive in a sense that attributes zero value to donated food that is, for example, close to the expiry date for selling [140,145]. However, in many cases, the possibility to incorporate this interpretation in national legislations is controversial and the EU Member States adopted different behaviours: not all have implemented VAT exemptions on food donations, and the implementation systems are different form one country to the other [140]. Beyond VAT exemption, several EU Member States have introduced fiscal incentives to food donations in the form of tax credit or tax deductions; the absence of similar incentives in other countries is then seen as a FW driver by some authors [140].

Table 5 shows a summary of the FW drivers identified in the Institutional sub-context related to Legislation and policy.

Table 5. Summary of identified FW drivers in the Institutional context—Legislation and policy sub-context.

Groupings of FW Drivers (Legislation and Policy)	Identified FW Drivers (Legislation and Policy)
ILP1—drivers related to the agricultural policy and to food quality and marketing standards	• Marketing standards for fruit and vegetables; • Farm overproduction related to government subsidies; • Fishery policy regulations determining by-catch discards (minimum size of caught fish; catching composition rules; fishing quotas);
ILP2—drivers related to food safety, consumer health and information, and animal welfare policies	• Compliance with safety standards on time limits on storing opened packaging, prepared food, unrefrigerated products, and temperature of frozen meat; • Differences in implementation and enforcement of safety rules among countries, food industry sectors, and production units of different size; • Compliance with safety standards on residuals of contaminants in food; • Differences in contaminants' tolerance among countries, food products, and prohibition of decontamination practices; • Increasing efficacy of methods for contaminants' detection in food; • Prohibition of decontamination practices; • Time and conditions of controls on import of fresh food; • Phytosanitary controls on imports; • Rigidity of legislation on novel food and differences in regulations among countries; • European restrictions on the possibility of using animal residuals for food and animal feed preparations; • Impracticability of obligation of relabelling or reprocessing food delivered with erroneous or misleading label information; • Complexity and fragmentation of European legislation on labelling information; • Multiple schemes in the European date labelling legislation; • Hindrances to food donations from the legislation on food product liability;
ILP3—drivers related to the waste and taxation policies and to other policies	• Waste disposal taxation and/or fees lower than the real environmental and operational costs of FW; • Lack of legislation establishing priorities in the use of food destined to waste and incentives from energy policy make energy production more convenient than recovery for redistribution or use in the animal feed industry; • Lack of tax breaks and fiscal incentives on food donations;

Source: own elaboration.

3.4. The Social Context

The social drivers under consideration involve consumer behaviours and lifestyles and can be grouped into three broad clusters as shown in the following Sub-Sections.

3.4.1. FW Drivers Related to Wide Social Dynamics That Are Not Readily Changeable (S1)

Individual behaviours of consumers are, in part, related to wide social dynamics that determine the S1 FW drivers. In the current circumstances, urbanisation, changing dietary habits and globalisation of agri-food markets are interconnected phenomena and affect the FSC structure, which adapts to evolving population needs and habits worldwide, by impacting on FW quantitatively and qualitatively [9,13]. The growth of populations living in big towns and rural emigration are coupled to agricultural and FSC modernization, which reduces production losses in the upstream FSC segments (pre-harvest, transportation, storage, processing), but increases FW in the downstream segments (retail, food services, households) [9].

Most of this FW increase is related to the adaptation of lifestyles to living and working conditions and to social dynamics of urban areas [13]. Some distinctive characteristics of the urban households show significant correlations with the amount of FW individually produced. Households consisting of few members or one single person, of young members, of children, and relatively high income seem to be the features that are mostly related with higher FW production per capita [9,13–16,22,30,55,104,146–151]. Direct comparisons between urban and rural households indicate that the former are significantly higher FW producers [15,152].

Differences in FW generating behaviours may also depend on culinary and food habits rooted in the ethnic origins of people [9,13], although urbanisation and globalisation tend to reduce dissimilarities by creating an increasingly homogeneous dietary and FW pattern worldwide [13]. Some authors have detected the presence of a geographical differentiation in the individual behaviours towards FW among the EU countries, which is likely to depend on contextual factors, for example: the income per-capita, which seems positively correlated to household FW generation, and the citizens' perception towards sustainability issues, indirectly measured through various indicators [15]. According to several surveys, consumers in general deem that modern "busy" lifestyles make it much more difficult to perform good practices correctly that facilitate FW avoidance [16,25,153–156]: in this sense, sociological analyses defined FW as "the fallout of the organization of everyday life" [136], and "a consequence of households enacting ordinary domestic practices and negotiating the contingencies of everyday life" [157]. Authors have also found gender-based diversities in FW generating behaviours, with women that seem to waste more than men in households [14,30,55,153,158,159], especially in single-person households and in meal consumption out of home because of excessive portion size [23].

3.4.2. FW Drivers Related to Consumers' Individual Behaviours that Are Not Readily Changeable (S2)

Consumers' choices related to food are motivated by intimate and instinctive expectations, which are the reference of FW drivers included in the S2 group. Consumers do not like to buy food products presenting imperfections, such as fresh fruit and vegetables misshaped or blemished and packed products with defects in the external wrappers and containers and in the labelling. All other things being equal (price, quality, portion size, etc.), consumers choose the food products that show the best external appearance, even when they know that the products left unselected on the shelves, in general, do not have inferior taste and nutritional qualities. The selective behaviour of consumers with respect to the aesthetical appearance of food, being transmitted from retailers and food services to all the upstream segments, affects the organization of the whole FSC and is considered a major FW driver [1,16,33,36,45,49,65,83,85,86].

External appearance of food is also a primary indicator of freshness, and consumers prefer to buy the freshest products available on the shelves for safety reasons and because they can be kept stored longer at home. This is a major S2 FW driver for all highly perishable food items [1,4,9,42,54,58,61,107]. When product freshness cannot be visually detected, as for packed food, date labelling becomes the main reference for selection and the majority of consumers tend to avoid the purchase of food close to the best-before and use-by dates [11]. This behaviour has been identified as a FW driver, whose effects may be amplified by consumer misunderstanding with respect to the real significance of date marks [1,4,58,83,85,136,137,151,160–163].

Food safety concerns are important drivers of selective behaviour in food consumption and strongly motivate consumers' suspicion towards products presenting imperfections in their external appearance or in packaging and this implies impacts on FW [134,136,147,161]. The wasting effect of safety fears may increase when consumers do not know the actual threats represented by defects in the external appearance of food items, or when they are unacquainted with the consumption or preparation of certain products, or with their taste, such as exotic or novelty food [49,78,81]. Furthermore, the amount of FW related to safety concerns may rise dramatically in case of food scares due to food contamination by microbes, toxins, pesticides, pharmaceuticals, and pollutants, or when the media simply attribute a hypothetical threat to public health to a product. In these cases, deep falls in consumer demand and massive product recalls determine disruptive consequences on the whole FSC and considerable amounts of food discards [43,58,164,165].

Consumers prefer the widest availability and possibility of choice of food products, independent of the season and the places of production and consumption. Therefore, supermarkets and food services try to offer and display the most varied and quantitatively rich assortments of food products, which impacts on the organization of all the FSC segments and on the FW generated. Examples, which also involve the Management and economy sub-context, are given by FW from overproduction and overstocking created in the upstream segments to ensure retailer supply also for short-notice orders, which is a particularly acute problem for products that have a very short shelf-life and are subject to considerable volatility in demand, such as ready-meals [33,75,77,83,85,96,166], and when other factors of demand volatility occur, as in the case of seasonal irregularities in weather [33,36,47,84,94,154], variable presence of tourists [33], promotional food sales by competitors [33,45,47,55,84], new food trends [84] and events such as Christmas and Easter [84,104,156,167]. In fact, volatility of food demand can be considered, by itself, an important S2 FW driver.

Other examples of FW driven by consumer preference for food abundance and variety are FW related to demand of off-season and exotic products [1,4,160,168]; FW arising when fresh products, such as fruit and vegetables, are displayed by paying more attention to aesthetic criteria attractive for consumers rather than to optimal preservation conditions that could extend the shelf-life [85]; and FW caused by increasing practice of serving buffet meals in restaurants and canteens [2,23,58,97,100]. Preference for wide food availability and variety at home also induces consumers into bad practices such as over-shopping and over-cooking, with effects in terms of household FW [11,104,156,168–172].

3.4.3. FW Drivers Related to Consumers' Individual Behaviours Modifiable through Information and Increased Awareness (S3)

Regarding the FW drivers depending on the individual behaviours of consumers that are modifiable through information and increased awareness (S3 drivers), the analysis of the available literature indicates that poor food skills and information are a first cause of considerable amounts of FW. This driver may include, for example, knowledge of elementary food practices such as interpretation of date labels [134,173], correct use of fridges, freezers and other kitchen appliances, proper food handling, storage and transportation, understanding and following instructions reported on packaging [46,79,82,134,174], and full use of packaging functionalities that extend the product life [46,81].

Beyond these basic factors, several studies and surveys have found that consumers' culinary skills and, more generally, information and awareness on the wider implications of food (e.g., nutritional properties and related dietary effects, conditions of safe use, cultural aspects, social and environmental implications) have a positive correlation with a reduced generation of FW in the households, since they contribute to create a positive attitude towards good practices at different levels: planning of food shopping and meals at home, food storage, meal preparation and portioning, reuse of leftovers and optimisation of food available at home, donation of the food that cannot be consumed for any reason, and sorting of kitchen waste [13–15,17,22,25,104,134,147,153,154,158,175–177].

Household FW is also driven by organisational aspects of food-related practices and routines at home. Lack of a correct planning of shopping and home meals, based on an inventory of food available at home and on the control of its freshness and edibility state, is indicated as a cause of over-shopping and purchase of products destined to be wasted [14,58,147,148,153,157,175,178]. In fact, the largest portion of avoidable household FW consists of food that has been bought and then discarded before any processing or use at home: for example, this corresponds to about two-thirds of the total avoidable household FW in the UK, according to estimations published in 2008 [151]. In a recent Italian survey, nearly 80% of interviewees declared that they throw no or little uneaten food in the waste, but almost all the FW causes that they stated (over-shopping, date label expired, food left too much in the fridge or in the pantry, bad look or smell, etc.) imply that most of the wasted food is actually uneaten [11].

Organisational aspects also involve the distribution among the household members of responsibilities related to food shopping, meal preparation and other kitchen duties, and the regular sharing of meals at home, where random occurrences are in general considered factors of potential FW generation [104,147,154–156,168]. This last element may include all the situations that deviate from ordinary routines, for example, in the occasion of special events (Christmas, Easter and other religious celebrations, parties, etc.) people tend to buy and prepare more food than necessary; food received as a gift and food bought for special occasions (e.g., in case of guest visits) have higher probabilities of being wasted [14,104,156,168,179]; when consumers, for some reason, try new food products or food they do not know (e.g., because they are attracted by the product marketing, they want to change something in their diet or simply try something new) [104,157,169,171] and when they give in to "temptation" of promotional offers or sales campaigns [12,116,134,147,153,156,169,180].

Frequency of food shopping seems correlated with lesser household FW production [31,147]. Moreover, bulk shopping, practiced by consumers to save time and to benefit from price offers, is indicated as an important determinant of household FW. However, consumers' behavioural patterns are complex and it has been found that frequent shopping may also induce unplanned and "spontaneous" purchases, which tend to increase FW [25,116,134,147,153,154,156,169,175,180].

Individual motivations of consumers to avoid the waste of food have been indicated as an important driver in several FW behavioural surveys. Three main types of motivations can be identified in the available literature: economic, i.e., the possibility to save money by reducing FW; personal gratification from performing efficiently food-related duties, being in control of the problem, and not feeling guilt for FW; environmental and humanitarian motivations, such as to contribute to a reduction of the FSC environmental impacts, existence of people hungry or in economic straits who can benefit from distribution of food surpluses, and social immorality of FW. In general, the economic motivation figures as the main reason for consumers to avoid FW, followed by personal gratification, while socio-environmental reasons are the weakest motivators [18,22,25,27,147,148,175,181,182]. A survey published in 2009 by The Australian Institute [148] even found that the mean value of the food yearly wasted by consumers motivated by money savings in their practices of FW avoidance was significantly lower than the mean value of the food wasted by consumers motivated by environmental or humanitarian reasons. The comparatively lower effect of environment as a motivator for good practices has been mostly explained with a generalised scarce perception by people of FW as an environmental problem [25,27,147,153]: for example, people have more tendency to associate FW reduction to a healthier diet rather than to a more sustainable food consumption [27]. Some studies that found out higher relevance of motivations such as "personal gratification", "sensation of being in control" or "doing the right thing" also highlighted that people better informed about food and nutrition have less probability of being big food wasters [25,158]. A recent comparative analysis of behaviours towards FW in Spanish and Italian youths showed the relevance of perceived behavioural control in performing correct FW practices [12].

Table 6 shows a summary of the FW drivers identified in the Social context.

Table 6. Summary of identified FW drivers in the Social context.

Groupings of FW Drivers (Social)	Identified FW Drivers (Social)
S1—drivers related to wide social dynamics that are not readily changeable	• Urbanisation and related changing dietary habits and globalisation of agri-food markets; • Adaptation of lifestyles to living and working conditions and to social dynamics of urban areas; • Household formed by few members or by one single person; • Young age of household members; • Presence of children in the household; • Relatively high income level; • Culinary and food habits of population; • Modern "busy" lifestyles; • Gender-based habits;
S2—drivers related to consumers' individual behaviours that are not readily changeable	• Selective behaviour of consumers with respect to the aesthetical appearance of food and food packaging; • Selective behaviour of consumers with respect to food freshness or supposed freshness, e.g., interpreted through date labels; • Food safety concerns; • Unacquaintance with consumption or preparation of certain food products, or with their taste; • Food scares due to fears for food contamination; • Consumers' preference for the wide and possibility of choice about food products; • Volatility of food demand;
S3—drivers related to consumers' individual behaviours that are modifiable through information and increased awareness	• Poor food skills and information; • Misinterpretation of date labels; • Incorrect use of fridges, freezers and other kitchen appliances; • Improper food handling, storage and transportation • Misunderstanding and/or neglecting instructions reported on packaging; • Misuse of packaging functionalities that extend the food products' life; • Poor culinary skills, information and awareness on the various implications of food fruition; • Lack of correct planning of food shopping and home meals; • Lack of control on food available at home, on its freshness and edibility state; • Irregular distribution among the household members of responsibilities related to food shopping, meal preparation and other kitchen duties; • Irregular sharing of meals at home; • Special events (Christmas, Easter and other religious celebrations, parties, guest visits, etc.); • Essays of new food products; • "Temptation" from promotional sales; • Practice of making bulk shopping; • Practices of unplanned and "spontaneous" food purchases; • Lack of individual motivations to avoid FW;

Source: own elaboration.

4. Discussion and Conclusions

4.1. Technological Drivers

The prioritisation of the different technological drivers remains difficult mainly due to the lack of data and quantification regarding the scale of losses attributable to the individual drivers. Often, references are quite anecdotal and subjective without giving an idea of relative importance—this is a key area to consider for compulsory reporting, since much data would otherwise remain confidential to the respective FSC actors. Not surprisingly the drivers often relate directly to the use of technology and often misuse or sub-optimal use of the production systems. Research data however suggests that the majority of FW in the EU occurs in the primary production and households' FSC segments, so it would be logical to prioritize these two sectors. In addition, it is worth noting that the environmental

impact of the food which is wasted in the later FSC segments also includes all the other environmental impacts already generated in the earlier stages of its production and processing [4].

Availability of appropriate technology is less of an issue in Europe and indeed European retailers tend to source from well-developed production operations in developing countries as part of their global supply chains. The use of technology introduces a human factor and this human factor is ultimately responsible for many of the technological drivers, e.g., labelling errors, production planning, etc.; therefore, management and organisation should also be considered. The causes of FW derived from suboptimal or incorrect utilization of modern technology (T3) can be opposed by reinforcing the technological capacity of production units, by improving the skills of their staff and consumers' information and awareness. This can be obtained through policy measures stimulating investments, modernization, and professional training in firms and by campaigns making consumers more attentive to products and processes that reduce FW impacts.

Losses associated with collateral effects of modern technologies (T2 drivers) were mainly identified in relation to by-catch in the fishing industry, products damaged in mechanical operations or the soft nature of certain fruit and vegetables, and animal welfare issues. It is possible that large volumes of wastes previously generated in the vegetable processing industry have been valorised, either as animal feed or utilised within the food chain, e.g., for use in processed foods, such as quiches, soups, etc. Attention on the issues of FW and environmental sustainability, along with the associated landfill taxation, has encouraged food processors to audit all waste and co-product streams to ensure their financial competitiveness. FW derived from T2 drivers could be faced with policy measures targeted to balance the asymmetries of technological progress and the externalities generated along the FSC. To this aim, typical measures may be represented by market-based instruments such as green taxes and subsidies, and tradeable permits that change the cost/benefit ratio for firms and consumers, by addressing their choices towards FW reducing solutions.

FW inherent to food characteristics and of its production and consumption, where technology has become limited (T1 drivers), are difficult to avoid, simply because there is lack of technological capacity. They are related to phenomena such as perishability of food and unpredictability of food production and consumption in some circumstances, which have FW consequences. The effects of these drivers could be mitigated by improving technology towards a more sustainable control over the variety of natural factors that still constrain production, processing, marketing, and consumption of food. More generally, technological drivers are important to identify potential improvements in the food chain and to reduce losses. In addition, technological means and devices can be relatively easier to modify than some drivers caused by human routines or unawareness, while not forgetting that economic issues, such as profitability, could prevent using the best technological practices, especially when the monetary value of the food product or raw material is low.

4.2. Institutional Drivers Related to Business Management and Economy

The prioritisation of the institutional drivers related to business management and economy remains difficult, mainly due to the lack of data and poor understanding of interconnections between policy, economy and the businesses' behaviours that generate FW. Further research is needed to understand better how business decisions affect the amount of FW within each production unit, as well as in the connected upstream and downstream industries. Such research should also highlight factors influencing the willingness of FSC operators to invest in new technology and training to avoid errors in production and in supply forecasting. In that sense, there is a strong interconnection between the technological and the business management drivers.

However, FSC companies may have large margins to contribute to FW reduction, considering that the most predominant drivers are in the IBM1 group related to FW addressable by management solutions within the business units. In the literature, a relative scarcity of FW causes from the FSC primary production segment was found for developed countries. This was quite unexpected and could depend on a higher relevance of the natural factors than of managerial choices for production losses

and waste at the farm level; but other possible explanations may be that research paid less attention to farm waste, also because of the lower value of farm products compared with the processed products of the downstream segments.

The FW causes related to the second group of drivers (i.e., IBE2—addressable by management solutions coordinated among different operators of the food supply chain) could be contrasted by specific policy measures and public authority initiatives aimed at improving relationships and collaboration between the FSC operators about FW issues. Measures addressed to mitigate the FW effects of market power imbalances along the FSC, through a fairer distribution of commercial risks, are also likely to have positive impacts, as well as initiatives reinforcing consumers' awareness with respect to various marketing strategies that are deemed to increase FW in the households.

The third group of identified business management and economy drivers (IBE3—drivers depending on broader economic and structural variables) could be contrasted with technological progress and huge policy initiatives, mostly at international level, since in many cases they are concerned with the FSC structural and infrastructural problems of low income countries.

4.3. Institutional Drivers Related to Legislation and Policies

A prioritisation of the Institutional drivers focusing on Legislation and policy is challenging without a tailored evaluation and impact assessment. Reliable data on the effects of these drivers on FW generation, especially at the primary production level, are still missing in the relevant sectorial literature. Although marketing and quality standards are cited very often as an important FW driver across the FSC, no quantification has been done to back up these claims. Therefore, it is recommended to evaluate the impact of the European marketing standards on FW generation at the farm, wholesale, retail, and consumer level.

The food redistribution sector also lacks monitoring and the importance of scarcity or absence of fiscal incentives and VAT exemptions on food donation have not been fully evaluated yet. Some of the institutional barriers to food donation and redistribution could be addressed with more guidance for food chain actors on how to interpret and transpose legislation at the national level.

Indeed, Legislation and policy drivers are related to the complexity of the FSC and its multi-sectorial aspects. Nevertheless, the impact of the drivers should not only be evaluated individually but also in their relation to the other drivers of the same or different nature to identify impact areas and possible actions at the national and European levels.

4.4. Social Drivers

Despite the most important part of FW in developed countries being commonly attributed to final consumers and households [4,9,158] and FW policy initiatives expecting the most significant FW reduction from improvements in consumers' attitudes [5,6,8], quantitative information and data about FW attributable to the different behaviours of consumers can be considered still insufficient, fragmentary and scarcely comparable. Beyond the problems that this lack of data may cause to an objective hierarchization of the Social FW drivers, the analysis shows that consumers' unawareness about FW issues and poor food and culinary skills are critical in determining FW. In fact, it seems that they act as background factors, which not only cause unawareness as regards the quantities of FW individually generated, the related environmental problems and the possible benefits from a more efficient food use, but also induce FW from conducts such as mishandling of food products, inadequate management and planning of home activities related to food (e.g., shopping, management of home storage, meal preparation) and misunderstanding of food labelling, and exposes consumers to potentially negative effects of some form of advertising that may stimulate bad practices (e.g., bulk offers and packaging sizes that induce over-shopping in consumers). Applications of the theory of planned behaviour have shown the relevant role played by perceived behavioural control in the performance of correct FW behaviours by individuals [12,14,22,27,177,183]. Hence, consumer driven FW can be reduced by influencing directly social attitudes through awareness and education

campaigns, but also indirectly through forms of sustainable marketing and advertising, more attentive to the possible impacts of behaviours encouraged in consumers. Such measures could be more effective if tailored for the specific contextual factors that contribute to differentiate the individual behaviours towards FW at the territorial level, therefore it would be useful to develop further research about these last aspects, as suggested by other studies [15].

4.5. A Cross-Contextual Prioritization and Some Conclusions

Despite the limitations caused by the impractical nature of an exhaustive hierarchy of FW causes supported by objective metrics, this study can be considered a unique wide-ranging overview based on a clustering that indicates main contexts of FW drivers and possibilities and types of suitable interventions. In the available literature, among the other main studies that deal with the identification of FW drivers and causes for the whole FSC in a European or global perspective, the Bio-Intelligence Service's study of 2010 [4] targeted a quantification of FW produced in the EU and limited the analysis of causes to four FSC post-farm segments (food manufacturing, wholesale/retail, food services, and households), by collecting information from the existing literature and interviews with experts. The investigation of the household segment was essentially built on previous research performed in the UK [151,167,184]. A mix of a literature review and expert interviews characterises also the article of Parfitt et al. (2010) [9] covering FW definitions, causes and drivers, quantifications, and projections and trends to the year 2050. In this study, the identification of main global FW drivers was based on the differences existing between developing, transitional and industrialised countries in the levels of FSC technology, urbanisation of society and diversification of diets. The FAO study of 2011 that reports the likely most cited estimation of the FW globally produced [1] proposes a list of major FW causes largely based on the dualistic concept that opposes low-income countries to medium- and high-income countries. In the former, food is chiefly lost during the production-to-processing FSC stages due to poor technology, facilities, and infrastructure. In the latter, food is extensively wasted in the final FSC segments, when it is ready for end consumption. The 2014 report of the Committee on World Food Security's High Panel of Experts investigating FW and losses [10] performs a global analysis that defines three different levels for a classification of FW causes: the "micro-level" identifies causes of FW and losses directly resulting from individual actions at each particular FSC segment; the "meso-level" includes secondary or structural causes that determine or contribute to the generation of food waste at the micro-level (such as relationships among different actors, FSC organizational aspects, state of infrastructures, etc.; the "macro-level" collects the systemic factors that favour the emergence of FW causes at the lower levels.

The present study shows that from primary production to final consumption, there is no one or few main determinants clearly responsible for FW, but rather it is the result of a complex pattern of extremely diversified and interconnected causes. In general, a considerable wastage of resources seems to be inherent to industrial-scale production, processing and distribution of food destined to large urban markets and mass consumption. The impressive growth of productivity that took place in the agricultural and food sector during the last century allowed an increasing industrialisation and urbanisation of society, but also made the FSC organisation much more complex, by multiplying the potential of FW occurrences. These phenomena are not limited to the food sector. Industrial-scale production and massive consumption of goods and services in many cases imply a significant waste of resources: a remarkable example can be taken from the energy sector, where about 54% of the total energy globally generated is estimated to be lost, i.e., not used, despite the large dependence on non-renewable sources, and the ratio is much higher in the most industrialised countries [185].

Table 7 displays a crosswise classification of the identified contexts, sub-contexts and groupings of drivers prioritised according to the possibility of interventions to be undertaken by individual stakeholders, interest groups, and policy makers for reducing FW. The table distinguishes:

A. FW related to the characteristics of food products and the ways through which they are produced and consumed (e.g., perishability of food; limited predictability of supply and demand; limited capacity of control over many factors of production which constrains the possibility to adapt quickly the supply to the evolution of demand; limited possibility of consumers to accumulate individual stocks of food, etc.);
B. FW related to social and economic factors and dynamics in population habits and lifestyles that are non-readily changeable (e.g., single-person households; young age of household members; young couples with small children; growing urban population; increased consumption of meals out-home; low price of food products; scarce finance for FSC infrastructures in developing countries, etc. All these are factors and long-lasting trends positively correlated with FW generation that cannot be modified in the short–medium term);
C. FW related to individual behaviours of consumers that are non-readily changeable (this refers to behaviours depending on general expectations of consumers towards food, for example, good appearance; freshness; possibility of acceding to broad quantities and varieties of food independent of places, season, and time, etc. These expectations can determine a vicious circle between consumers' bad attitudes that are a source of wastage and FSC operators' marketing strategies that gratify such attitudes. Progress in technology and management can deal with the problem, but its originating causes—the consumers' expectations—are unlikely to be eradicable);
D. FW related to other priorities targeted by private and public stakeholders (the possibility of generating FW may be a minor concern with respect to other priorities of the private and public stakeholders. For example, for private companies, profit is a priority and this justifies choices in technology, management, and marketing solutions that balance potential wastage of food with increases in product sales, reduction of production costs or diminished risks of damages to the company's brand image from non-complying with safety or other commercial standards. For public authorities, legislative provisions improving issues such as food safety, food security, consumer information, and animal welfare may overcome the concern for potential FW generation derived from such legislation);
E. FW related to non-use or sub-optimal use of available technologies, organizational inefficiencies of supply chain operators, inefficient legislation, and bad behaviours of consumers depending on unawareness, scarce information, and poor food skills. This group includes a wide range of FW causes that could be considerably reduced by improving technological and organizational efficiency of supply chain operators, the quality of legislative provisions potentially impacting on FW, and the consumer behaviours and attitudes towards food.

The probability of modifying the causes of FW listed in Table 7 is increasing from A to E. In the first part of the list, most of the potential change lays in technological and organisational innovations that ease the constraints related to intrinsic characteristics of food products and to the ways they are produced and used. At the end of the list, changes are potentially more feasible, since they largely depend on FSC efficiency improvements through the correct application of available technology, better organisation, more accurate policy design also considering the different specific situational contexts at the local level, and increased consumer awareness.

This study indicates that wastage is inherent to large-scale production and mass-consumption of food and to the daily-life organization of urban populations in modern society. For these reasons, it will be difficult to eradicate FW in the near future; but the study also suggests that significant improvements could be obtained in a relatively short term, by increasing efficiency of FSC operators. The extreme complexity of the FSC does not allow easy solutions applicable to all circumstances. The causes of wastage need to be clearly identified within each single activity and process of the supply chain. It is then necessary to set very specific procedures for monitoring FW generation in the different FSC segments and in each type of activity, and to find out appropriate methods for any single situation. This will be mostly a task of individual operators: companies, researchers, FW campaigners, and consumers. The main tasks of public authorities and policy makers are to identify priority areas

of intervention, to design appropriate policy measures and incentives and create a framework which enables society to undertake the necessary engagement to prevent and reduce a largely avoidable wastage of resources.

Table 7. Cross-contextual prioritization of FW drivers.

Cross-Contextual Prioritization of FW Drivers	Groupings of Drivers	Possibilities for FW Reduction
(A) FW related to the characteristics of food products and the ways through which they are produced and consumed	T1	Mostly depending on progress in technology and FSC organisation
(B) FW related to social and economic factors and dynamics in population habits and lifestyles that are non-readily changeable	IBE3, S1	Mostly depending on progress in technology and FSC organisation
(C) FW related to individual behaviours of consumers that are non-readily changeable	S2	Mostly depending on progress in technology and FSC organisation
(D) FW related to other priorities targeted by private and public stakeholders	T2, IBE2, ILP1, ILP2, ILP3	Mostly depending on policy measures stimulating FSC operators to improve good practices for FW reduction, within the business and through FSC agreements
(E) FW related to non-use or sub-optimal use of available technologies, organisational inefficiencies of supply chain operators, inefficient legislation, and bad behaviours of consumers depending on unawareness, scarce information, and poor food skills	T3, IBE1, ILP1, ILP2, ILP3, S3	Mostly depending on the amendment of inefficient legislation and on improvements in the individual actions of consumers and FSC operators obtainable through increased awareness, skills, and correct application of available technology

Source: own elaboration.

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Abbreviations

The following abbreviations are used in this manuscript:

AHDB	Agriculture and Horticulture Development Board
BBSRC	Biotechnology and Biological Sciences Research Council
EEA	European Economic Area
EPA	Environmental Protection Agency
EPM	European meeting of the FUSIONS European Platform
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FSC	Food supply chain
FUSIONS	Food Use for Social Innovation by Optimising Waste Prevention Strategies—European Project of the 7th Framework Programme for Research and Technological Development of the European Commission
FW	Food waste
HGCA	Home Grown Cereals Authority
HLPE	High Level Panel of Experts of the Committee on World Food Security
IBE1	Institutional food waste drivers related to business management and economy addressable by management solutions operated within one single business units

IBE2	Institutional food waste drivers related to business management and economy addressable by management solutions coordinated among different operators of the food supply chain
IBE3	Institutional food waste drivers related to business management and economy depending on broader economic and structural variables, not readily addressable by management solutions at the level of single business units or the supply chain
ILP1	Institutional food waste drivers related to legislation and policies, specifically to the agricultural policy and to food quality and marketing standards
ILP2	Institutional food waste drivers related to legislation and policies, specifically to food safety, consumer health and information, and animal welfare policies
ILP3	Institutional food waste drivers related to legislation and policies, specifically to waste and taxation policies and to other policies
LEI	Landbouw Economisch Instituut (Agricultural Economics Institute)
NHSE	National Health Service England
NSW	New South Wales
OECD	Organisation for Economic Co-operation and Development
RPM	Regional meeting of the FUSIONS European Platform
S1	Social food waste drivers related to wide social dynamics that are not readily changeable
S2	Social food waste drivers related to consumers' individual behaviours that are not readily changeable
S3	Social food waste drivers related to consumers' individual behaviours modifiable through information and improved awareness
T1	Technological drivers inherent to the characteristics of food, and of its production and consumption, where technology has become limited
T2	Technological drivers related to collateral effects of modern technologies
T3	Technological drivers related to the suboptimal use of, and mistakes in the use of modern technology
UK	United Kingdom
UN	United Nations
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
VAT	Value Added Tax
WRAP	Waste and Resources Action Programme

Appendix A

Table A1. Participation of stakeholders in meetings of the FUSIONS European Platform (2013–2014).

Type of Organisation	Number of Stakeholders	Countries
Food retailers	13	UK, Turkey, The Netherlands, Sweden, Italy, Denmark, Greece, Hungary.
Consumer groups, social organisations, charities, and other non-governmental organisations	33	UK, The Netherlands, Poland, Germany, Sweden Finland, Italy, Hungary, France, Russia, Estonia, Switzerland, Spain, Ireland, Greece, Czech Republic, Belgium.
Food service/Hospitality sector	6	Italy, UK, Hungary, Greece, Thailand, The Netherlands, Belgium.
Governments, Policy makers, Food safety authorities and Regulators	24	Greece, Italy, Sweden, The Netherlands, Belgium, UK, Ireland, Hungary, Finland.
Food producers/manufacturers	8	Denmark, UK, The Netherlands, Finland, Greece, Sweden.
Waste Management	14	Belgium, Austria, Sweden, Portugal, Finland, Germany, The Netherlands, Spain, Greece, Italy.
Other industry: Agriculture, food packaging, ICT, supplier companies, etc.	26	Italy, Finland, Sweden, Belgium, UK, Switzerland, Portugal, The Netherlands, India, USA, France.
Universities and knowledge institutes	27	Greece, UK, Germany, Sweden, The Netherlands, Denmark, Finland, Norway, Switzerland, Italy, Hong Kong, Spain.

Regional (RPM) and European (EPM) Meetings of the FUSIONS European Platform (2013–2014)

(1) RPM Central Europe: 16 May 2013, Hohenheim, Germany;
(2) RPM Southern Europe: 20 May 2013, Padua, Italy;
(3) RPM Scandinavia: 23 May 2013, Helsinki, Finland;
(4) RPM North West Europe: 7 June 2013, Paris, France;
(5) EPM: 17–18 October 2013, Amsterdam, The Netherlands;
(6) RPM Southern Europe: 14 March 2014, Athens, Greece;
(7) RPM Scandinavia: 6 May 2014, Stockholm, Sweden;
(8) FUSIONS Social Camp on "Social innovation for food waste prevention and reduction": 8 April 2014, Bologna, Italy;
(9) RPM Central Europe: 9 May 2014, Düsseldorf, Germany;

Source: Own elaboration.

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