FOOD WASTE PREVENTION AS A TOOL FOR CLIMATE CHANGE MITIGATION: A CASE STUDY FROM GREECE

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Abstract

Since the publication of the findings that consumers in the UK throw away 31% of the food that they buy, food waste is becoming an increasingly significant global issue. Food waste is generated throughout the entire life cycle of food. Since significant resources are required for food production, manufacturing, transportation, storage, retailing and preparation, food waste is a waste of valuable resources with obvious economic and environmental implications. To make matters environmentally worse, food waste typically ends up in landfills and, due to its high biodegradability, contributes to the global greenhouse gases generation. Thus, food waste prevention, among its other positive contributions, can also act as a tool for the mitigation of man-made climate change.

The aim of this paper is the estimation of the GHG emissions associated with food waste generation in Greece. The scope of the research included both the emissions upstream of the waste management and those associated with the management of food waste.

The results indicate that emissions of 5,609.2 Gg of CO_2 eq. are associated with food waste in Greece. In order to reduce the burden on global warming resulting from food waste, emphasis should be placed on the prevention of food waste generated throughout the life cycle of food stuff.

Keywords: greenhouse gases, food waste, prevention

Introduction

There is evidence that the most environmentally damaging form of human consumption is eating [1]. On the same time, there is a rising demand for food, driven by an increase in world population and by the increasing affluence coupled with a desire to eat meat [2]. Moreover, the production of food faces serious pressures due to the increased urbanisation, land degradation, non-food uses of crops and cropland for the production of biofuels, and climate change [2]. So, the production of food is affected by climate change, due to the climate change impacts on key agriculture factors; but on the same time, food choices and proper food management can also have positive impacts on the mitigation of climate change [3]. More specifically, following the pioneering work by Carlsson-Kanyama [4] much of the debate has focused around the contribution that food and dietary choices make to global warming [5, 6], because the emissions of the major gases that contribute to the greenhouse effect, are closely related with food production and consumption [4]. Moreover, the impact of food related emissions is projected to increase over time because of world population growth and the increased consumption of animal products [3]. However, as the demand for food increases, so does the amount of food suitable for human consumption that it is wasted. The wastage of food is an inconvenient fact; roughly 40% of the food produced globally spoils before it even reaches the table.

Food waste generation

Food waste is an increasingly important stream due to the ethical, financial and environmental implications that it relates to. Food waste is *"composed of raw or cooked food materials and includes food loss, before, during or after meal preparation in the household, as well as food discarded in the process of manufacturing, distribution, retail and food service activities"* [7]. Thus, food waste is generated throughout the life cycle of food. From the environmental standpoint, since significant resources are required for food production, manufacturing, transportation, storage, retailing and preparation, food waste is a waste of valuable resources with obvious environmental implications. To make matters environmentally worse, food waste typically ends up in landfills and, due to its high biodegradability, contributes to the global greenhouse gases generation [8]. Therefore, it makes good sense to prevent the generation of food waste as a measure towards the mitigation of greenhouse gases generation.

The overall causes underlining the dynamic of waste generation seems to be sector- and country- specific. As Parfitt et al. explain "the limited data suggests that losses are much higher at the immediate post-harvest stages in developing countries and higher for perishable foods in industrialized and developed economies" [9]. Also, in six Swedish retail stores, it was calculated that approximately 70% of fresh fruit and vegetable waste was pre-store waste, discarded at supplier's expenses, by the stores [10]. Even though the generation of food waste from households is only a part of the whole picture, there are reports that households contribute greatly to the food waste problem [7, 11]. In affluent economies, such as those in industrialised countries, post-consumer food waste accounts for the greatest part of the losses and most of the avoidable food waste fraction is derived from private households [9, 12].

Moving on to the actual figures reported for food waste by various international organisations, the FAO of the United Nations reports that the per capita food waste generation by consumers in Europe and North-America is 95-115 kg/year [13]. The European Parliament reports an even higher value of 179 kg/person/year as the total amount of food waste generated in the EU27 [14]. However, specific data referring to countries, even developed, are very scarce to find. For example, recent waste composition analyses of household waste in two Austrian provinces showed that on average 6.6 % (9.0 kg/inh./y.) and 10.1 % (17.7 kg/inh./y.) of the residual waste was avoidable wasted food [15]. Also recently, the average amount of avoidable food waste reported for Finland was 63 kg/household or 23 kg/person [12].

Regarding Greece, the first preliminary data on food waste generation were extracted recently. More specifically, based on the average values resulting from the fifty-two households, the total food waste generation in Greece is estimated to be 98.9 kg/inh./y [16]. Note that this figure only refers to households, i.e. does not include data referring to the upstream (to the household) life cycle stages of food. Note also that this figure is within the range

that both the FAO and the EU report for food waste generation by the Europeans [7, 13, 14]. The results of the same study indicate that 30.1% of the overall food waste generated is avoidable, corresponding to 29.8 kg/inh./y. The avoidable food fraction can be further be split as cooked food that was not consumed and as food items that were not consumed before their expiration date. The avoidable food waste fraction consists mainly of cooked food (24.5%), vegetables (14.9%), fruits (24.9%), dairy products (11.3%) and bread (13.6%) [16].

The implications of food life cycle in global warming

Food, through its life cycle from production to its final consumption, impacts adversely on global warming, among other numerous other natural resources, such as land and water which are needed for plants cultivation (see Figure 1). Focusing on global warming, energy and its associated greenhouse gases (GHG) emissions are resulting from the production, transportation, processing, preservation and cooking of food [4]. Agriculture accounted for 10-12% of the total global anthropogenic emissions in 2005 [17]. Agriculture accounted for about 60% of N_2O and about 50% of CH_4 [17]. Different food items pose varying degrees of adverse burdens on global warming. For example, GHG emissions associated with meat products include N_2O from animal feed production, and methane emissions from enteric fermentation. Finally, manure management results in both CH_4 and N_2O emissions [18]. The calculation of the GHG emissions is mainly based on Life Cycle Assessment, a well established methodology for assessing the environmental impacts of produced goods and services throughout their life cycle [19].

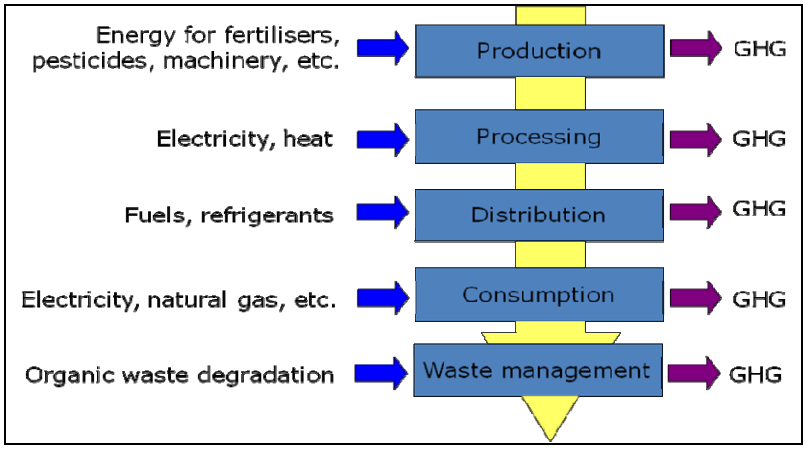

Figure 1. Life cycle GHG emissions from food.

After the production and processing of food and its delivery to our homes, refrigeration and cooking takes place. Both of these activities use energy, mainly in the form of electricity; therefore they put an extra burden on the GHG generation. The following generic energy use factors are reported: 3.5 MJ/kg for boiling, 7.5 MJ/kg for frying, 0.8 MJ/kg for microwaving and 9.0 MJ/kg for roasting [20].

Food waste management options, such as landfilling and composting, either centralized or at home, have GHG emissions associated with them. The GHG of interest are mainly methane and nitrous oxide because they have high global warming potential. The CO_2 emitted during food waste management originates from the degradation of plant material and is usually accounted as neutral with respect to global warming [21]. For instance, a value of 100-239 kg CO_2 eq. per ton (ww) for home composting of organic household waste is reported [22]. This figure is within the same order of magnitude as seen from large centralized composting plants [22]. Regarding GHG emissions from landfills, an average value of 55 kg CH_4/ton ww is reported in [23].

The aim of this paper is the estimation of the GHG emissions associated with food waste generation in Greece. The scope of the research includes both the emissions upstream of the waste management and those associated with the management of food waste.

Methodology

Food waste contributes two-fold in the generation of GHG. First of all, along with the food wasted, all the GHG emissions associated with the production, processing, distribution, refrigeration, and cooking of food are also wasted. Then, there are the emissions associated with the management of food waste. Figure 2 presents graphically the GHG calculation procedure of the present study.

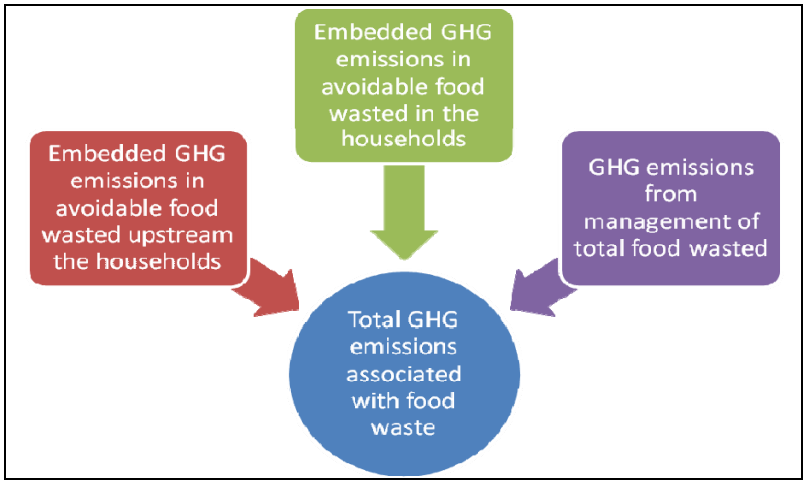

Figure 2. Representation of the GHG calculation procedure.

Data for the generation of food waste generation in Greece were taken from the FAO food balance sheet for 2009 [24]. A food balance sheet presents a comprehensive picture of the pattern of a country's food supply during a specified reference period. The food balance sheet shows for each food item i.e., each primary commodity availability for human consumption which corresponds to the sources of supply and its utilisation. The total quantity of foodstuffs produced in a country added to the total quantity imported and adjusted to any change in stocks that may have occurred since the beginning of the reference period gives the supply available during that period. On the utilisation side a distinction is made between the quantities exported, fed to livestock plus those used for seed, losses during storage and transportation, and food supplies available for human consumption. Thus, a food balance sheet is a good source of information for the food losses up to the household life cycle stage. These losses for Greece in 2009 are presented in metric tons in the second row of Table 1.

The CO_2-eq. emission factors (presented in the fourth row) for most of food items in Table 1 were extracted from the Barila database [25]. Emission factors for the remaining food stuff were extracted from Wallen [6]. Regarding the food wastage by the Greek households, the aforementioned data from [16] are used. Also, the population of Greece for 2009 was also extracted from the FAO balance sheet as 11,327,000 people. This number was utilized for the estimation of the per capita GHG emissions.

Results and discussion

Table 1 presents the food losses during storage and transportation expressed as the annual amount of wastage per capita for Greece in 2009. It also includes the CO_2-eq. emission factors per kg of food item, and finally the associated GHG emissions from the food losses up to the household level. An annual value of 77.80 kg of CO_2 eq. per capita of GHG emissions is estimated, associated with the food losses up to the household food life cycle stage. These emissions are avoidable emissions in the sense that the food product was produced, but later wasted.

Table 1. Per capita GHG emissions associated to food losses in Greece for 2009.

Food Items				
	Waste	**Waste**	**Emission factor**	**Annual emissions**
	1000 metric tons	**kg/cap/y**	**g CO_2 eq/kg**	**kg CO_2/cap/y**
Cereals - Excluding Beer	229	20.2	1,000	20.22
Wheat	55	4.9	1,000	4.86
Rice (Milled Equivalent)	4	0.4	2,750	0.97
Rye	1	0.1	1,000	0.09
Oats	4	0.4	1,000	0.35
Starchy Roots	80	7.1	500	3.53
Potatoes	80	7.1	164	1.16
Pulses	3	0.3	640	0.17
Beans	1	0.1	1,130	0.10
Pulses, Other	2	0.2	640	0.11
Oilcrops	30	2.6	3,530	9.35
Olives	22	1.9	3,530	6.86
Vegetables	445	39.3	250	9.82
Tomatoes	158	13.9	250	3.49
Onions	10	0.9	250	0.22
Vegetables, Other	277	24.5	250	6.11
Fruits - Excluding Wine	303	26.8	70	1.87
Oranges, Mandarines	142	12.5	70	0.88
Lemons, Limes	10	0.9	70	0.06
Bananas	4	0.4	70	0.02
Apples	28	2.5	70	0.17
Grapes	14	1.2	70	0.09
Fruits, Other	104	9.2	70	0.64
Alcoholic Beverages	4	0.4	4,813	1.70
Wine	4	0.4	2,240	0.79
Eggs	2	0.2	4,813	0.85
Milk - Excluding Butter	33	2.9	1,138	3.32
Total		**180.9**		**77.80**

In addition to the aforementioned food products that were wasted in the stages prior to the household, there are also the food avoidable food items that are wasted by the Greek households. The total amount of avoidable food wastage by the Greek households is 29.8 kg/cap./y. [16]. The breakdown of this food wasted is presented in the second row of Table 2 [16]. Then, the emissions factors per food item is given [6, 24] and the total annual amount of GHG emissions per capita is estimated. This amounts to 38.2 kg CO_2-eq./cap./y.

Finally, there are the GHG emissions of resulting from the management of food waste, regardless of being avoidable or non-avoidable. In Greece 98% of food waste ends up in the landfill while the remaining is composted. GHG emissions from landfilling are estimated based on the 55 kg CH_4/ton emission factor reported by [23] while for

composting an average value of 170 kg CO_2 eq./ton is utilized [22]. Methane emissions are converted to CO_2 eq. emissions by multiplication by a factor of 25 based on the IPCC guidelines [26].

Table 2. Avoidable food wastage and associated GHG emissions from the Greek households.

			Emission factor	Total emissions
	%	kg/cap/y	g CO_2/kg	kg CO_2/cap/y
Bread	13.6	4.05	983	4.0
Fruits	24.9	7.42	70	0.5
Vegetables	14.9	4.44	250	1.1
Dairy	11.3	3.37	1,138	3.8
Cooked with meat	6.1	1.82	5,360	9.7
Cooked food	18.4	5.48	2,500	13.7
Deserts	2.6	0.77	3,700	2.9
Other	8.2	2.44	1,000	2.4
Total avoidable		29.80		**38.2**

Table 3 presents the results of the calculation of GHG emissions associated with food waste in Greece. The actual numbers and the relative contributions are presented following the breakdown presented in Figure 2. The total GHG emissions of 5,609.2 Gg of CO_2 eq. per year are calculated, associated with food wasted in Greece. As expected, more than 75% of it is related to food waste management. However, this study reveals that approx. 25% of the calculated emissions, are associated with the embedded GHG emissions with the food products that are wasted each year in Greece.

Table 3. Summary of GHG emissions associated with food waste in Greece.

	CO_2 eq. Gg/y	**%**
Embedded GHG emissions in avoidable food wasted upstream the households	881.2	15.7
Embedded GHG emissions in avoidable food wasted in the households	432.8	7.7
GHG emissions from management of total food wasted	4,295.2	76.6
Total	**5,609.2**	**100.0**

GHG emissions resulting from the life cycle of food are attributed mainly to (i) the waste, and (ii) the agriculture categories of the IPCC classification. In Greece, for 2011, the agriculture contribution to the net GHG emissions was 7.79% while the respective of waste was 4.09% [27]. However, also a percentage of the energy related emissions should be attributed to food waste, due to the energy consumed for the refrigeration and cooking of food. Moreover, food is transported; thus, a share of the transport related GHG emissions should be also attributed to food. Both of the aforementioned contribution of food waste should be calculated and assessed as a future extrpolation of the present study.

Regarding the limitations of the study, note that the carbon footprints for the food wasted are calculated based on databases which include data that are not originating from Greece. More research is required towards this direction for the compilation of a database which reflects the local conditions in Greece.

Conclusions

Food is the most damaging form of consumption on the global level. However, the demand for food is rising due to the rising world population and the increasing level of affluence. On the same time, the food perfectly suitable for consumption by humans that is wasted is also increasing. Along with the food wasted, all the material and energy inputs along with their respective GHG emissions are also wasted.

Based on the assumption presented, an estimation of the GHG emissions associated with food waste in Greece has been conducted. The results indicate that emissions of 5,609.2 Gg of CO_2 eq. are associated with food waste in Greece. In order to reduce the burden on global warming resulting from food waste, emphasis should be placed on the prevention of food waste generated throughout the life cycle of food stuff.

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