New methodology for facilitating the food wastage quantification.
Identifying gaps and data inconsistencies
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Highlights
- It identifies the potential food-waste generation at local and supra-local scale.
- It presents a visual tool for decision making in issues related to food waste.
- It generates a comparative framework between different municipalities.
- It contributes to the detection of gaps and inconsistencies of data reported in previous studies.

Abstract
This work aims at providing a new methodology to facilitate the process of quantifying the food waste according to European standards all along the agrifood chain combining information that is becoming available at local level.

The baseline data needed is taken from the Statistical classification of economic activities in the European Community (NACE), particularly with the more disaggregated level called “classes”. This information has been combined with data from the trading income tax at municipal scale thanks to the use of the Geographic Information Systems (GIS) and the common codes for NACE classes, generating a visual tool for the localization of points with high potential food-waste generation.

The result is an intuitive and easy to use methodology that simplify the decision making process in order to quantify the potential focus of food waste at local level. Thanks to the use of this methodology, it is possible to geographically identify the potential food waste-generation focus at municipal scale. Furthermore, it is possible to identify all economic activities which could generate food surpluses, classified according to stages of the agrifood chain at local level. Furthermore, the methodology will be easily replicable throughout the European Union at the municipal scale.

This new methodology generates straightforward and easy-to-interpret results for the decision making process in the framework of the quantification of the food waste at local and supralocal scale and it provides adequate procedures which are easy adaptable to the specific circumstances in each municipality. Moreover, this method could have applications for larger territorial contexts, as the national scale, detecting possible points for improvement of the current official figures at this respect.

Keywords
Food waste, food losses, quantification methodology, food wastage, waste quantification, agrifood chain

Introduction
According to the Food and Agriculture Organization of United Nations report, roughly one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year [1].

The negative impacts of the global food waste problem are not only related to the reduced availability and consumption of food, but also are directly involved in environmental impacts such as greenhouse gas emissions, consumption of surface and groundwater resources and land occupation [2].

Food wastage occurs at different stages of the food value chain: production, post-production procedures, processing, distribution, and consumption [3]. The methodology for estimating the food wastage at the global scale is referred as a “macro-approach” [4]. This approach is based on a comparison of inputs and outputs using mass or energy balances.
According to current estimations [5], approximately a 63 per cent increase of crop calories is required from 9,500 trillion kcal per year in 2006 to 15,500 trillion kcal in 2050 in order to assure of adequate calories in all regions around the world.

Thus, thanks to the reduction of the current food loss and waste, it is possible to improve food availability without increasing the agricultural land and the environmental impacts associated to it.

This social and environment problem has been further emphasized by the European Parliament [6] and the challenge of food waste measurement and of quantification was also addressed within the framework of the European Union [7] where the food waste figures at national level were published.

These data have served as the starting point for those Member States which have no studies regarding the food waste at national level. However, the European Court of Auditors puts into question the effectiveness provided for by European rules. It includes the target to halve the food waste per capita by 2030 throughout the agrifood chain [8, 9] because there is no a base year defined in order to set the reduction target for 2030 [10].

This lack of information at national level was also expressed in the European project called FUSIONS [11] where it is possible to identify significant differences between European Union Member States in terms of the availability of information about food waste at national level:

| Country          | 1. Production (NACE 1-3) | 2. Processing (NACE 10-11) | 3. Wholesale and logistics (NACE 46) | 4. Retail and markets (NACE 47) | 5. Redistribution (food donation etc.) | 6. Food service (NACE 56) | 7. Household |
|------------------|-------------------------|----------------------------|--------------------------------------|---------------------------------|----------------------------------------|--------------------------|-------------|
| Austria          |                         |                            |                                      |                                 |                                        |                          |             |
| Belgium          |                         |                            |                                      |                                 |                                        |                          |             |
| Bulgaria         |                         |                            |                                      |                                 |                                        |                          |             |
| Croatia          |                         |                            |                                      |                                 |                                        |                          |             |
| Cyprus           |                         |                            |                                      |                                 |                                        |                          |             |
| Czech republic   |                         |                            |                                      |                                 |                                        |                          |             |
| Denmark          |                         |                            |                                      |                                 |                                        |                          |             |
| Estonia          |                         |                            |                                      |                                 |                                        |                          |             |
| Finland          |                         |                            |                                      |                                 |                                        |                          |             |
| France           |                         |                            |                                      |                                 |                                        |                          |             |
| Germany          |                         |                            |                                      |                                 |                                        |                          |             |
| Greece           |                         |                            |                                      |                                 |                                        |                          |             |
| Hungary          |                         |                            |                                      |                                 |                                        |                          |             |
| Ireland          |                         |                            |                                      |                                 |                                        |                          |             |
| Italy            |                         |                            |                                      |                                 |                                        |                          |             |
| Latvia           |                         |                            |                                      |                                 |                                        |                          |             |
| Lithuania        |                         |                            |                                      |                                 |                                        |                          |             |
| Luxembourg       |                         |                            |                                      |                                 |                                        |                          |             |
| Malta            |                         |                            |                                      |                                 |                                        |                          |             |
| Netherlands      |                         |                            |                                      |                                 |                                        |                          |             |
| Poland           |                         |                            |                                      |                                 |                                        |                          |             |
| Portugal         |                         |                            |                                      |                                 |                                        |                          |             |
| Romania          |                         |                            |                                      |                                 |                                        |                          |             |
| Slovakia         |                         |                            |                                      |                                 |                                        |                          |             |
| Slovenia         |                         |                            |                                      |                                 |                                        |                          |             |
| Spain            |                         |                            |                                      |                                 |                                        |                          |             |
| Sweden           |                         |                            |                                      |                                 |                                        |                          |             |
| United Kingdom   |                         |                            |                                      |                                 |                                        |                          |             |

Figure 1 Countries Providing Data. FUSIONS.
In red “no data available” / Yellow “low quality” / Green “sufficient quality”

Those countries that contain information designated as “sufficient quality” (green colour) are fundamentally linked to the existence of national reports carried out to have the food waste figures in their own countries. The remaining countries generally publish as official figures the information provided in the above-mentioned report by the European Commission [7] which usually come from estimates with certain gaps and inconsistences.

The quantification methods used to measure the food waste issue at national scale is called as a “micro approach”. This approach uses sample data regarding specific agrifood chain actors. Within the micro approach, there is no single method to measure the food waste issue along the entire food chain, but there a wide variety of methodologies which could be used [12].

The group of methods was incorporated into the recommendations by FUSIONS on quantitative techniques to estimate the level of wasted food across EU-28 [13]. Moreover, one of the main conclusions was the
importance of the harmonization of results between countries, sectors and steps in the food supply chain. For this purpose, FUSIONS recommended the use of the codes from the Statistical classification of economic activities in the European Community (NACE).

Inside classification of NACE, there are different categories and levels established according to the greater or lesser degree of specificity of the economic activities. FUSIONS suggested using the more specific digit code if possible [14]. These recommendations may represent a step forward for dealing with the current difficulty to compare food waste studies. They are normally adapted to their specific objective, focus only on certain steps along the agrifood chain and use different data and methodologies to measure the current food waste.

At local level, the situation is quite similar despite the existence of a similar action protocol to quantify the food waste at this scale [15]. Despite the fact that this protocol is ample and robust, visual tools might be required in order to facilitate the implementation of the procedures and build an enabling framework for decision making within the general course of action to gather data from the food waste at municipal scale.

While this protocol allows a high degree of flexibility for adapting to different geographic scales and case studies. Thus, the contribution of the geographic component, for example through visual tools, to facilitate decision making processes defining the location of potential focus of food waste might be a step in the right direction towards quantifying the current food waste to certain spatial categories, such as the municipal level. Furthermore, the definition of what entities should be made part of the identification of the generating sources of food waste could avoid certain gaps and lacks of definition in the process of quantifying and thereby preventing the possibility of these gaps may result in inactions in relation to tackling the food waste problem.

In addition, this methodology helps assess the representativeness of the data about food waste at local level previously obtained, and it allows for the development of a comparative framework between different municipalities. Furthermore, it can be useful to identify possible gaps and inconsistencies in official data published at national level.

Methodology
The proposed methodology is based on the classification of Statistical Classification of Economic Activities in the European Community (NACE), where different categories are divided into sections, divisions, groups and classes (see Figure 2):
Thus, those categories, which could potentially generate food surpluses, have been defined and broken down in classes. In this manner, it avoids referring to higher categories, as has been the case in previous studies [7]. The main drawback of these previous analyses is the possibility of including data regarding economic activities which could potentially generate food surpluses not intended for human consumption.

Taking into account the classes proposed by NACE, three types of situations have been distinguished:

- Potential Food-Generation Surpluses. Commercial activities defined by the official EUROSTAT document [16] that might be susceptible to generate food surpluses.
- Non-Potential Food-Generation Surpluses. Commercial activities that cannot be susceptible to generate food surpluses.
- In-situ Verification. Commercial activities that may occasionally produce food-generation surpluses and others with non-potential food generation. For this reason, it is necessary to verify in-situ the concrete economic activity linked with the specific case and its relation with the agrifood value chain.

![Figure 3 and 4 Example of the detailed structure of NACE, identifying the different types of classes in accordance with their potentiality as a food surpluses generator](image)

After defining all classes from NACE, under one of the three typologies stated above: Potential Food-Generation Surpluses, Non-Potential Food-Generation Surpluses and In-situ Verification, those categories which are referred as Potential Food-Generation Surpluses and In-situ Verification have been selected and they have been classified according to the stage of the agrifood chain to which it belongs:
Thus, the methodology proposes to consider the entire agrifood chain, highlighting the following main steps: Production, Manufacturing, Distribution and Consumption. Thanks to this categorization, it is possible to define which economic activities are potentially generators of food surpluses along the agrifood chain. Therefore, it helps to identify the group of economic activities where it is necessary to focus on the food waste quantification throughout the agrifood chain or for a specific step, according to the local legal frameworks or strategies.

Once this general framework is obtained, applicable to any municipal area within the European Union, the information is linked with the trading income tax at local level because all the entities, public and private, are connected with a particular class from NACE, identified by a specific code.
In this manner, thanks to the use of the GIS, it is possible to link the information on typologies classified as Potential Food-Generation Surpluses, Non-Potential Food-Generation Surpluses and In-situ Verification, with each of the entities which are part of the municipality studied.

The geographical information included in the trading income tax makes possible to create maps at local scale, where all potential focus of food surpluses generation are defined as well as their economic impact along the entire agrifood chain and classified according to the different stages.

The location of these potential focuses could define the singularity of each municipal territory regarding the food waste generation because the households are the only missing component to complete all the relevant information about the food waste situation in each municipality. However, this component can be determined without so much difficulty to estimate the food waste generation because it is possible to use the municipal census and reliable rates of food waste generation per capita.

Likewise, another way of displaying the potential focus of food surpluses generation is using a data table which provides to identify the number of entities related to the different types catalogued as Potential Food-Generation Surpluses and In-situ Verification, so that these entities are displayed and classified according to the stages of the food value. Therefore, it is possible to delimitate the entire agrifood chain related to the potential to generate food surpluses at local level.

Furthermore, it generates a comparative framework between different municipalities thanks to the use of this methodology (Figure 8). It delimits all the economic activities likely to generate food surpluses for each stage of the agrifood chain so as to avoid remaining simply final numbers of food wastage generated and find some of the main reasons of this problem as a result of the principal economic activities that produce it and helps the decision-making process.
Figure 8 Example of the comparison between two municipalities regarding the number of entities with potential food-generation surpluses categorized by steps of the agrifood chain

Results
The most relevant results thanks to the use of this methodology are obtained at local level. Obtaining all the potential focuses of food surpluses generation throughout the agrifood chain, for each and all phases, it is possible to identify all the entities susceptible to quantify the food waste situation at each of these stages, in a visual and intuitive manner. It facilitates the work of the policy-makers to establish strategies for the quantification of the food waste.

Figure 9 Case of study of the Localization of Potential Food-Generation Focus. The municipality of Zamudio (Spain)
The alternative way of display in tabular form allows the visualization of the typology of the economic activities which are potential focus of food surpluses generation and they are located in a specific municipality. In the case of study (Figures 11 and 12), the number of entities which are related to the potential food surpluses generation are shown in the municipality of Zamudio, where it is possible to appreciate its condition as an industrial city because the majority of its economic activities are located in the distribution and consumption step and very few in the production step, along the agrifood chain.

![Figure 10 Case of study of the municipality of Zamudio. Number of entities with potential food-generation surpluses categorized by steps of the agrifood chain.](image)

It is possible to compare with other municipalities around the European Community. In this case, it has been compared with a municipality with similar population size but with an agricultural character:
| Division | Group | Class | ISIC Rev. 4 | Municipality of Zamudio | Municipality of Karrantza |
|----------|-------|-------|-------------|-------------------------|--------------------------|
| 01       |       | 01.1  | 01.11       | 0111                    |                          |
|          |       |       |             | 0112                    |                          |
|          |       |       |             | 0113                    |                          |
|          |       |       |             | 0114                    |                          |
|          |       | 01.2  | 01.21       | 0121                    |                          |
|          |       |       |             | 0122                    |                          |
|          |       |       |             | 0123                    |                          |
|          |       |       |             | 0124                    |                          |
|          |       |       |             | 0125                    |                          |
|          |       |       |             | 0126                    |                          |
|          |       |       |             | 0127                    |                          |
|          |       |       |             | 0128                    |                          |
| 01       |       | 01.4  | 01.41       | 0141*                   | 87                       |
|          |       |       |             | 0142*                   | 50                       |
|          |       |       |             | 0142                    | 2                        |
|          |       |       |             | 0143                    |                          |
|          |       |       |             | 0144                    | 14                       |
|          |       |       |             | 0145                    |                          |
|          |       |       |             | 0146                    | 1                        |
|          |       |       |             | 0147                    | 19                       |
|          |       |       |             | 0148                    |                          |
|          |       | 01.5  | 01.50       | 0150                    | 4                        |
|          |       |       |             | 0151                    |                          |
|          |       | 01.6  | 01.61       | 0161                    | 1                        |
|          |       |       |             | 0162                    |                          |
|          |       |       |             | 0163                    |                          |
|          |       | 01.7  | 01.70       | 0170                    | 1                        |
|          |       |       |             | 0171                    |                          |
| 03       |       | 03.1  | 03.11       | 0311                    |                          |
|          |       |       |             | 0312                    |                          |
|          |       | 03.2  | 03.21       | 0321                    |                          |
|          |       |       |             | 0322                    |                          |
|          |       |       |             | 0323                    |                          |
|          |       |       |             | 0324                    |                          |
|          |       |       |             | 0325                    |                          |
|          |       | 03.3  | 03.31       | 1010*                   | 1                        |
|          |       |       |             | 0332                    |                          |

Figure 11 Case of study of the comparison between the municipalities of Zamudio and Karrantza. Number of entities with potential food-generation surpluses categorized by steps of the agrifood chain.

The data analysis was also used as a basis for the definition of strategies so as to quantify the food waste at local level. This analysis can be performing through the stages within the agrifood chain as well as the different NACE categories (Sections, Divisions, Groups and Classes).
Moreover, this methodology contributes to the detection of gaps and inconsistencies in previous studies of the food waste quantification by comparing the number of entities potentially generators of food surpluses detected, thanks to the use of this methodology, with those entities where actions of quantification of food waste were carried out. Thus, it allows checking the level of representativeness of the data of the agrifood chain at local level as well as the main steps of the value chain.

Finally, with regard to its applicability, it is worth noting that the flexibility of the methodology is not only related to different characteristics of municipalities across the European Community but it is also possible to adapt to other territorial scales, as indicated in figure 13 with the analysis of economic activities potentially generate food surpluses at regional level.

![Figure 12 Case of study of the Municipality of Zamudio. Selection of economic activities with a number of entities with potential food-generation surpluses categorized by steps of the agrifood chain.](image-url)

| Step Agrifood Chain | Section | Division | Group | Class | ISIC Rev. 4 | Municipality of Zamudio |
|---------------------|---------|----------|-------|-------|-------------|------------------------|
| Production          | SECTION A — AGRICULTURE, FORESTRY AND FISHING | 01 Crop and animal production, horticulture and related service activities | 01.4 Animal production | 01.49 | Raising of other animals | 0149 | 1 |
| Manufacturing       | SECTION C — MANUFACTURING | 10 Manufacture of food products | 10.1 Processing and preserving of meat and production of meat products | 10.13 | Production of meat and poultry meat products | 1050* | 1 |
|                     |         | 10 Manufacture of food products | 10.2 Processing and preserving of fish, crustaceans and molluscs | 10.24 | Processing and preserving of fish, crustaceans and molluscs | 1020 | 1 |
|                     |         | 10 Manufacture of food products | 10.5 Manufacture of dairy products | 10.51 | Operation of dairies and cheese making | 1050* | 2 |
|                     |         | 10 Manufacture of other food products | 10.8 Processing of tea and coffee | 10.81 | Processing of tea and coffee | 1079* | 1 |
|                     |         | 11 Manufacture of beverages | 11.0 Manufacture of beverages | 11.02 | Manufacture of wine from grapes | 1102* | 1 |
|                     |         | 11 Manufacture of beverages | 11.0 Manufacture of beverages | 11.03 | Manufacture of olive and other fruit wines | 1103* | 1 |
|                     |         | 11 Manufacture of beverages | 11.0 Manufacture of beverages | 11.05 | Manufacture of beer | 1103* | 1 |
|                     |         |                           | 56.31 Wholesale of fruit and vegetables | 5630* | 1 |
|                     |         |                           | 56.32 Wholesale of meat and meat products | 5630* | 4 |

11
This approach would facilitate the making decision processes related to the food waste, establishing a basic framework that it is based on the economic activities which are many in numbers in relation to be potentially food surpluses generators.

Conclusions
This document sought to make a contribution proposing a new methodology for facilitating the food wastage quantification with the aim of making progress on improving the food waste knowledge and evaluating the level of reliability of the current official figures at local and supra-local scale and it allows for the development of a comparative framework between different municipalities.

Moreover, this methodology represents a step forward to identify information and data gaps about the current food waste data at different scales. Thanks to the proposed methodology is possible to specify more aspects related to the different economic activities likely to generate food surpluses. Thus, it is possible to identify the group of economic activities which are providing the current official figures at national level and at the same time it helps to detect gaps in specific activities.

Based on the identification of those gaps is possible to give priority to studies at local and regional scales to fill the existing lack of information regarding the food waste and improving the reliability of the official figures at different scales.

Furthermore, it aims to prompt thought, dialogue and constructive debate about the need for further progress in the food waste quantification at the different levels of management (local and national), particularly for searching a rigorous vision and diagnosis of the situation in order to establish a basis about where to set reduction targets in the short, medium and long term.

This report therefore emphasises the need to move towards better methodologies to quantify the food waste, using information which is already available. This would entail an effective and pragmatic way of creating a diagnosis about the food waste at local scale, but at the same time it seeks to provide a critical review to drive and lead to new quantification studies about this problem at different scales. Thus, it would avoid remaining information with possible means of improvement as official figures because these data could not be used as the basis for carrying out strategies for the current food waste reduction. That aspect represents...
a fundamental step to address the problems and propose solutions or improvements of this global phenomenon which is having severe negative effects at economic, social, environmental levels as well as an important impact on social and ethical issues.

**Future work**
The detection of inconsistencies can also apply to the national scale, especially for those countries where the official figures are from the above-mentioned European Commission report [7], because the quantification methodology used data from animal and vegetal waste broken down into some sections, divisions, groups and classes from NACE.

Nevertheless, that methodology barely uses classes from NACE, therefore the categories employed for food waste quantification at national level encompassed not only economic activities likely to generate food surpluses but also another classes moved away from the concept of food waste generation, as well as not including classes which are susceptible to generate food waste along the agrifood chain.

Thus, using the methodology proposed is possible to detect gaps, information needs and inconsistencies within the current official figures of food waste at national level. To do this, it is necessary to compare the categories employed to prepare the national report about food wastage, with those classes likely to generate food surpluses. In this way, the current official figures could be improved in terms of information quality and showing gaps and shortcomings. Thanks to that, it would be possible to provide a more comprehensive idea of their adequacy to serve as a baseline or it is necessary to promote further initiatives in the area of the food waste quantification at national scale.

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**Bibliography**

[1] J. Gustavsson, J. et al., 2011. Global Food Losses and Food Waste - Extent, Causes and Prevention. FAO. Gothenburg.

[2] N. Scialabba et al., 2013. Food Wastage Footprint. Impacts on Natural Resources. FAO.

[3] Lipinski, B. et al., 2013. Reducing Food Loss and Waste. Working Paper, Installment 2 of Creating a Sustainable Food Future. World Resources Institute. Washington DC.

[4] L. Delgado et al., 2017. The Reality of Food Losses A New Measurement Methodology. The International Food Policy Research Institute (IFPRI). Washington DC.

[5] Searchinger, T. et al., 2013. The Great Balancing Act. Working Paper, Installment 1 of Creating a Sustainable Food Future. World Resources Institute. Washington DC.

[6] E.U. Parliament., 2012. European parliament resolution of 19 January 2012 on how to avoid food wastage: Strategies for a more efficient food chain in the EU. Brussels.

[7] V. Monier et al., 2011. Preparatory study on food waste across EU 27. European Commission (DG ENV) Directorate C Industry. Paris.

[8] U. G. Assembly., 2015. Transforming our world: the 2030 Agenda for Sustainable Development. A/Res/70/1. New York.

[9] Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions., 2015. Closing the loop – an EU action plan for the circular economy. COM/2015/0614 Final. Brussels
[10] European Court of Auditors, 2016. Combating food waste: An opportunity for the EU to improve the resource-efficiency of the food supply chain. Luxembourg.

[11] A. Stenmarck et al., 2016. Estimates of European food waste levels. EU Fusions. Stockholm.

[12] H. Møller, et al., 2014. Report on review of (food) waste reporting methodology and practice. EU Fusions.

[13] H. Møller, et al., 2014. Standard approach on quantitative techniques to be used to estimate food waste levels. EU Fusions. Fredrikstad.

[14] C. Tostivint, et al., 2016. Food waste quantification manual to monitor food waste amounts and progression. EU Fusions. Paris.

[15] C. Hanson et al., 2016. Food loss and waste accounting and reporting standard (FLW Standard). Food Loss & Waste Protocol

[16] European Commission., 2008. NACE Rev. 2 – Statistical classification of economic activities in the European Community. Luxembourg.