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The Effect of Different Types of Diet on Greenhouse Gas Emissions in Greece

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ABSTRACT

Diet modifications are explored for the mitigation of greenhouse gases emissions worldwide. The current paper aims at estimating the carbon footprint of the diet of the Greek consumers in 2011. Based on food items consumption data, equivalent CO_2 emission factors, the total carbon footprint associated with the per capita Greek diet patterns is calculated. Data for this task are retrieved from readily available resources of existent literature. The per capita carbon footprint resulting from the consumption of food items in Greece in 2011 for the reference scenario is calculated to be 1,827.4 kg CO_2/y. In addition, alternative diet scenarios are proposed, their carbon footprint is calculated and suggestions are made for possible sustainable dietary changes. The results indicate that transition to a lacto-ovo-vegetarian diet constitutes a very drastic change towards mitigating greenhouse gases. However its acceptance by the public is very questionable. Thus, the second alternative scenario, which anticipates the substitution of beef by mainly pork and chicken, becomes more relevant. These results could serve as a yardstick for policy interventions aiming at reducing GHG emissions via diet modifications in Greece.

Keywords. diet, scenario, GHG, Greece

1 Introduction

Studies suggest that human dietary choices can significantly affect global warming (Carlsson-Kanyama, 1998; Geeraert, 2013; Meier and Christen, 2013; Saxe et al., 2013; Tukker et al., 2011; Wallén et al., 2004). It is estimated that 27% of the environmental impacts of European total consumption, are related to the consumption of food (Tukker et al., 2011). Twenty-five percent of all greenhouse gas emissions (GHG) in Germany are attributed to human nutrition (Meier and Christen, 2013). The impact of food related GHG emissions is projected to increase in the near future because of the increasing world population coupled with the global increasing consumption of foods of animal origin (Geeraert, 2013). The development of appropriate strategies for mitigating climate change, requires adequate and accurate measurements of the carbon emissions resulting from the production and consumption of food products (Amani and Schiefer, 2011a). Diet change has been suggested and tested as a tool for the mitigation of climate change (Amani and Schiefer, 2011b; Hallström et al., 2015).

The understanding of dietary change as a measure of more sustainable food systems requires improved knowledge of the dietary context in different scenarios. There have been several studies from different European countries addressing dietary changes and their respective impact in environmental terms (Bruun Werner, 2014; Fazeni and Steinmüller, 2011; Hoolohan et al., 2013; van Dooren et al., 2014; Vieux et al., 2012). The aim of the current study was to explore the effect of selected, different dietary patterns on the annual per capita GHG emissions in Greece. As review of literature in the scientific databases reveals, this research is the first one focusing on the GHG analysis of dietary patterns in Greece.

The paper starts with the review of literature focusing on scenario building for diet change as a measure of mitigating climate change in various European countries. Then the methodology for scenario building for the present research is described and key data sources are identified and explained. In the next section the results are presented and discussed. Finally, based on the presented results, conclusions are drawn and stated.

2 Literature review

food through its life cycle, from production to its final consumption, impacts adversely on numerous natural resources. Land is needed for its cultivation and water is required for its production and processing. In addition, the production, transportation, processing, preservation and cooking of food, requires energy and leads to the emissions of GHG (Carlsson-Kanyama, 1998). Meat production often requires more energy than the production of fruits and vegetables (Aston et al., 2014; Macdiarmid, 2013).

Therefore, there is a well recognized, urgent need for the adoption of sustainable human diets globally, both for the promotion and maintenance of human health (Komduur et al., 2009; Michaelowa and Dransfeld, 2008; Ruth, 2007; Sanders, 2004) and for the protection of the planet. The Food and Agriculture Organisation defines sustainable diets as "…those with low environmental impacts which contribute to food and nutrition security and to healthy life for the present and future generations" (Food and Agriculture Organisation of the United Nations, 2010).

In order to assess the environmental impacts of diets, different indices are employed. The review article by Amani and Schiefer (2011b), based on more than 50 LCA case studies of food products, and the review article by Hallström et al. (2015) which analysed 49 dietary scenarios collected from 14 peer-reviewed journal articles, revealed that climate change is the most frequently assessed impact category. Moreover, the quest for sustainable diets is reflected in the following recently published references: Sáez-Almendros et al. (2013) assessed the sustainability of the Mediterranean diet compared to the current Spanish diet and a typical Western dietary pattern, using four environmental indices. The current Spanish dietary pattern was estimated form the FAO food balance sheets for 2007. The Mediterranean diet showed the lowest footprints in all the environmental pressures, whereas the western diet showed the highest. Vieux et al. (2012) investigated the sustainability of different diet scenarios of a sample of adults in France, based on the assessment of GHG emissions. In order to address the variability of the GHG emissions for each food item, the authors assumed that the emissions follow a probability distribution. The authors calculated a mean per capita diet-related GHG contribution of 4,170 g CO_2 eq. per day, attributed mainly to meat and deli meat products (Vieux et al., 2012). Meier and Christen (2013) examine the environmental sustainability of four different diets based on six indicators, namely: global warming potential, ammonia emissions, land use, blue water use, phosphorus use and primary energy use. In addition, Tukker et al. (2011) examined the current and alternative suggested diets for Europe. The authors used data from the 2003 food balance sheets for the 27 countries of the European Union. Saxe et al. (2013) examined the GHG emissions for three different Nordic diets. The authors calculated a total ranging from 1,760-1,920 kg CO_2 eq. per person per year. They found that a change towards a diet containing less animal foods and more fruit and vegetables, supports climate change mitigation. Finally in another recent study, Friel et al. (2013) suggested an alternative, healthier and environmentally friendlier, diet in Australia without giving any actual GHG emission numbers.

3 Methods

The total annual carbon footprint per capita, per dietary pattern, was calculated as the sum of the per capita consumption of each food item included in the diet, multiplied by its respective GHG emission factor expressed in CO_2 equivalents. In the following paragraphs, the outline of each alternative scenario is presented, and the sources of the emission factors are discussed.

3.1 Dietary scenarios

Scenario building is a well established approach when tackling the impacts of diets on climate (Aston et al., 2012; Meier and Christen, 2013; Sáez-Almendros et al., 2013; Saxe et al., 2013). In dietary scenario analysis, the methodological approach (i.e., study design and approach of scenario development, choice of functional unit, system boundaries, impact categories, and method for uncertainty analysis of used data and results) can have a decisive effect on the quality and results of the analysis (Heller et al., 2013). In the current study, the latest available data of the Greek per capita food consumption, in kg of food item/capita/y, for year 2011 were derived from the FAO food balance sheets (Food and Agriculture Organisation of the United Nations, 2014). This set of data compiles the reference scenario of the present study, presented in the table in the appendix. The use of the FAO food balance sheets as a source for national dietetic data is well established in the literature (Aston et al., 2014; Sáez-Almendros et al., 2013; Tukker et al., 2011).

Two alternative dietary scenarios, were created, based on the recommendations by Nilsson and Sonesson (2010), by substituting certain food items of the reference scenario. The substitute food items had a lower carbon footprint; however, they were nutritionally equivalent (in terms of calories and proteins) to the food items in the reference scenario. Therefore, for each scenario, the g of CO_2 eq. per kcal of dietetic energy and the g of CO_2 eq. per g of dietetic protein intake was also calculated. The use of alternative functional units, i.e., other than mass, for the environmental assessment of dietary scenarios is recommended in order to avoid biased conclusions (Heller et al., 2013).

The first alternative scenario is the transition from the conventional diet to a lacto-ovo-vegetarian. Thus, the mitigation of GHG emissions in the first alternative scenario is achieved via the total exclusion of meat products from the diet. The compilation of the diet of the 1st scenario was very challenging, because it corresponds to a very drastic diet change. A lot of issues had to be resolved in terms of protein and calories intake in order to achieve the required nutritional equivalency of the two scenarios. Thus, compared to the reference dietary scenario, the consumption of dairy products and eggs was increased, as well as the consumption of fruits and vegetables following the recommendations by Plaisted and Adams (2002) and Winston and Mangels (2009) for increased intake of natural fibers, vitamins, antioxidants, etc. Also, rice, potatoes, wheat and pulses were added. The dietary variations between the reference scenario and scenario 1 are outlined in Table 1.

Table 1.
Main diet components of the lacto-ovo-vegetarian diet (alternative scenario 1)

Food item	Change from reference scenario
Wheat	+10%
Rice	+40%
Potatoes	+10%
Pulses other	+80%
Oranges	+30%
Bananas	+10%
Apples	+30%
Grapes	+30%
Eggs	+40%
Milk	+50%
Meat	-100%
Seafood	-100%

The 2nd alternative scenario focused exclusively on the substitution of meat products. More specifically, the 2nd scenario aimed at decreasing the release of GHG by the substitution of beef by pork and chicken. The dietary variations between the reference scenario and scenario 2 are outlined in Table 2.

Table 2.
Main diet components of the beef substitution by pork and chicken (alternative scenario 2)

Food item	Change from reference scenario
Bovine Meat	-100%
Pigmeat	+60%
Poultry Meat	+60%

3.2 GHG emissions of food items

In the international literature, calculation of the GHG emissions of food products is mostly based on Life Cycle Assessment, a well established methodology for assessing the environmental impacts of produced goods and services throughout their life cycle (Kendall et al., 2013; Kramer et al., 1999).

It is very hard to find country-specific, homogeneous data on CO_2 eq. factors for food products because there are so many products, production practices, and variable plant cultivation or animal husbandry system boundaries during the life cycle of each food item within different geographical and time limits (Nijdam et al., 2012). Recently, Saéz-Almendros et al. (2013) provided a list of literature sources regarding GHG emission factors associated with food, but they didn't provide the actual figures. Vieux et al. (2012) provide a comprehensive list of food related GHG emission factors using a statistical approach, with lower and upper limit for the factor of each food item. Saxe et al. (2013) and Aston et al. (2012) provide a list with actual CO_2 eq. data compiled from various sources, mostly Scandinavian and British.

Focusing on Greece, review of the relevant literature demonstrates that there is a lack of comprehensive information regarding CO_2 eq. emission factors associated with the Greek food products. There are only very few relevant sources which implicitly present the GHG emissions associated with some agricultural Greek products (Abeliotis et al., 2013; International EPD System, 2015a; International EPD System, 2015b; Kaltsas et al., 2007; Litskas et al., 2011; Michos et al., 2012; Nanos et al., 2014). All of the aforementioned data of Greek origin refer to the cultivation-farm gate system boundary in LCA terms (Hallström et al., 2015).

Therefore, regarding the present study, the CO_2 eq. emission factors for most of the food items were extracted from the Barilla (2010) database, which makes readily available a lot of food data, free of charge. Most of the GHG data in this database originate from the Ecoinvent database, the Danish food LCA database and the Environmental Product Declaration system (International EPD System, 2015a; International EPD System, 2015b). Emission factors for the remaining food items were extracted from Wallén et al. (2004) and Nijdam et al. (2012).

The carbon footprint data originating from certain environmental product declarations of Greek origin are also used in this study (International EPD System, 2015a; International EPD System, 2015b). The estimation of the carbon footprint of each food item does not include transportation, retail, refrigeration at home, cooking, or the resources necessary for waste disposal.

4 Results

The results of the reference scenario, expressed in kg of CO_2 equivalents, resulting from the sum of the quantities of each food item consumed in Greece in the year 2011 multiplied by the respective emission factors for each food item, are presented in the appendix. The source reference of the carbon footprint for each food product is also presented in the appendix.

More specifically, the per capita carbon footprint resulting from the consumption of food items in Greece in the year 2011, is calculated at approximately 1,827.4 kg CO_2 eq./y. (appendix). The breakdown of the carbon footprint per food group category is presented in Figure 1. The contribution of meat is dominant (40.15%), followed by dairy products and eggs (24.96%) and cereals (8.31%). In terms of the diet-related carbon intensity (Vieux et al., 2012) this footprint is "translated" to 1.5 g CO_2 eq./Kcal (Figure 2) and 45 g CO_2 eq. per g of protein intake (Figure 3).

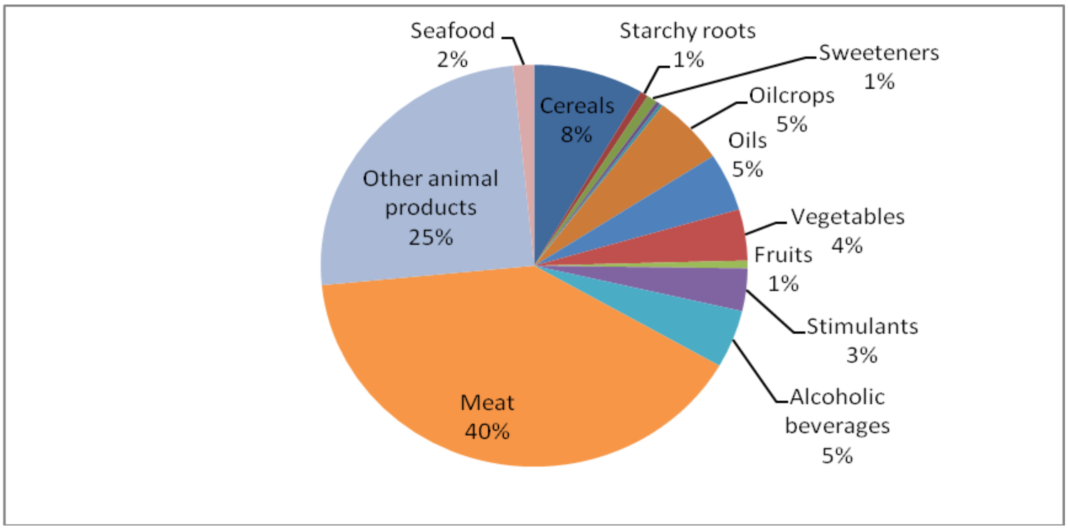

Figure 1. Breakdown (%) of contribution per food group for the reference scenario.

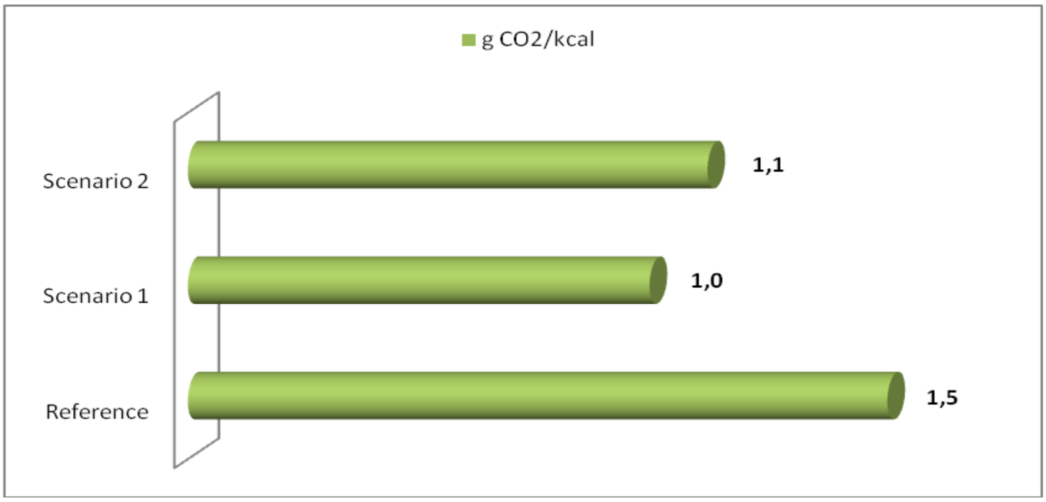

Figure 2. Representation of the carbon footprint per kcal of dietetic energy intake for the three alternative scenarios.

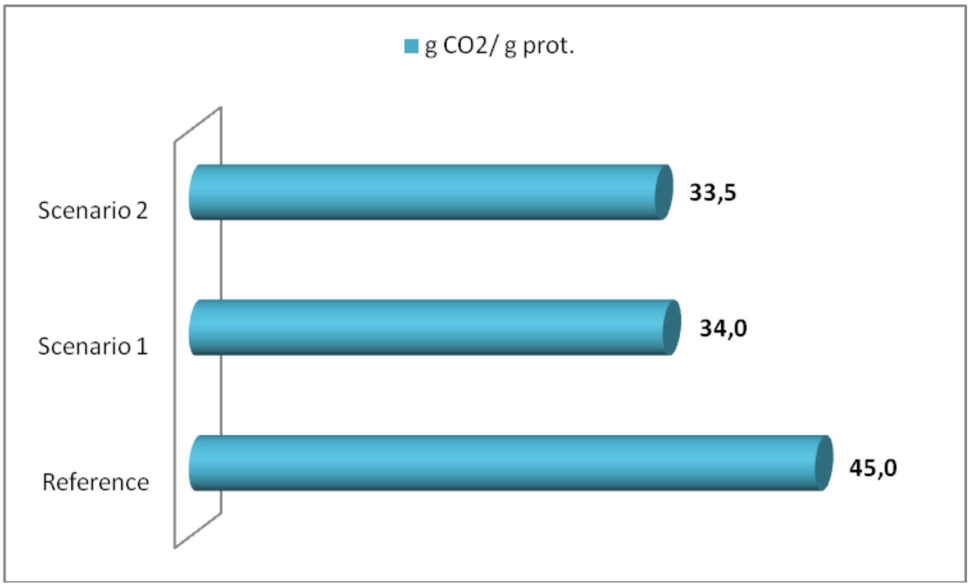

Figure 3. Representation of the carbon footprint per g of dietetic protein intake for the three alternative scenarios

For each one of the alternative scenarios, presented in Table 1 and Table 2 respectively, only the variations of the per capita consumption of food items which are substituted are shown. The consumption for all other food items remained unaltered, as presented in the reference scenario (appendix). It has been shown in the past that it is relatively easy to create a climate friendly diet if its energy and protein content is low (Saxe et al., 2013). It is very important to note that in the current study, the energy and protein content of the food items which were substituted in the alternative scenarios were very similar to the food products which replaced them.

The results that refer to the lacto-ovo-vegetarian version of the diet (scenario 1), indicate that the annual per capita footprint is estimated to be 1,212.7 CO_2 eq./y (see Table 4) corresponding to a diet-related carbon intensity of 1.0 g CO_2 eq./Kcal (Figure 2) and 34 g CO_2 eq. per g of protein intake (Figure 3).

The dramatic shift from the reference scenario diet to the lacto-ovo-vegetarian, results to a reduction of the annual per capita CO_2 emissions by 33.6% (see Table 3). This was anticipated, as it is well documented that usually meat consumption constitutes a bigger environmental burden compared to foods of plant origin. However, this shift might not be realistic, mainly because animal husbandry, besides meat, also provides society with milk, and eggs. Moreover, the protein quality is not taken into account, i.e., protein digestibility which is higher in protein sources of animal origin compared to their vegetarian counterparts.

The substitution of meat protein with the plant-based equivalent protein, reduces the environmental burden. In this study, the GHG emissions of the lacto-ovo-vegetarian diet were 33.6% lower compared to the reference scenario (see Table 3).

Table 3.
Overall carbon footprint per food product category for each scenario.

	Reference (g CO_2 eq./cap./y.)	**%**	**Scenario 1 (g CO_2 eq./cap./y.)**	**%**	**Scenario 2 (g CO_2 eq./cap./y.)**	**%**
Cereals	158.9	8.31	166.6	13.74	147.1	10.65
Starchy roots	11.8	0.61	11.9	0.98	10.8	0.78
Sweeteners	15.3	0.80	12.7	1.05	12.7	0.92
Pulses	5.9	0.31	9.0	0.74	7.5	0.54
Treenuts	4.7	0.24	4.6	0.38	4.6	0.33
Oilcrops	105.5	5.52	37.3	3.08	37.3	2.70
Oils	89.2	4.67	90.9	7.50	90.9	6.59
Vegetables	78.7	4.12	81.7	6.74	81.7	5.92
Fruits	12.0	0.63	11.3	0.93	9.5	0.69
Stimulants	65.6	3.43	71.1	5.86	71.1	5.15
Alcoholic beverages	89.1	4.66	63.9	5.27	63.9	4.63
Meat	767.5	40.15	0.0	0.00	362.7	26.27
Other animal products	477.2	24.96	651.8	53.74	451.1	32.67
Seafood	30.3	1.59	0.0	0.00	29.8	2.16
Total	**1,911.7**	**100.0**	**1,212.7**	**100.0**	**1,380.8**	**100.0**

Regarding the relative contribution of the various food groups in the total carbon footprint of scenario 1 (see Figure 4), dairy products and eggs contribute now approx. 54% followed by cereals (~14%) and oils (~7%).

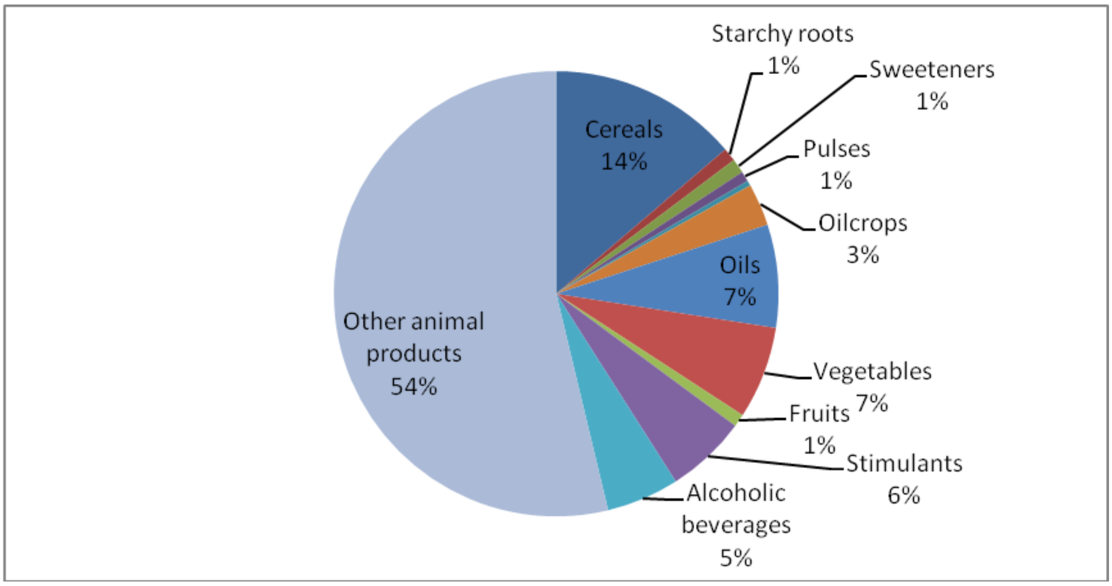

Figure 4. Breakdown (%) of contribution per food group for scenario 1.

Moving on to scenario 2 (see Table 2), by substituting beef with pork and chicken, the annual per capita footprint was estimated at 1,380.8 kg CO_2 eq./y, corresponding to a diet carbon intensity of 1.1 g CO_2 eq./Kcal and 33.5 g CO_2 eq. per g of protein intake. Thus, this diet yields to a reduction of the respective GHG emissions by 24.4%, compared to the conventional diet. Regarding the contribution of the various food groups (see Figure 5) in the total carbon footprint, products of animal origin are ranked first (~33%), meat is ranked second (~26%) while cereals (~11%) are ranked third.

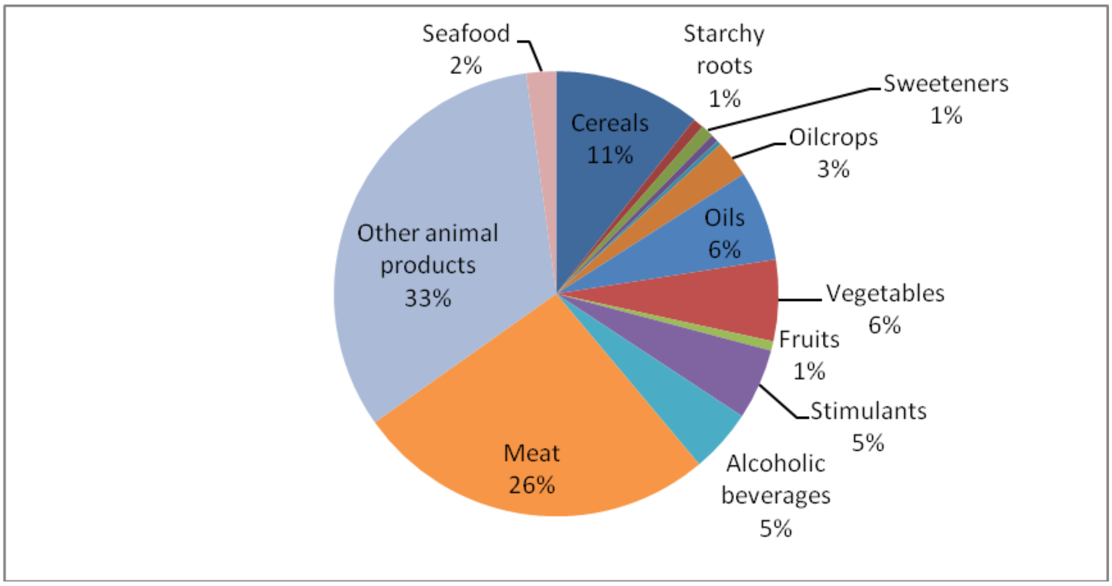

Figure 5. Breakdown (%) of contribution per food group for scenario 2.

5 Discussion

The GHG burden of the reference scenario, corresponding to the diet of Greeks in 2011, was estimated at approx. 1.83 t CO_2 eq. per capita per year. This result is comparable to other similar studies in western European countries: for instance, an annual value of 2.05 t CO_2 eq. per capita reported for Germany (Meier and Christen, 2013). Similarly, Vieux et al. (2012) estimated the mean individual diet-associated GHGE in France at 4,170 g CO_2 eq./day corresponding to annual emissions of 1.52 t CO_2 eq. per capita. In another study, Saxe et al. (2013) calculated a value of 1.92 t CO_2 eq. per capita in Denmark for 2006, while

Aston et al. (2014) estimated the total daily GHG emissions attributable to dietary intakes for 2000 in the UK at 3.96 kg CO_2 eq. per capita. In all of the aforementioned cases, the main contributor to diet-associated GHG emissions, was the consumption of meat and meat products, typical characteristic of diets in developed countries (Macdiarmid, 2013), which is in accordance with the results of the present study.

The results that refer to the lacto-ovo-vegetarian diet of the present study (i.e., scenario 1), indicate a reduction of 33.6% of the GHG emissions. This percentage is in good agreement with the results reported for Germany in 2006, i.e. a reduction of 23.9% between the reference diet and the lacto-ovo-vegetarian diet (Macdiarmid, 2013) and the % reduction in GHG emissions for vegetarian diets reported in the review article by Hallström et al. (2015). Overall, this scenario is in agreement with the finding that the environmental impacts of a non-vegetarian diet are expected to be 1.5-2 times higher compared to a vegetarian one (Reijnders and Soret, 2003).

In addition, scenario 1 does not negate completely animal husbandry: dairy products and eggs require the existence of productive animals. However, with a lacto-ovo-vegetarian diet a quality shift is achieved towards a more climate friendly pattern: both the CO_2 eq. per g of protein and per kcal are reduced drastically. It is important to note however, that according to Pimentel and Pimentel (2003) both diets, the conventional and the lacto-ovo-vegetarian, are probably not sustainable in the long run. It is evident, however, that the latter diet is environmentally preferable over the conventional. Moreover, Nilsson and Sonesson (2010) also mentioned that the transition to a lacto-ovo-vegetarian diet can have the reverse effects: productive animals also produce dung that can be used as organic fertilizer. Thus, the reduction in the numbers of productive animals can yield to the increased use of synthetic fertilisers.

Overall, scenario 1 presents a very drastic change in the current dietary habits of the Greek population and as a result, it might not be realistic or acceptable as a proposed population dietary change. Recent studies have shown that Greeks are great “meateaters” and that adherence to the traditional Mediterranean diet is declining (Dilis et al., 2012). In addition, such a drastic and rapid dietary change, might affect the intake of iron and other key minerals, if it is not followed by proper and thorough meal planning (Broadley, 2010). It is suggested that the crucial step in any drastic diet change, is to get people to like and prefer the proposed new diets, and it is well documented that such changes take time to occur (Saxe et al., 2013). In addition, any changes need to be realistic in terms of acceptability and cost, if they are to have any prospect of being accepted by the general public (Macdiarmid, 2013).

Regarding scenario 2, it is evident that the substitution of beef by pork and chicken reduces the carbon footprint of the diet; moreover, this 2nd alternative scenario seems to be a very realistic approach in trying to mitigate the GHG emissions resulting from the Greek diet. However, the scenario still depends on meat. According to Nilsson and Sonesson (2010), this scenario is an easy way for those who wish to be fed on meat but also want to reduce their carbon footprint. Moreover, chicken offers a very good alternative compared to beef and pork. Nilsson and Sonesson (2010) reported a reduction of 58% resulting from the respective substitution is Sweden. The difference between the percentages in Greece (approx. 24%) and Sweden can be attributed to the differences among the diets, and the different carbon footprints of the corresponding food items in the two researches.

By the substitution of meat proposed in the 2nd scenario, the percentage of the contribution of the meat food category to the overall diet footprint is reduced to approx. 26% compared to more than 40% of the reference scenario (see appendix). In terms of externalities, the adoption of this scenario will reduce the imports of beef in Greece but probably it will increase the imports of pork and chicken.

Finally, the main limitations of the study are that the carbon footprints for the alternative scenarios were calculated based on databases which include data that are not originating from Greece. More work is required towards this direction for the compilation of a database which reflects the local conditions in Greece. Also, since dietary habits change over time a new estimation which reflects the current situation in Greece should be compiled. Moreover, since the impact of food includes almost all aspects of natural resources, a more spherical approach is required which includes more environmental impacts than just climate change, in order to assess the real impact of food consumption in Greece.

6 Conclusions

The carbon footprint associated with the food items consumed by the Greek population for the year 2011 has been estimated. The carbon footprint of alternative dietary scenarios has also been calculated, which was shown to be lower compared to the reference scenario. The transition to a lacto-ovo-vegetarian diet constitutes a very drastic change towards mitigating greenhouse gases followed by the substitution of beef by mainly pork and chicken, as an alternative dietary scenario. One limitation of the present study is that the system boundary, in most of the case studies that the data are derived from, is limited to the farm gate; i.e., the emissions from distribution and consumption are excluded. Nonetheless, when considering for example a vegetarian diet, the transportation accounts for a higher part of the environmental impact than a diet including meat; accordingly, for more precise results in comparing these diets, a widening of the system boundary needs to be taken into account.

The starting point of the present study was the assumption that a growing number of consumers would like to make environmentally friendly food choices and that the governments of countries in different parts of the world are interested in placing policy measures that increase consumers' opportunities and motives for eating in a sustainable manner. Since no such initiative has been proposed for Greece, as yet, the results of the present study could serve as a yardstick for policy interventions aiming at reducing GHG emissions via diet modifications in Greece.

References

Abeliotis, K, Detsis, V, and Pappia, C. (2013). Life cycle assessment of bean production in the Prespa National Park, Greece. *Journal of Cleaner Production,* **41**: 89-96.

Amani, P., Schiefer, G. (2011a). Review on suitability of available LCIA methodologies for assessing environmental impact of the food sector. *International Journal on Food System Dynamics*, **2**: 194-206.

Amani, P., Schiefer, G. (2011b). Data availability for carbon calculators in measuring GHG emissions produced by the food sector. International Journal on Food System Dynamics, **2**: 392-407.

Aston, L.M., Smith, J.N., and Powles, J.W. (2012). Impact of a reduced red and processed meat dietary pattern on disease risks and greenhouse gas emissions in the UK: a modelling study. Retrieved October 20, 2015 from BMJ Open 2012:2:e001072. doi.10.1136/bmjopen-2012-001072.

Barilla. *Double Pyramid: Healthy Food for People, Sustainable Food for the Planet*, Barilla Center for Food and Nutrition. Parma; 2010.

Broadley, M.R., White, P.J. (2010). Eats root and leaves. Can edible horticultural crops address dietary calcium, magnesium and potassium deficiencies? *Proc Nutr Soc.,* **69**:601-612.

Bruun Werner, L., Flysjö, A., and Tholstrup, T. (2014). Greenhouse gas emissions of realistic dietary choices in Denmark: The carbon footprint and nutritional value of dairy products. *Food & Nutrition Research*, **58**: 1-16.

Carlsson-Kanyama. (1998). A. Climate change and dietary choices – how can emission of greenhouse gases from food consumption be reduced? *Food Policy* **23**:277-293.

Dilis, V., Katsoulis, M., Lagiou, P., Trichopoulos, D., Naska, A., and Trichopoulou, A. (2012). Mediterranean diet and CHD: the Greek European Prospective Investigation into Cancer and Nutrition cohort. *British J Nutr.* **108**:699–709.

Fazeni, K., Steinmüller, H. (2011). Impact of changes in diet on the availability of land, energy demand, and greenhouse gas emissions of agriculture. *Energy and Sustainable Society*, **1**: 1–14.

Food and Agriculture Organisation of the United Nations. Food balance sheet Greece 2011. Retrieved October 20, 2015 from http://faostat.fao.org/site/368/DesktopDefault.aspx?PageID=368#ancor..

Food and Agriculture Organisation of the United Nations (2010). *International Scientific Symposium. Biodiversity and Sustainable Diets-United Against Hunger.* Rome: FAO Headquarters.

Friel, S., Barosh, L.J., and Lawrence, M. (2013). Towards healthy and sustainable food consumption: an Australian case study. *Public Health Nutrition*: 1-11.

Geeraert, F. (2013). Sustainability and dietary change: the implications of Swedish food consumption patterns 1960-2006. *International Journal of Consumer Studies,* **37**: 121-129.

Heineken Sustainability Report 2012. Calculating our carbon footprint. Retrieved October 20, 2015 from http://www.sustainabilityreport.heineken.com/improve/green-commerce/calculating-our-carbon-footprint.html..

Hallstrom, E., Carlsson-Kanyama, A., and Borjesson, P. (2015). Environmental impact of dietary change: a systematic review. Journal of Cleaner Production, 91, 1-11.

Heller, M. C., Keoleian, G. A., and Willett, W. C. (2013). Toward a life cycle-based, diet-level framework for food environmental impact and nutritional quality assessment: A critical review. *Environmental Science and Technology,* **47**(22): 12632-47.

Hoolohan C., Berners-Lee M., McKinstry-West J., and Hewitt C.N. (2013). Mitigating the greenhouse gas emissions embodied in food through realistic consumer choices. *Energy Policy*, **63**: 1065–1074.

International EPD System. Environmental Product Declarations No 274 “Extra Virgin Olive Oil by 69 olive growers in Southern Greece”. Retrieved October 20, 2015 from http://www.environdec.com/en/Detail/?Epd=8054#.VDFXvWd_vxo.

International EPD System. Environmental Product Declarations No 310 “Kiwi fruit”. Retrieved October 20, 2015 from http://www.environdec.com/en/Detail/kiwi_fruit#.VDFXgWd_vxo.

Kaltsas, A., Mamolos, A., Tsatsarelis, C., Nanos, G., and Kalburtji, K. (2007). Energy budget in organic and conventional olive groves. *Agriculture, Ecosystems & Environment*, **122**: 243-251.

Kendall, A., Yuan, J., and Brodt, S.B. (2013). Carbon footprint and air emissions inventories for US honey production: case studies. *International Journal of Life Cycle Assessment*, **18**: 392–400.

Komduur, R.H, Korthals, M., and te Molder, H. (2009). The good life: living for health and a life without risks? On a prominent script of nutrigenomics. *British Journal of Nutrition*, **101**: 307-316.

Kramer, K.J., Moll, H.C., Nonhebel, S., Wilting, H.C. (1999). Greenhouse gas emissions related to Dutch food consumption. *Energy Policy*, **27**:203-216.

Litskas, V, Mamolos, A, Kalburtji, K, Tsatsarelis, C, and Kiose-Kampasakali, E. (2011). Energy flow and greenhouse gas emissions in organic and conventional sweet cherry orchards located in or close to Natura 2000 sites. *Biomass and Bioenergy,* **35**: 1302-1310.

Macdiarmid, J.I. (2013). Is a healthy diet an environmentally sustainable diet? *Proc Nutr Soc.* **72**:13-20.

Meier, T., Christen, O. (2013). Environmental Impacts of Dietary Recommendations and Dietary Styles: Germany as an Example. *Environmental Science & Technology*, **47**: 877-888.

Michaelowa, A, Dransfeld, B. (2008). Greenhouse gas benefits of fighting obesity. *Ecological Economics*, **66**: 298-308.

Michos, M., Mamolos, A., Menexes, G., Tsatsarelis, C., Tsirakoglou, V., and Kalburtji, K. (2012). Energy inputs, outputs and greenhouse gas emissions in organic, integrated and conventional peach orchards. *Ecological Indicators*.**13**:22-28.

Nanos, G.D., Dianellos, G., Tsintsirakou, I., Kandri, E., Zafeiridis, I., Sarantidou, M., and Makri, M. (2014). CO_2 emission from apple tree cultivation in Mount Pelion. *Georgia-Ktinotrofia*, **6**:164-168 (in Greek).

Nijdam, D., Rood, T, and Westhoek, H. (2012). The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. *Food Policy*, **37**: 760-770.

Nilsson, K., Sonesson, U. (2010). Changing diets – what is the influence on greenhouse gas (GHG) emissions of different consumption patterns?. In: Notarnicola B., Settanni E., Tassielli G. and Giungato P. (edited by), *LCA food VII international conference on life cycle assessment in the agri-food sector*. Universita Degli Studi Di Bari. 357-362.

Pimentel, D., Pimentel, M. (2003). Sustainability of meat-based and plant-based diets and the environment. *American Journal of Clinical Nutrition*, **78:** 660S-663S.

Plaisted, C.S., Adams, K.M. (2002). Vegetarian Diets in Health Promotion and Disease Prevention. In: Berdanier, B.D. (edited by), *Handbook of Nutrition and Food*, CRC Press.

Reijnders, L, Soret, S. (2003). Quantification of the environmental impact of different dietary protein choices. *American Journal of Clinical Nutrition*, **78**: 664S-668S.

Ruth, L. (2007). Nutrigenomics: impacts on markets, diets, and health. Part 1: biotechnology and diagnostics. *Genes Nutr.,* **2**:21.

Sáez-Almendros, S., Obrador, B., Bach-Faig, A., and Serra-Majem, L. (2013). Environmental footprints of Mediterranean versus Western dietary patterns: beyond the health benefits of the Mediterranean diet. *Environmental Health,* **12**: 118-124.

Sanders, T.A. (2004). Diet and general health: dietary counselling. *Caries Res.,* **38** Suppl 1: 3-8.

Saxe, H., Meinert Larsen, T., and Mogensen, L. (2013). The global warming potential of two healthy Nordic diets compared with the average Danish diet. *Climatic Change*., **116**: 249-262.

Tukker, A., Goldbohm, R.A., De Koning, A., Verheijden, M, Kleijn, R., Wolf, O., Pérez-Domínguez, I., and Rueda-Cantuche, J.M. (2011). Environmental impacts of changes to healthier diets in Europe. *Ecological Economics*, **70**: 1776-1788.

van Dooren, C., Marinussen, M., Blonk, H., Aiking, H., and Vellinga P. (2014). Exploring dietary guidelines based on ecological and nutritional values: a comparison of six dietary patterns. *Food Policy*, **44**: 36–46.

Vieux, F., Darmon, N., Touazi, D., and Soler, L.G. (2012). Greenhouse gas emissions of self-selected individual diets in France: changing the diet structure or consuming less? *Ecological Economics*, **75**: 91-101.

Wallén, A., Brandt, N., and Wennersten, R. (2004). Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science and Policy*, **7**: 525-535.

Winston, J.C., Mangels. A.R. (2009). Position of the American dietetic association: vegetarian diets. *Journal of the American Dietetic Association*, **109**:1266-1282.

Appendix: Components of the Greek diet in 2011 (reference scenario).

	food kg/y	kg CO_2 eq./kg food	Reference	kg CO_2/y
Cereals - Excluding Beer				
Wheat	124.8	1.00	Wallen et al. (2004)	124.8
Rice (Milled Equivalent)	7.3	2.40	Barilla (2010)	17.5
Barley	0.4	1.00	Wallen et al. (2004)	0.4
Maize	1.6	1.00	Wallen et al. (2004)	1.6
Rye	0.3	1.00	Wallen et al. (2004)	0.3
Oats	0.2	1.00	Wallen et al. (2004)	0.2
Cereals, Other	2.3	1.00	Wallen et al. (2004)	2.3
Total cereals				**147.1**
Starchy Roots				
Potatoes	65.4	0.16	Barilla (2010)	10.7
Sweet Potatoes	0.4	0.16	Barilla (2010)	0.1
Total starchy roots				**10.8**
Sugar & Sweeteners				
Sugar (Raw Equivalent)	24.6	0.47	Barilla (2010)	11.6
Sweeteners, Other	1.3	0.47	Barilla (2010)	0.6
Honey	1.4	0.40	Kendall et al. (2013)	0.6
Total sweeteners				**12.7**
Pulses				
Beans	2.8	2.00	Nijdam et al. (2012)	5.6
Pulses, Other	1.9	1.00	Nijdam et al. (2012)	1.9
Total pulses				**7.5**
Treenuts	10.9	0.42	Wallen et al. (2004)	4.6
Total treenuts				**4.6**
Oilcrops				
Groundnuts (Shelled Eq)	0.3	0.10	Kramer et al. (1999)	0.0
Coconuts - Incl Copra	0.3	0.10	Kramer et al. (1999)	0.0
Sesameseed	0.8	0.10	Kramer et al. (1999)	0.1
Olives	9.3	4.00	Kaltsas et al. (2007)	37.2
Total oilcrops				**37.3**
Vegetable Oils				
Soyabean Oil	0.9	2.70	Kramer et al. (1999)	2.4
Groundnut Oil	0.3	2.70	Kramer et al. (1999)	0.8
Sunflowerseed Oil	7.3	2.70	Kramer et al. (1999)	19.7

Cottonseed Oil	0.3	2.70	Kramer et al. (1999)	0.8
Sesameseed Oil	0.3	2.70	Kramer et al. (1999)	0.8
Olive Oil	14.7	4.00	International EPD System (2015a)	58.8
Maize Germ Oil	2.8	2.70	Kramer et al. (1999)	7.6
Total oils				90.9
Vegetables				
Tomatoes	76.9	0.15	Barilla (2010)	11.8
Onions	21.6	0.45	Barilla (2010)	9.7
Vegetables, Other	133.6	0.45	Barilla (2010)	60.1
Total vegetables				81.7
Fruits - Excluding Wine				
Oranges, Mandarines	40.3	0.07	Barilla (2010)	2.8
Lemons, Limes	6.5	0.07	Barilla (2010)	0.5
Grapefruit	1.3	0.07	Barilla (2010)	0.1
Bananas	7.7	0.07	Barilla (2010)	0.5
Apples	7	0.22	Nanos et al. (2014)	1.5
Pineapples	1.5	0.07	Barilla (2010)	0.1
Dates	0.1	0.07	Barilla (2010)	0.0
Grapes (excl. wine)	20.3	0.07	Barilla (2010)	1.4
Fruits, Other	35.8	0.07	Barilla (2010)	2.5
Total fruits				9.5
Stimulants				
Coffee	5.7	7.96	Wallen et al. (2004)	45.4
Cocoa Beans	2.8	7.96	Wallen et al. (2004)	22.3
Tea	0.4	7.96	Wallen et al. (2004)	3.2
Spices	0.5	0.30	Wallen et al. (2004)	0.2
Pepper	0.1	0.30	Wallen et al. (2004)	0.0
Pimento	0.1	0.30	Wallen et al. (2004)	0.0
Spices, Other	0.2	0.30	Wallen et al. (2004)	0.1
Total stimulants				71.1
Alcoholic Beverages				
Wine	15.4	2.24	Barilla (2010)	34.5
Beer	34.7	0.68	Heineken (2012)	23.6
Beverages, Fermented	0.1	2.24	Barilla (2010)	0.2
Beverages, Alcoholic	3.1	1.80	Kramer et al. (1999)	5.6
Total alcoholic beverages				63.9
Meat				
Bovine Meat	18.7	30.40	Barilla (2010)	568.5
Mutton & Goat Meat	12.8	2.36	Wallen et al. (2004)	30.2

Pigmeat	31.8	5.00	Nijdam et al. (2012)	159.0
Poultry Meat	14.7	3.00	Nijdam et al. (2012)	44.1
Meat, Other	2.5	3.00	Nijdam et al. (2012)	7.5
Total meat				809.3
Other animal products				
Offals edible	2.7	2.36	Wallen et al. (2004)	6.4
Butter, Ghee	1.1	8.80	Barilla (2010)	9.7
Cream	3.7	1.14	Barilla (2010)	4.2
Fats, Animals, Raw	0.7	4.80	Kramer et al. (1999)	3.4
Eggs	8.9	4.00	Barilla (2010)	35.6
Milk - Excluding Butter	279.9	1.40	Nijdam et al. (2012)	391.9
Total other animal products				451.1
Fish, Seafood				
Freshwater Fish	2.6	1.80	Nijdam et al. (2012)	4.7
Demersal Fish	5.4	1.20	Nijdam et al. (2012)	6.5
Pelagic Fish	4.8	1.20	Nijdam et al. (2012)	5.8
Marine Fish, Other	1.2	1.20	Nijdam et al. (2012)	1.4
Crustaceans	1.6	2.01	Wallen et al. (2004)	3.2
Cephalopods	2.6	2.01	Wallen et al. (2004)	5.2
Molluscs, Other	1.5	2.01	Wallen et al. (2004)	3.0
Total seafood				29.8
			Total	1827.4