Modelling of food waste from farm to fork within a CGE framework

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Abstract

Worldwide around 1.3 billion tonnes of food gets wasted each year with much of it ending up in landfill or incinerators and contributing to climate change. It is a problem we will continue to face for coming decades. In this paper we focus on developing a method and database required to include a food waste along the supply chain in a CGE model. Food waste can be generated as post- harvest losses, during manufacturing and processing, during retail and transport and during consumption. Food waste generated in the various stages can be collected as organic waste and composted or collected as rest waste and incinerated and landfilled. The system also tracks emissions as a result of using different waste treatment alternatives. By modelling the entire waste flow starting from post-harvest losses to final consumption, it becomes possible to analyse the entire food waste problem and analyse where policies would have the most impact to reduce food waste.

Introduction

Worldwide around 1.3 billion tonnes of food gets wasted each year with much of it ending up in landfill or incinerators and contributing to climate change. It is a problem we will continue to face for coming decades. Within this challenge lies an opportunity – reducing food waste can lead to reducing hunger, increasing efficiency of the food chain and contribute to a more sustainable and circular economy. However there may also be some adverse impacts on for example farmer income. Whether this complex challenge can provide economically feasible outcomes can best be analysed in an economic systems context – best represented in a Computable General Equilibrium (CGE) framework. MAGNET has already include municipal solid waste (Bartelings and Verma, 2021), including specifically food waste. However in this project we focused on the introduction of food waste along the supply chain, including post-harvest losses, food waste during manufacturing and processing and food waste generated during retail and trade.

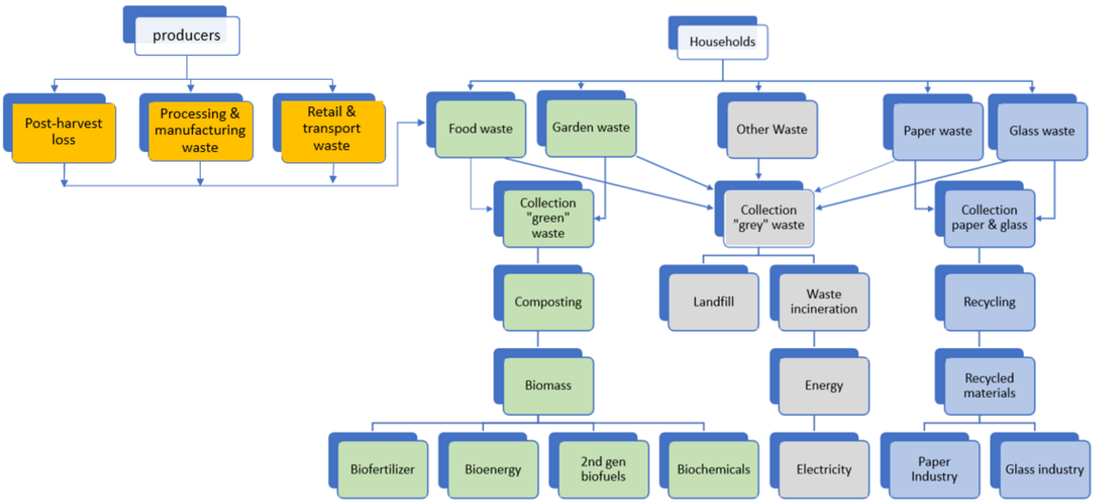
Methodology

In this paper the MAGNET model (Woltjer et al, 2014) is extended to include food waste from farm to fork. Originally the waste module in MAGNET captured only municipal waste. We specifically looked at modelling a link between consumption of goods that generate waste and type of waste generated/collected/treated. We choose to introduce such a link by modelling waste as a margin commodity. This means that if a household consumes a good it will also need to demand some waste collection services. The same holds for producers, when producers demand food commodities they will also generate waste and need to demand collection and waste treatment services. The idea is that consumer or intermediate price of a commodity now includes both the price for original commodity and the price of collecting waste generated as a result of consumption of the said commodity. In this way the new commodity can be seen as a composite bundle of original commodity, and waste collection services required to collect waste associated with consumption or intermediate use of that commodity. Data from ESTAT (2022) was included in the new module.

In MAGNET, households and industries are assumed to generate waste in relation to the changes in demand for the commodity upon which the waste flows are based. More specifically, there is a price substitutability between the purchase of commodity 'c' and the waste flows that accrue upon that transaction. The logic is that if the unit price of generated waste on purchases of (food) commodity 'c' rises relative to the price of (food) commodity 'c', then by only focusing on relative price changes, the waste rate will fall as more commodity will be purchased and less waste will be generated. However, this 'price effect' should not dominate since it is logical to assume that if (food) waste generation is falling, there is a degree of complementarity (i.e., 'quantity effect') such that less of the (food) commodity will be demanded in concert with less waste. In order to avoid overly strong 'price' effects (i.e., rising demands for commodity 'c' when the waste generated falls), the sensitivity of this substitutability (i.e., elasticity) must be small. The result is that the quantity effect will dominate the price effect

The figure below captures the way waste streams are modelled in MAGNET and covers the entire cycle from generation of waste to collection, treatment and disposal. The left hand side of the picture is new. Producers will generate food waste and demand waste collection services. Like household food waste, they can demand either green waste collection or rest waste collection. If producer food waste is collected as green waste, the waste will be send to an composting unit and be composted. If it is collected as rest waste it will go to final disposal: landfilling and incineration.

The private households generate waste in the process of consumption and demand waste collection services to collect the waste. In contrast to producer waste that focusses only on food waste as of yet, consumption of a commodity can generate one or more of five kinds of waste types – food waste, garden waste, paper waste, glass waste and other (unsorted combination) waste. Depending on the waste material generated, there are different options of collection and treatment. Three types of waste collection services exists: collection of Rest waste or " grey waste" (WCR) collection of organic or "green" waste (WCG) and collection of glass and paper (WCGP). The type of collection method determines how waste can be treated. WCR waste is either landfilled or incinerated; WCG waste is composted and WCGP waste is recycled. Only landfilled waste will not produce useful materials to circle back into the economy.



Waste stream schematic including food waste producers

Implementation: Production, processing, retail-distribution waste in the model

Like for the household waste we will model the production of producer food waste as a margin commodity. If producers use primary agriculture products (intermediate demand) they will generate waste as shown in Figure 1.

Instead of just two prices (basic and producer), the structure now has three prices: basic prices for all non-bundled commodities and waste collection services $[PDS, PMS]$, basic prices of bundled commodity $[PDS\_W, PMS\_W]$ and producer prices of bundled commodities $[PFD\_W, PFM\_W]$. The basic price for bundled commodity are weighted average of basic price for non-bundled commodity and price of waste collection service $[DPDSW, MPDSW]$.

Similarly there are now two types of quantities: a non-bundled $[\mathrm{QFM}, \mathrm{QFD}]$ and a bundled $[\mathrm{QFMT}, \mathrm{QFDT}]$ quantity where the latter is an aggregate of the non-bundled quantity and an aggregate waste collection $[QFMW, QFDW]$ quantity. Allocation of aggregate to different collection services quantities is denoted by $QMBW, QDBW$. These denote quantity variables for collection of waste by service wc, in region r, generated during consumption of imported and domestic commodity c respectively.

$PDS(wc, r)$ denotes the basic market clearing price for collection service wc in region r, note that waste collection services are not internationally traded. These are domestic services provided by government to collect waste coming from region r's consumption of both imported and domestic commodities. This implies that only domestic market price $[PDS]$ exists for waste collection services. The imported or domestic dimension in quantity variables $[QMBW, QDBW]$ originates solely from source of origin of commodity c. The associated imported and domestic value coefficients are $VWCSFM$ and $VWCSFD$ respectively.

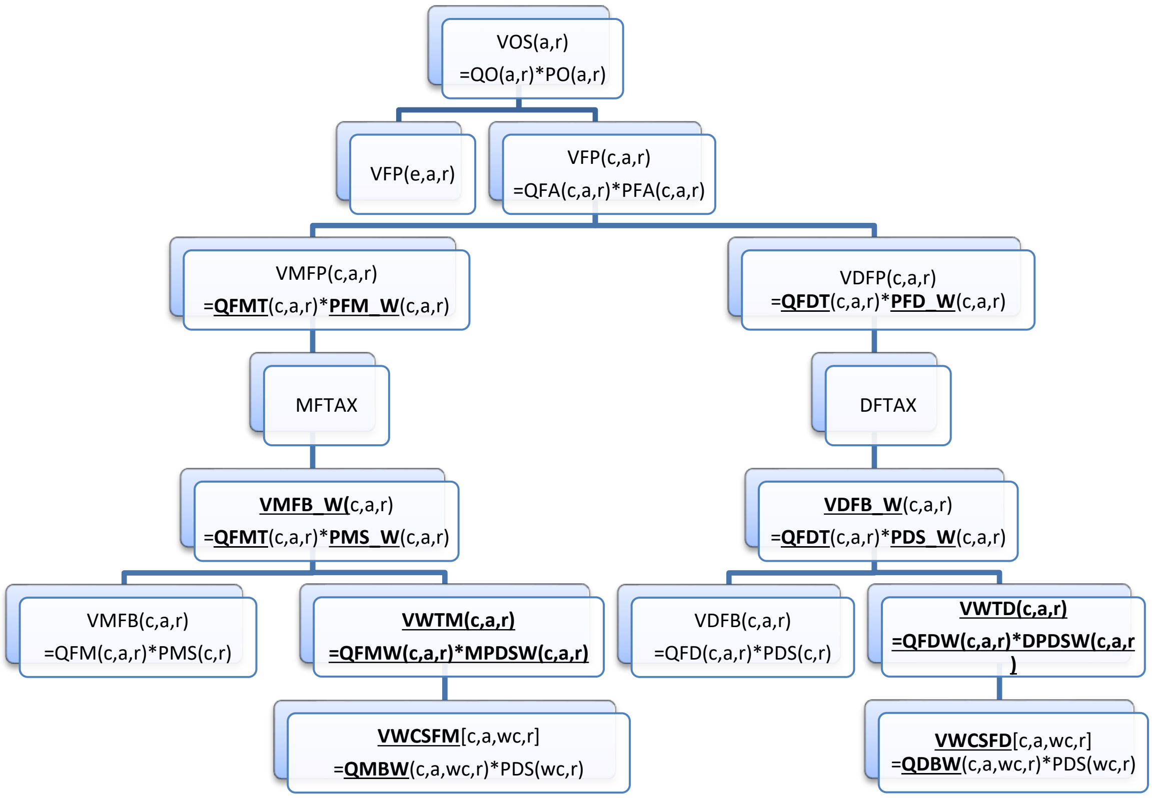
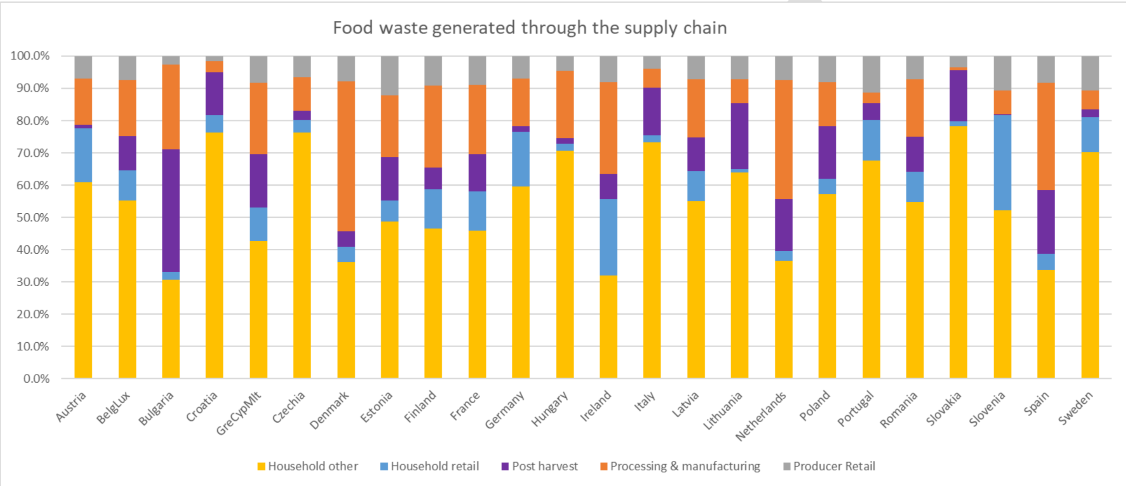


Figure 1 Intermediate demand including waste margin commodity

Value of aggregate waste collection $[VWTM$ and $VWTD]$ is added to value of expenditure on the *imported* and domestic intermediate demand $[VMFB$ and $VDFB$ respectively] to get the bundled expenditure on a commodity at basic prices $[VMFB\_W, VDFB\_W]$. Any intermediate demand tax/subsidy [$MFTAX, DFTAX$] is added to this bundled expenditure to get the intermediate demand on the imported and domestically procured commodity [$VMFP, VDFP$], to finally provide total expenditure on a commodity [VFP] in a region.

Data

Data from ESTAT (2022) was included in the new module. The figure below shows how much food waste is generated in the different stages in the model in the EU. For most European countries, households generate the largest amount of food waste. On average 65% of the food waste in the EU in generated by households. However there is quite some differences between EU member states, for example Bulgaria, Denmark, Netherlands and Spain have far more food waste at the producers level (about 60%).



Source: constructed from ESTAT (2022)

To implement the module as discussed in the previous paragraph we needed to translate the Eurostat data to values which could be included in the MAGNET database. In the GTAP database waste is included in the sector waste and water "wtr". We assume that intermediate demand for waste collection services is already present in the GTAP database but that this is included in the intermediate demand for "wtr". Therefore we can subtract the demand for waste collection services from the intermediate demand for "wtr" and add this to demand for waste collection services. This means that the overall production value of the various sectors is not changed. The quantity of food waste in kton is taken from the Eurostat database.

The Eurostat database provided data about food waste in different stages of the production trees. Three stages are distinguished food waste generation during primary food production "prim" (also called post-harvest losses); during processing and manufacturing stage "proc" and during retail and transport stage. The primary food waste collection has been included in the primary agricultural sectors; the retail food waste collection has been included in the food service sectors "trd", "afs, "whs" and transport sectors "otp","wtp" and "atp". The processed food waste collection has been included in any non- retail sector that uses over 1% of the total intermediate demand of the primary product in the country. This excludes the possibility of a primary sector using its own primary commodity as this is considered waste generation during the primary process. Finally the production of waste collection services and waste treatment are increased to collect and treat the extra producer food waste.

The next step is to assign the food waste to activities in the database. To determine which activities the waste can be assigned we calculate shares based on intermediate demand of food waste producing commodities.

For food waste produced during the primary stage we assume that this can be linked by intermediate demand of the waste producing commodity by the same activity, for example demand of the commodity pdr by the activity pdr. For food waste generated during the processing stage we calculate intermediate demand shares. To avoid small numbers we assume that a sector should at least use more than 1% of the waste producing commodity before food waste is assigned. Food waste generated during the retail stage is assigned based on intermediate demand shares. The finally the food waste can be assigned to activity by multiplying it with the just calculated shares:

This leads to the following distribution for EU in Figure 2.

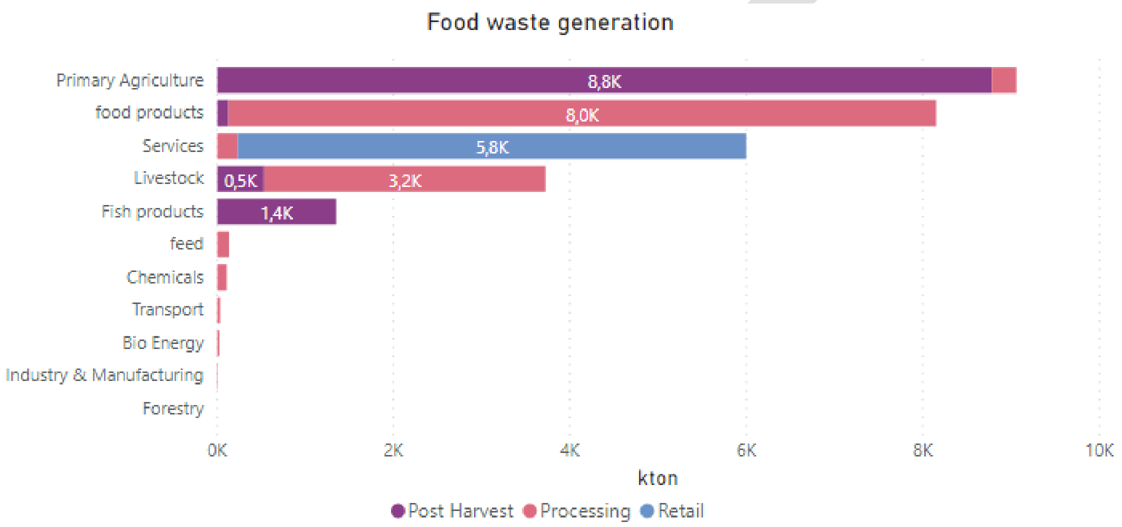


Figure 2 Waste generation by activity and stage (in kton, 2014)

Source: Constructed from Eurostat

By multiplying the quantity with food collection prices gathered in the household waste module, we can calculate the value of waste collection. The prices used for waste collection are shown in the table below

cost(dollar/tonne)	Collecti on rest	collection green	collection glass paper
High income Countries	100	100	50
Upper Middle income countries	75	75	38
Lower Middle income countries	53	53	26
Low income countries	35	35	18

Source: WorldBank

The value of waste generation by activity is calculated in a similar way by using the intermediate demand shares. However the value of waste generation needs to be taken from the intermediate demand of "wtr" in the activity in question. Therefore we check whether the value is not more than 80% of the initial demand of "wtr". If it is higher than 80% of the "wtr" demand the value of waste collection is scaled down.

We take this approach because there is a lot of uncertainty in the prices used of waste collection and therefore we assume that when the value of waste collection is higher than the available value of “wtr”, the initial prices are too high and need to scaled down.

The resulting average price of food waste collection is shown in Figure 3.

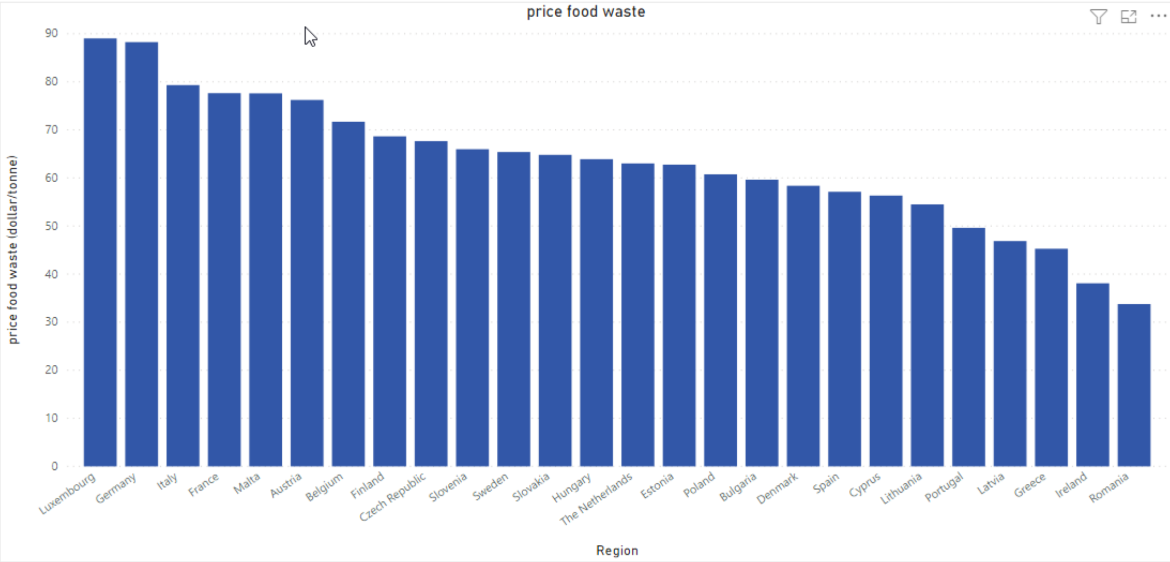


Figure 3 Average price food waste collection (dollar/tonne, 2014)

Source: Constructed from WB data

We assume that food waste is collected in a similar way as household food waste. So part of it will be collected as organic waste and part of it will be collected as rest waste. As the amount of food waste that is separated and collected as green waste, differs quite a lot between member states, we see the same trend in producer food waste as Figure 4 shows.

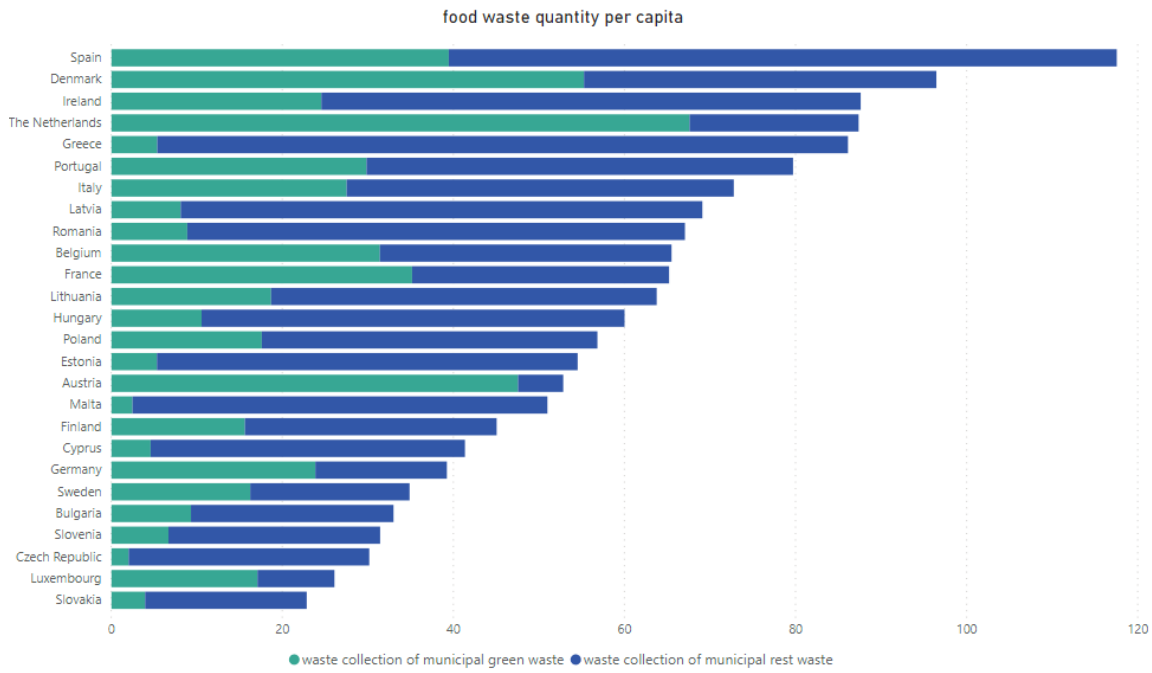


Figure 4 Collection of food waste by type (quantity per capita, 2014)

Source: Constructed from WB data

Data consumer food waste

The Eurostat database also provided data about the generation of consumer food waste. The data provided in this database did not match the data calculated based on the world bank database for every member state as figure 4 shows.

In the original household waste module, we calculated the food waste based on total organic waste collected as published by the world bank and a foodwaste share based on fusion database. This fusion database only reported food waste data for 11 regions in Europe. We calculated an average food waste share for the EU and applied this share to the missing EU member states. This procedure is less precise then the currently available data and there for we decided to adjust the food waste data for the EU member states.

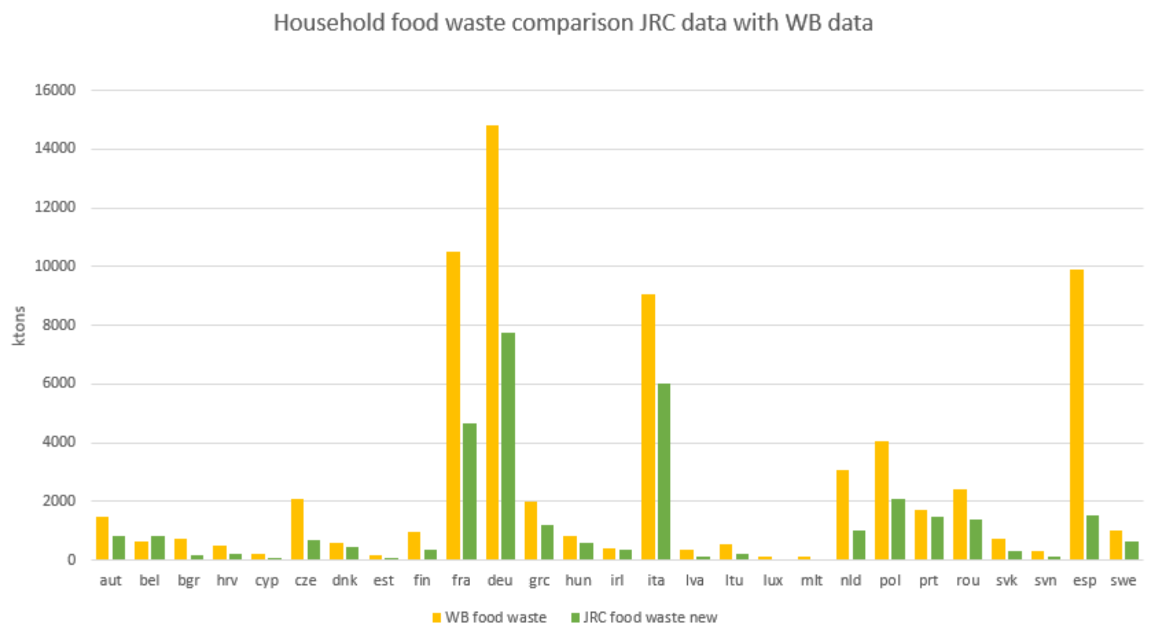


Figure 5 Total food waste generation households

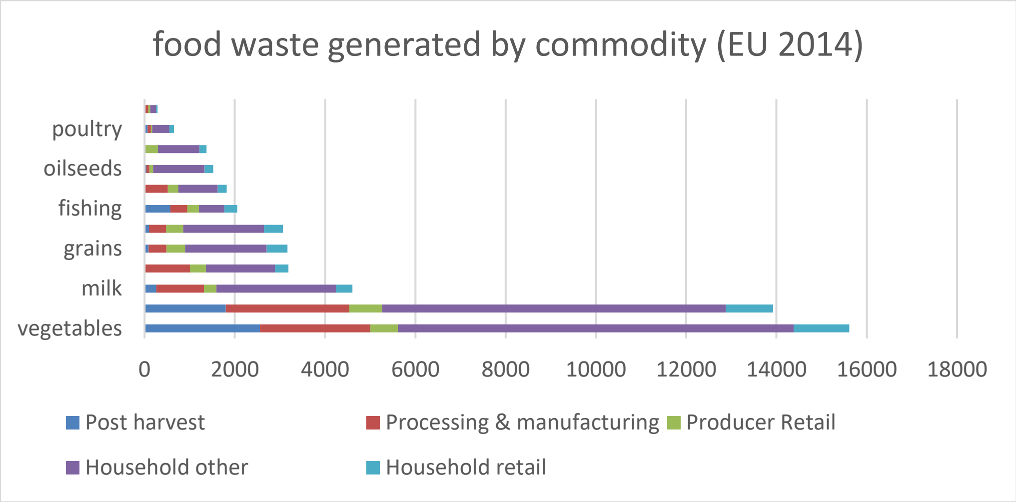
Source: Eurostat and World Bank

Figure 5 shows the food waste generated by households according to the Eurostat database and calculated based on world bank database. In most cases the food waste generated is lower in the Eurostat database. To account for the new food waste data we adjusted the food waste share. The total organic waste generated based on World Bank data is kept constant. So if the food waste increased in a country then the amount of garden waste decreased and vice versa. On average the EU food waste share decreased from 60% to 45%. This means that far more garden waste is generated and collected for the EU member states. However the changes per member states differ quite a lot (Figure 6).

Figure 6 food waste share households

Source: Eurostat and World Bank

The new module also makes it possible to track which primary commodities contribute to the food waste problem. The graph below shows how much food waste comes from which commodity in the EU. Most of the food waste comes from fruit and vegetables.



Source: constructed from ESTAT (2022)

Results

The model has been used to simulate how food waste generation and treatment will develop in the EU in the next 30 years. The baseline for the study follows the time path from 2014 to 2030. The baseline assumes a continuation of current policies, regulations, and market trends on the future situation of the wider bioeconomy. The European Commission's Global Energy and Climate Outlook reference is used for the baseline shocks (Keramidas et al., 2021).

-forthcoming-

Conclusions

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References

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