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Environmental Assessment of the Agricultural Sector

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To my lovely planet

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Introduction

In the European Union (EU) already for 20 years protection of environment makes a part of the Common Agricultural Policy (CAP). Through the years it has become increasingly important. The sustainable consumption and production strategies recommend a reorientation of the market frameworks towards sustainability practices, engagement of retailers and food producers to produce and choose more environmental friendly choices, with more information to the consumers, support changes of dietary and support for niche practices (BIO Intelligence Service, 2012).

One of the main problems recognized in sustainable development goals and sustainable agricultural objectives is Climate change. Farming contributes significantly to the overall Greenhouse gases (GHG) in the atmosphere, which is approximately 10-12 percent of total GHG emissions, but when taking in consideration also land-use change, including deforestation driven by agricultural expansion for food, fiber and fuel the number rises to approximately 30 percent (Smith et. al., 2007). The data availability of the agricultural sector is rather limited, and few studies have assessed this sector with a focus on GHG emissions. An understanding of how much GHGs are released from different parts of the supply chain is crucial information for the possibility to mitigate GHGs from the agricultural sector. Agriculture faces many challenges, as the growing population, rise in global calorie intake, food security and climate change mitigation and adaptation. There is a need to understand the possibilities and choose those that do not have a negative tradeoff with sustainable development goals. The changes have to also follow the EUs consumption patterns to not results in an exporting of the production to other countries, which has a risk to result in a worse total impact.

There are two distinct methodological approaches for environmental impact assessment; Life Cycle Assessment (a bottom up approach) and Input-Output Analysis (a top down approach). The two methodologies differ significantly but there is not an immediate choice between them if the scope of the study is on a sectorial level. Instead, as an alternative, hybrid approaches which combine these two approaches have emerged.

The aim of this study is to analyze in a greater detail the agricultural sectors contribution to Climate change caused by the consumption of food products. Hence, to identify the food products that have the greatest impact through their life cycle, identifying their hotspots and evaluating the mitigation possibilities for the same. At the same time evaluating methodological possibilities and models to be applied for this purpose both on a EU level and on a country level (Italy).

1. Background

1.1 Sustainable Development

The concept of sustainable development has become a wide set objective in the European Union (EU), being included in various goals and polices through the community. Sustainable development was elaborated as an idea to change the view that was proceeding that development has no limits and to deal with the negative impacts socially and environmentally, which started to show as a consequence from the industrial revolution. Environmental resources had started to disappear which showed that environment has its limits and has to be more protected. The definition of sustainable development according to the United Nations World Commission on Environment and Development (UNWCED) is: *"Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs"*. Over the last 25 years, beginning with international discussions on how to deal with the problems of development, the aim of sustainable development has become involved and incorporated in international policies. The meaning was defined in the Brundtland report *"Our common future"* of the UNWCED in 1987. Further, on the Earth Summit in Rio de Janeiro 27 principles were defined, setting ground for an international plan and goals to be achieved (Grunkemeyer & Moss, 1999). In the European Community sustainable development essence has been incorporated in a broad range of policies through the EUs Sustainable Development Strategies, which where adopted in Gothenburg 2001. European Council in 2005 further elaborated on these objectives and concluded the aim to be: economic prosperity, social equity, environmental protection and international responsibilities (Commission of the European Communities, 2005). EUs objectives for the whole community is to improve the quality of life through sustainable communities that use resources efficiently, prosper economy through innovation and to ensure prosperity, environmental protection and social cohesion.

Today the sustainable development is the key guide on how the development on our planet should continue, by not compromising the resources for the next generations. In 2006 EU reviewed its sustainable development strategy which resulted in new key objectives; environmental protection, social equity and cohesion, economic prosperity and meeting our international responsibilities. These further results in 7 key challenges (Council of the European Union General Secretariat, 2006);

1. Climate change and clean energy - Limit climate change and its costs and negative effects to society and environment

2. Sustainable transport - Ensure the transport systems meet society's economic, social and environmental needs whilst minimizing their undesirable impacts on the economy, society and the environment
3. Sustainable consumption and production - Promote sustainable consumption and production patterns
4. Conservation and management of natural resources - To improve management and avoid overexploitation of natural resources, recognizing the value of ecosystem services
5. Public health - Promote good public health on equal conditions and improve protection against health threats
6. Social inclusion, demography and migration - Create a socially inclusive society by taking into account solidarity between and within generations and to secure and increase the quality of life of citizens as a precondition for lasting individual well-being
7. Global poverty and sustainable development challenges - Actively promote sustainable development worldwide and ensure that European Union's internal and external policies are consistent with global sustainable development and its international commitments

In 2008, European Commission proposed new set of sustainable actions to foster a more sustainable consumption and production both in the EU and internationally. These actions deal with improvement of production technologies and more environmental friendly goods with the stimulation of the demand. For this type of actions and policies there is also a need for reliable methods and data to assess the environmental performance of products and consumption (European Commission, 2008). Sustainable consumption and production objectives promote the aim by addressing social and economic development within the carrying capacity of the ecosystem and decoupling economic growth from environmental degradation, to improve the environmental and social performance, achieve a level of Green Public Procurement by the States and increase its global market in environmental technologies and eco-innovations (Council of the European Union General Secretariat, 2006).

The challenge is to have a sustainable economic growth that does not affect environment negatively, which challenging due to climate change and the growing demand for energy and resources with the growing population in the world. It has been shown that taken early action in tacking climate change results in more and earlier benefits at lower costs rather than acting later (Commission of the European Communities, 2009a). EUs Sustainable Consumption and Production Action Plan and Policies that were set in 2008 were developed to ensure a lower environmental impact of products and to grow the demand for this type of products. The aim is also to develop new opportunities for businesses in the green sector. This is regulated through different tools and available policy instruments (European Commission website 2):

- Ecolabel,
- Eco-Management and Audit Schemes (EMAS),
- Green Public Procurement (GPP),
- Environmental Technologies Action Plan (ETAP),
- Eco-design of Energy-related Products Directive (EuP)
- Integrated Product Policy (IPP),
- Thematic Strategy on the Sustainable Use of Natural Resources,
- Thematic Strategy on Waste Prevention and Recycling.

The Council of the European Union states that "*all EU institutions should ensure that major policy decisions are based on proposals that have undergone high quality Impact Assessment (IA), assessing in a balanced way the social, environmental and economic dimensions of sustainable development and taking into account the external dimension of sustainable development and the costs of inaction*" (Council of the European Union General Secretariat, 2006). This emphasizes the importance of an integrated approach for sustainable development regarding policy decisions, meaning that it is to be integrated taken in considerations all three dimensions; social, environmental and economical.

1.1.1 Sustainability in the Agricultural Sector

The past objectives of the EU community to increase agricultural productivity and with this intensified agricultural production has left the EUs environment damaged. This can bee noticed in five areas (McCormick, 2001):

1. Water pollution caused by runoff from agricultural land
2. The effect of landscapes by increasing agricultural land
3. Damage of the soil form intensive production
4. Air pollution from burning of straw and wood, or smell from manure or animal slurry
5. Damaged biodiversity from the use of pesticides and fertilizers, the loss of mixed farming systems, reclamation of wetland and the alteration of habitat

In EU, already for 20 years, protection of environment is a part of the Common Agricultural Policy (CAP). Through the years it has become increasingly important. Since the Mac Sharry reform in 1992, EU has started with subsidies for good environmental practice, which further was elaborated with agro-environmental schemes in 1999 with Agenda 2000 (Delayen, 2007). The EU Strategy for 2020 has set three goals; food safety, environment and climate change and territorial balance. As a sector, agriculture contributes to the production of environmental public goods as; landscape, farmland biodiversity, climate stability and effects of natural disasters. As such it also contributes to the damaging of the same through pollution, soil depletion and loss of biodiversity, etc.. Agricultural sector has also a potential to mitigate GHG emissions. These three challenges are apart of the EU 2020 Strategy goals for Smart growth, Sustainable growth and Inclusive growth (European Commission, 2010).

To be able to preserve the environment that is affected by agriculture there are different rules that farmers have to follow to not damage the surroundings and preserve the landscapes. The CAP follows two principles i) polluter pays principle, where the farmers is obliged to follow the rules for environmental protection on his own expense, and ii) provider gets principle where they are compensated by voluntarily engaging in different environmental issues beyond legal requirements. This is reflected through two mechanisms Cross-compliance (polluter pays principle) and Agri-environmental measures (provider gets principle). Cross compliance is a compulsory mechanism for all farmers receiving direct payments, which oblige the farmer to follow legislative standards set in EU for environment and to keep the land in good agricultural and environmental conditions. Agri-environmental measures encourage farmers to adapt environmentally friendly techniques by compensating them for the costs as for example integrated farm management or growing organically. A part for these two mechanism, there are also measures that target market stability as payments to the farmers in Less Favored Areas or measures compensating economic disadvantage in a region as Water Framework Directive (European Commission website).

Agriculture uses approximately 40% of water and land resources in the member countries of the Organisation for Economic Co-operation and Development (OECD), which affects the environment negatively. In some cases it is hard to isolate the agricultural contribution to pollution and environmental impacts, for areas as soil and water quality in which cases the impact of other economies is also important or in the cases where environmental state contributes to impacts it self (OECD 2008).

The majority of the consumers in EU do not consider buying products that are environmentally friendly will have a great impact on the environment, as only 55% claim that they are aware of the impact that products have when buying them (The Gallup Organisation, 2009). This study shows clearly that the consumers in EU need more knowledge and information about the environmental impact of products and what effect this have globally.

In 2012, based on the policies set by the Commission in 2011, the Sustainable consumption and production policies were revised and new recommendations were identified. The results of the study for food and drink sector showed that it is a sector with an important environmental impact to be addressed, especially for the meat and diary products, that the focus for change until now has been stronger on the production rather than consumption issues. The strategies recommended are to reorient the market frameworks towards sustainability practices, engage retailers and food producers to produce and choose more environmental friendly choices, with more information to the consumers, support changes of dietary and support for niche practices (BIO Intelligence Service, 2012).

Three main policy objectives were identified:

1. Encourage more sustainable and healthy food and drink consumption by; continuing work on voluntary agreements, introduce taxes based on environmental performance of the products, develop an EU level sustainable labeling scheme, inform the public, promote green public procurement practices and support local initiatives.
2. Reduce direct GHG emissions from food and drink consumption by; educating, improve energy and water use efficiency.
3. Reduce food waste and packaging waste by informing and educating, voluntary agreements and support best practice.

To be able to develop and implement change in dietary of consumers, labeling and institutional support there is a need to address lack of data and studies of impacts across food products (BIO Intelligence Service, 2012).

1.1.2 The Cost of Mitigation

The Polluter Pays Principle (PPP) is defined by OECD as *"The polluter-pays principle is the principle according to which the polluter should bear the cost of measures to reduce pollution according to the extent of either the damage done to society or the exceeding of an acceptable level (standard) of pollution."* (Glossary of Environment Statistics, 1997). As an environmental policy principle it goes back to 1970s and sense then it has been internationally accepted as a way of allocating cost of pollution prevention and control measures. Early as 1985 in the European Commission the PPP was though to be a policy instrument to be applied in to the agricultural sector, but the line between the subsidize applied to the farmers in the EU and the PPP were not clearly distinct. This can be due to the difficulties of allocating pollution from farming as it is not always coming from one distinct source or from the concerns that the agricultural sector should be treated in a different way from other sectors due to its social, economical and political differences from other sectors. The difficulty of allocating a direct pollution source from the sector is due to:

- the pollution caused is often not immediate
- difficult to allocate the polluter
- difficult to specify precisely the action taken to pollute in a legislative context

This leads to a difficulty in finding a cost-effective policy measure of PPP (Baldock, 1992).

The agricultural farm businesses differ from other enterprises as it is usually small business or in many cases family owned small farms, which cannot afford to bear the cost of the pollution. At the same time many markets are artificial in which case the CAP influences the end price of a product. Adding additional cost on production could also inhibit the competitiveness on the market. At the same time governments give high priority to the sector with the aim to maintain self-sufficiency and production (Baldock, 1992). The sector as such makes it difficult to apply the same type of measures as for other sectors in the economy. The policies, even PPP, have to be adjusted and adopted for the agricultural sector to not give a negative trade off in the economy. The agriculture pollution is second generation and more difficult to control at the same time there are certain environmental management difficulties when it comes to pollution controlling policies. This is due to technical issues, to private property rights arrangements, and economical and political considerations. This is also why the cost internalization in agriculture has been limited. When comparing the cost of environmental protection to the production cost it has been shown to be relatively small for the agricultural sector in a study of six European countries, where in the Netherlands a country with the high environmental control, only 0,79% of the agricultural GDP was the total cost of environmental protection. The abatement cost in European countries and US for the agriculture has also shown to be low compared to other industries. The direct pollution abatement expenditures are small in pollution-intensive industries and in the agricultural sector. The pollution abatement costs related to production costs are also small in the food sector when compared to pollution intensive industries (Tobey and Smets, 1996).

The sharing of environmental costs between all players in the economy, not just the producers, but both institutions, political and social structures, has a potential to result in more successful outcome. However, even if the environmental damage is clear and measurable the decision of implementing a cost on environmental damage will be weighed between divergent and interests. In this way the responsibility taken through cost of environmental damage will depend on estimates of the economic and social costs and on scientific conclusions and recommendations (O'Conner, 1997).

One important aspect to take in consideration is also how big is the loss or how big is the gain of improving the negative environmental impact. There are two distinct ways of emissions mitigation; by control (emissions are stored, trapped or disposed by using pollution control equipment) or prevention (emissions are reduced are prevented by better use of resources though recycling process innovation, etc.). The try to control emissions by specific equipment could have a higher cost then preventing the emission by continuing the production. The pollution caused in the production can bee seen as lack of inefficiency and that waste is a cost. In this reasoning, polluting prevention could also lead to increase of productivity and efficiency, which at the same time could lead to lowering of emission more then aimed at. Nevertheless, also prevention of emission leads to an initial cost due to measures which should be applied to mitigation, but also initial emission reduction could be easier gained then with time if required. It will progressively be more difficult to improve the efficiency and lower further emissions. This was demonstrated by Hart et al., (1996) where it was shown that the initial cost invested will be paid of in the first two years. However, the biggest benefits can be gained from firms that have a high pollution rate as there is many low cost improvements to be made. It was also concluded that the marginal costs of reducing emissions seldom exceed marginal benefits. Even if the most to gain are the inefficient firms, the other firms have also an advantage not taken in calculation of the market by introducing more environmentally friendly products (Hart et al., 1996).

1.2 Climate Change

One of the main problems to deal with in sustainable development goals and sustainable agricultural objectives is Climate change. Climate change, according to Intergovernmental Panel on Climate Change (IPCC), is defined as any change in climate over time, due to natural variability or as a result of human activity (IPPC, 2011). The IPCC, was established by the United Nations Environment Programme (UNEP) and the World Meterological Organization (WMO) with aim to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. The IPCC is today's leading international body of the assessment of climate change. In the first report the IPCC issued in 1990, it was confirmed that the earth was warming, but without knowing the cause. Through the second and third report, 1995 and 2001 respectively, a more clear picture on the causes for the warming of the earth was becoming evident, due to more research and advances in models, leading to the fourth assessment report of IPCC in 2007 with the conclusion that global warming, with a very likely certainty (meaning more than 90% probability), was caused by humans, because of the increase in anthropogenic Greenhouse gas (GHG) concentrations (IPCC 2007; Powell, 2011).

GHG are defined as "gaseous constitutes of the atmosphere, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds" (IPPC, 2011). This property causes the greenhouse effect. The main GHG in the atmosphere are: water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) (IPPC, 2011). It has been shown, that from 1970 to 2004 global GHG emissions have grown with an increase of 70% due to human activities. During that time, the most increase was generated mostly by energy supply, transport and industry (IPCC, 2007). In Figure 1, it is shown a clear correlation between the CO_2 concentration, carbon emissions and temperature for the last 1000 years.

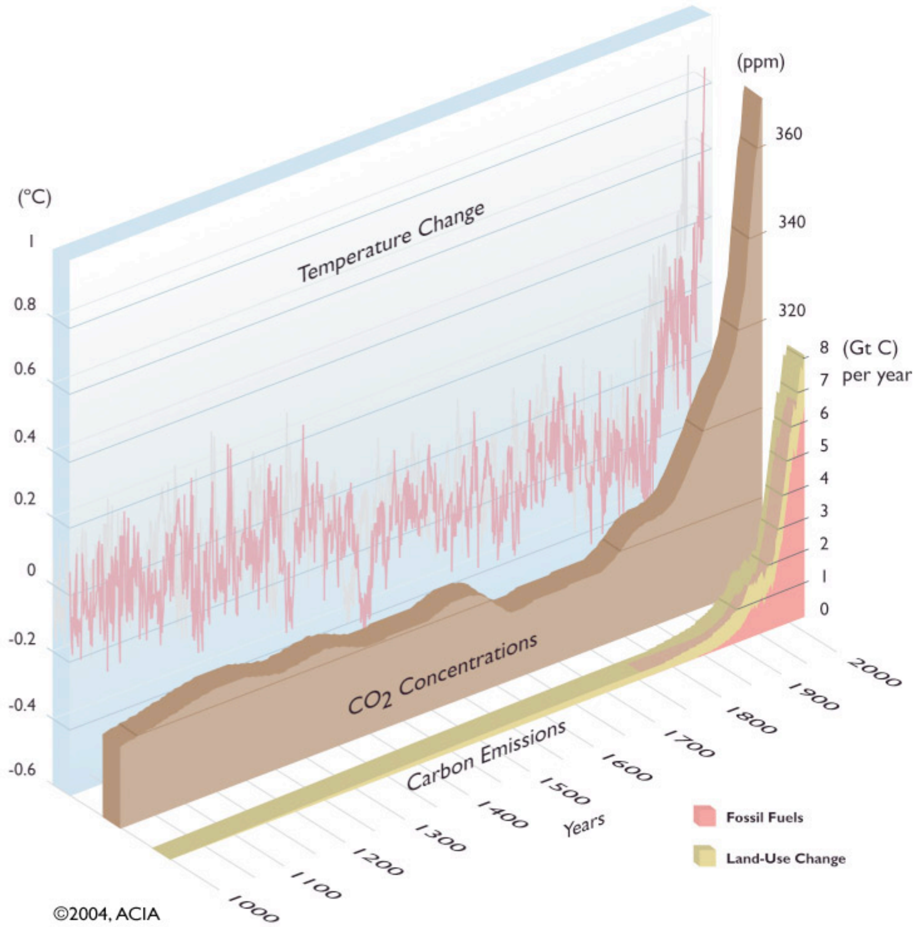

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Figure 1. The case of global warming (Arctic Climate Impact Assessment; copyright ACIA, 2004).

Two major international agreements have been adopted to address climate change; the 1992 UN Frameworks convention on Climate Change (UNFCCC) and the 1997 Kyoto Protocol. The UNFCCC established a framework for international cooperation on climate change with the ultimate objective of preventing dangerous man-made interference with the climate system. The Kyoto Protocol, which entered into force in 2005, is a first step towards reversing the global trend of rising emissions. The Protocol sets legally binding targets for 37 industrialized countries to reduce their emissions of six GHG which are; CO2, CH4, N20, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (United Nation, 1998). For EU this goal is 8% below 1990 by 2012. However, EU greenhouse gas emissions make up only a limited share of global emissions. While the EU is on track to achieve its greenhouse gas emission reduction targets resulting from the Kyoto protocol, global CO2 emissions are today some 40% higher than they were in 1990, the Kyoto base year. It is estimated that in order to limit the average global temperature increase to less than 2°C compared to pre-industrial levels, global greenhouse gas emissions must be reduced to less than 50% of 1990 levels by 2050 (Commission of the European Communities. 2009a). To be able to reach these goals, the EU has agreed on a climate change and energy package, which will enhance the possibilities to achieve the goals for 2020, to have the greenhouse emission under 20% below 1990 levels. As part of this commitment, a reduction of 10% in 2005-2020 has been agreed for the sectors not covered by the Emissions Trading System (ETS) (Commission of the European Communities. 2009b). ETS is a trading system for CO2 emissions that covers over 11.500 energy-intensive installations across the EU. The aim of the ETS is to help member states achieve compliance with the commitment of lowering the emissions, through the mechanism of buy or selling allowances depending on their total quantity of CO2 emissions that states have granted their companies (European Commission, 2005).

The goal of EU was to reduce GHGs by 20% by 2020 which is on the way to be met. The new target for 2050 is to reduce GHG emission by 80-95%, for which it will be necessary to have long term strategies and policy challenges if the goals are to be reached (Commission of the European Communities, 2011).

The GHG emissions in EU are accounted for by calculating the productions GHG emissions, but there are substantial emissions that are emitted from the demand of EU consumers, through import. In Figure 2 it is shown how EU exports much less GHG emissions than importing meaning that the balance is not equal. It would mean that EU emits in a way more than it is accounted for even if the production is taken place abroad the consumption and the demand to produce these goods comes from EU. The fact that EU also imports this much goods from abroad could be an opportunity to demand the production to be produced with more sustainable technologies (WWF, 2008).

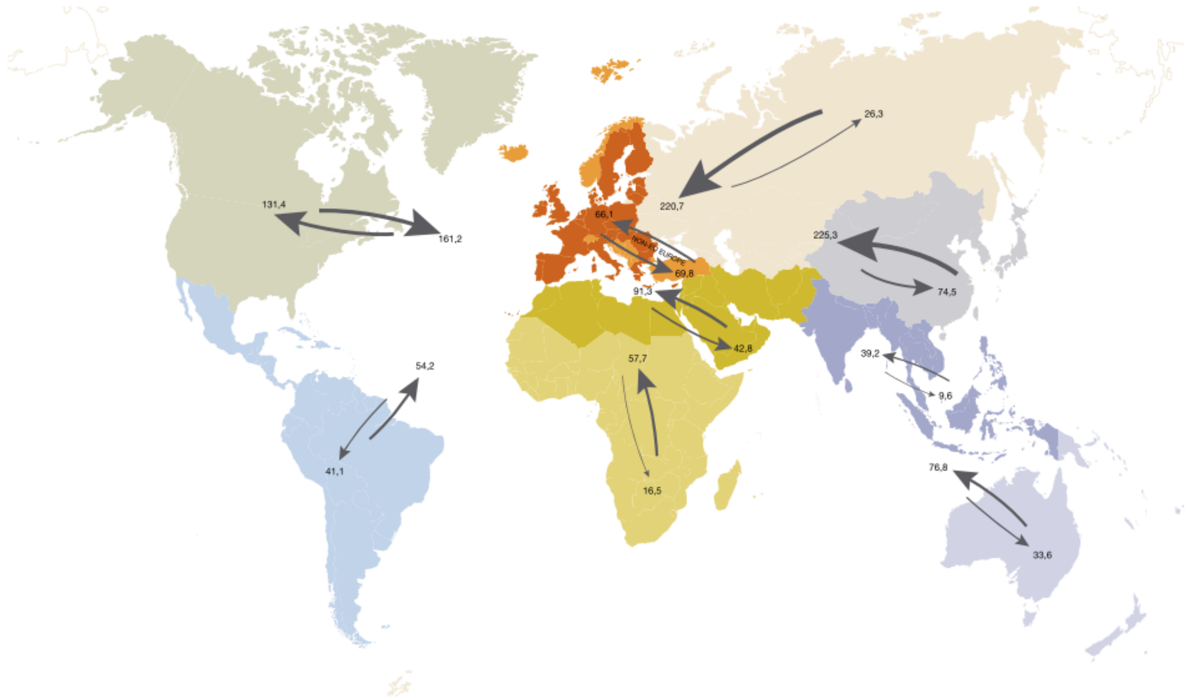

Figure 2. The CO2 emitted in each region to produce imports to the EU and the CO2 emitted in the EU to produce exports to each region. In million tones, 2001. WWF (2008)

The EUs CO2 emissions due to consumption are ca 12% higher then emissions caused by production which are accounted for (Bang et al., 2008). This means that other countries, where these products are produced are being responsible for the demand of EUs consumption. There is also the risk when reducing the emissions in the EU that it could lead to shifting of the emissions to other countries, seeming that the emissions have been lowered but instead they have been exported. That is why, for a sustainable consumption and production policy it is significant to take in consideration the whole picture of emissions, to understand better the development and shiftings to be able to base decisions on relevant problems that can occur (BIO Intelligence Service, 2012).

1.2.1 Climate Change in the Agricultural Sector

Climate change will affect different sectors, especially agriculture. Hence agriculture has an effect on livelihood, food production and the overall economy of countries, possible negative impacts on agriculture from climate change will affect also all these matters. At the same time agriculture can contribute to GHG mitigation.

Agriculture is responsible for significant amounts of GHG emissions, mainly CO2, CH4 and N2O. The main part of CO2 emission are from microbial decay or burning of plant litter and soil organic matter (Smith et. al., 2007). The CH4 emissions are mainly from livestock digestion processes and stored animal manure. With N2O coming mostly from organic and mineral nitrogen fertilizers (EUROPA, 2010). CH4 and N2O are present in smaller quantities than CO2 in the atmosphere, but they have a global warming potential (GWP) impact that is much greater, 23 times greater for CH4 and 296 times for N2O (Garnett, 2008). At the farm stage, the dominant GHGs are N2O and CH4, where CO2 emissions are present in a smaller quantity. However, if land use change is added to the calculation, it adds significantly increase of greater amount of CO2. Beyond the farm gate, CO2 from fossil fuel use dominates with the refrigerant gases as well (Garret, 2011).

Farming contributes significantly to the overall GHGs in the atmosphere, which is approximately 10-12 percent of total GHG emissions, but when taking in consideration also land-use change, including deforestation driven by agricultural expansion for food, fiber and fuel the number rises to approximately 30 percent (Smith et. al., 2007). If we look at it from another point of view, from the supply chain point of view, agriculture overall contribution increases even more. Agricultural products, fresh and processed go through a long supply chain until they reach the customer, even after that, the customer leaves agricultural waste after the purchase which further adds up to the GHG emissions, even without taking in consideration the customers travel to and from the store, using a car adds it up. An understanding of how much GHGs are released from different parts of the supply chain is crucial information for the possibility to mitigate GHGs from the agricultural sector. We should also understand, in what way could we decrease does amounts why still having a feasible chain. In a study made by European Commission, in 2006, it was found that food accounts for 31% of the EU-25's total GHG impacts, with a further 9% arising from the hotel and restaurants sector (Tukker et al., 2006). In the Figure 3, we can see a breakdown of the United Kingdom's supply chains GHG emissions, which shows different parts of the chain as they all contribute to the emissions.

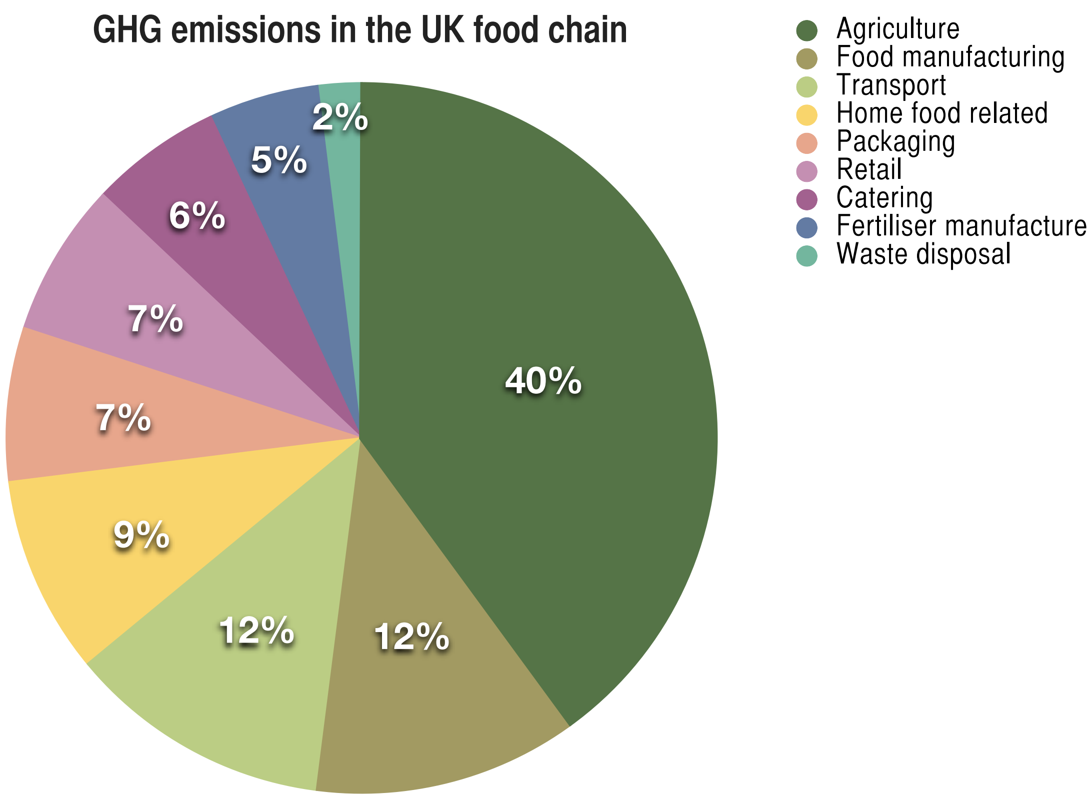

Figure 3. Breakdown of food chain GHG emissions in the UK excluding land use change (Garnett 2011).

According to the analysis made by the Commission, to reach the EU goals to reduce GHG emissions, agriculture as a sector has to reduce its non-CO2 emissions by 20% until 2005, by 36 - 37% by 2030 and by 42 - 49% until 2050 compared to emissions in 1990. By 2050 agriculture is thought to represent a third of total EU emissions in contrast of today which it represents a fifth, showing an increase importance of the sector in mitigating strategies. (Commission of the European Communities, 2011)

There are many challenges as to reduce, mitigate GHG emissions, but also to adapt to the rise of temperature and the changing climate. Synergies and trade-offs exist between adaptation and mitigation options, as for example for the sector of agriculture. Agriculture faces many challenges, as the growing population, rise in global calorie intake, food security and climate change mitigation and adaptation. There is a need to understand the possibilities and choose those that do not have a negative trade-off with sustainable development goals. To minimize negative tradeoffs across all these objectives agricultural sector faces different challenges that have to come together.

There is also the question of consumer, producer responsibility in the agricultural supply chain, meaning does the consumer because of his demand have the responsibility of choosing more environmental products, adapting also to new diets and not taking the car to the shop, or is the producer responsible not only until the farm gate but even when choosing who to sell his products to, how will they be transported and so on. There is no easy answer to this; probably a share of responsibility will be necessary.

By assessing the environmental impact of all EUs products using an input-output analysis to show the impact of production and consumption on the environment three product groups were identified with the highest impact. These product groups are: food and drink, private transport and housing. They are responsible for 70-80% of the total environmental impact of consumption, for which food and drink are responsible for 20 - 30% and specifically for global warming 4 to 12%. The products that are causing most impact are meat and meat products, and then diary products (Tukker et al., 2006).

The agricultural and food sector was also identified as a significant sector contributing to climate change from the European Environment Agency (EEA) study of Environmental pressures from European consumption and production. In the study four economical sectors were identified as contributing to 75% of GHG emissions from the production; agriculture, the electricity industry, transport services and some basic manufacturing industries. The agricultural sector provides only 4% of gross value added and results in being on of the sectors with high environmental pressure intensity. To be able to achieve the EUs high objectives of GHG emissions both reductions in eco-efficiency improvements and structural changes seems to be necessary. The changes have to also follow the EUs consumption patterns to not results in exporting of the production to other countries which could be then even less environmentally effective. Four product groups in EU contribute the highest impact from GHG emission and those are; construction works, food products, products of agriculture, forestry and fisheries, and electricity, gas and water services. Out of the consumed products the agriculture and food products result also to be highly pressure intensive (European Environment Agency, 2013).

1.3 Territorial- and Consumption Based Accounting

The reporting of GHG emission to IPCC is done based on territorial accounting, meaning production based. As can bee seen in Figure 4 a producer responsibility contains Goods and services produced and consumed in country A, moreover the exports from that country to the rest of the world (ROW). Where a consumer responsibility takes in consideration also the Goods and services produced and consumed in country A, with the imports of that country from the ROW for domestic final consumption.

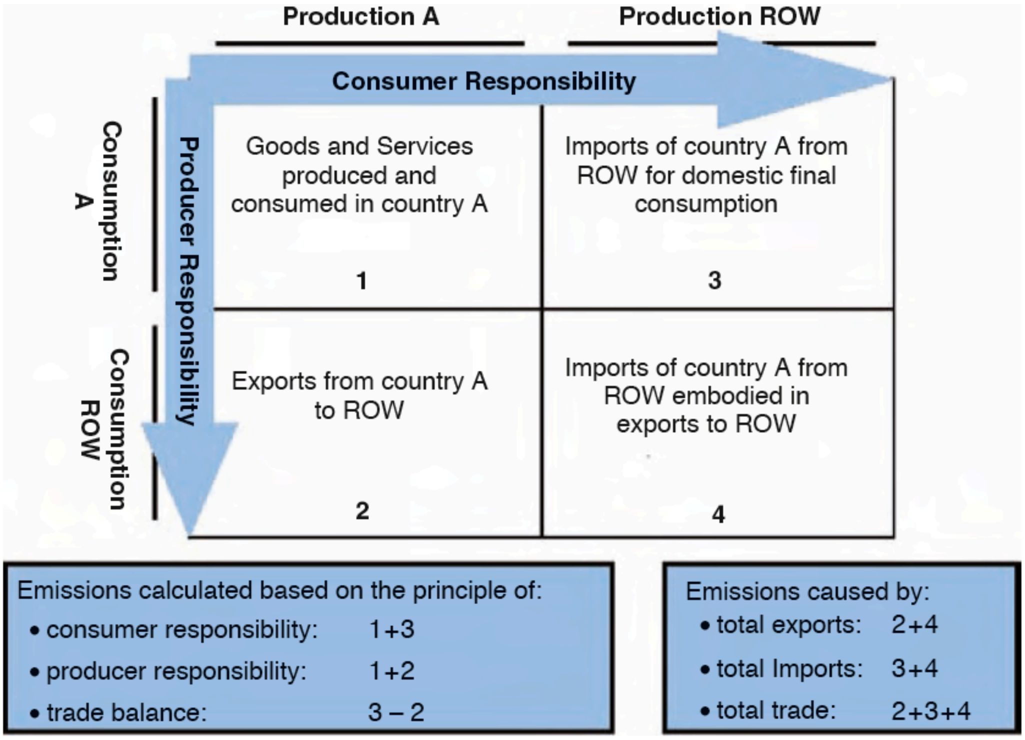

Figure 4. Producer versus consumer responsibility (Suh, 2009).

Taking in consideration a consumer perspective GHG embodied in international trade could show a significantly different number of responsibilities for the countries GHG emissions (Serrano and Dietzenbacher, 2008). Due to increased globalization of production networks, there is increasing interest in the effects of trade on the environment (Hertwich and Peters, 2010). Peters and Hertwich (2008), argue that if nations that import more embodied emissions than they export were to become partially responsible for emissions occurring elsewhere, the exporting nations (mainly China and other developing countries) might be more willing to play an active role in post-Kyoto climate commitments. In this sense a country is responsible also for the imports from other countries. From the Extended Producer Responsibility (EPR) framework, it is argued that the producers should take a responsibility not only for the environmental impact of their products downstream (treatment and disposal) but also upstream (selection of materials and in the design of products) (Serrano and Dietzenbacher, 2008). Even if there are different examples of implementing both approaches, most of them are in a less qualitative and ad-hoc way, than quantitative and systematic way, in selecting, screening, ranking or influencing other agents in the supply chain (Serrano and Dietzenbacher, 2008). Assessing the GHGs in different sectors has shown to be rather complicated, as there are different methods and possibilities, unsure data collection and complicated and expensive methods. Every country in agreement with Kyoto protocol, reports their emissions. This numbers are territorial (production) based, meaning, not taking in consideration the imports of the country, which comes back to responsibility of GHGs.

Wiedmann 2009 identified the main opportunities followed from consumption based accounting that complements the territorial based approach which can then be used for international policies as climate change. One of the challenges with climate change is to agree on how much responsibility each country should carry. With this type of accounting it can be based on data which can also quantify economic and environmental trade linkages between countries. Peters and Hertwich, (B 2006) argue that consumption accounting should replace production based accounting for policy indication as it can account for carbon leakage, it does not punish a country for intensive exports and gives a greater flexibility for reducing emissions (Peters and Hertwich, B 2006). Consumption based accounting can be used for communication of consumption based GHG emissions to the consumers, to make them aware of their choices. It can be a calculation data tool for national, regional and local policies for sustainable consumption and production and climate change mitigation by identifying hot spots in supply chain and unsustainable consumption patterns and trends. It can also be used to understand if carbon leakage occurs and trace if the shift of emissions has been developed (Wiedmann, 2009).

The total of GHG emissions from production based accounting and from consumption based accounting would be the same but the method of allocation is different. For production based accounting the allocation is on production of industries and includes exported products and in consumption based accounting the allocation is on the final consumer and includes imports but not exports. Even if consumption accounting shows how much of a countries consumption is produced in different countries, which is an important tool for mitigation policies this type of accounting has a wider system boundary and suffers from more uncertainties in the calculations then production based accounting. Uncertainties are related from reallocation of emissions from technologies to sectors instead from fuel consumption in production based and from inclusion of imports rather then productions of a country (Peters 2008).

2. A Critical Review of Environmental Assessment Methodologies

2.1 Bottom-up and Top-down Approaches

In the following part two distinct methodologies for environmental assessment are presented, Life Cycle Assessment (a bottom up approach) and Input-Output Analysis (a top down approach). The two methodologies differ significantly but there is not an immediate choice between them if the scope of the study is on a sectorial level. Instead, hybrid approaches which combine these two approaches have emerged, which are also reviewed in this chapter.

2.1.1 Life Cycle Assessment

LCA is a life cycle analysis method which uses a bottom up approach meaning an analysis that begins at the bottom of the supply chain and measures each process that leads up to a product system (Grant, 2009), taking in consideration the whole product system from cradle (raw materials extraction) to grave (products disposal) (Baumann and Tillman, 2004). Even if LCA has been used since 1970s, it did not get a kick start until the 90s, during these years also the methodological standardization for LCA started to be developed resulting in the ISO 14040 series, which sets the main guidelines for performing a LCA (Udo de Haes, 2002). As a common environmental assessment tool, it has been applied in different range from decision making as process design and development, learning as identification of improvement possibilities and for communication for eco-labels (Baumann and Tillman, 2004). When it comes to assessing of the environmental burdens of a country the discussions have often been about how to assign the responsibilities of a country, by territorial/producer responsibility or consumer responsibility. The LCA assumes full consumer responsibility as it places the consumer at the end of the chain (Lenzen et al., 2007).

A LCA is done in four phases; 1) Goal and scope definition where the functional unit of the study is determined, 2) Inventory analysis, where the consumption of resources, the waste flows and emission in the life cycle are determined setting the system boundaries, 3) Impact assessment, where the impact categories are analyzed in the connection to the resources used in the life cycle and 4) Interpretation, where the results are defined and interpreted (Rebitzer, et al., 2004). LCA is conducted by using a process flow diagram, which describes all processes of the system and their interrelationships in a diagram (Guinée et al., 2002), or by a matrix formulations (Heijungs 1994) which presents a product system in a matrix using a linear equation to solve an inventory problem (Suh and Huppes, 2005). The main difference is that the matrix based LCA can represent infinite orders of upstream process relations within the system boundary and a process flow diagram cannot (Suh et al., 2004).

Despite the fact that LCA has been used widely and is highly appreciated by the environmental assessment community it is not problem free. In the first phase, by defining a functional unit various errors can be introduced to the study from missed, not correctly specified or not correctly prioritized functions, from assigning functional units to multiple or difficult to quantify functions, or different way in which the reference flows are allocated to functional units (Reap et al., 2008 1). When making a comparison study, in theory the functional unit should be the same, but in practice the functional unit can differ due to secondary functions, which introduces interpretation possibilities from the practitioner (Grant, 2009).

LCA is rather a complex and time consuming analysis to carry out hence the many processes a product has in its life cycle. To be able to perform an analysis one has to limit the scope of the analysis to the most important inputs due to time restriction or unavailable data, thus the activities and processes in a LCA are determined by a boundary selection. If appropriate boundaries have not been assigned there is the danger that the product dose not reflect the reality which gives misleading results because processes outside this boundary are not accounted for resulting in truncation error (Reap et al., 2008 1). Even if these cutoffs are small, the sum of the cutoffs in the assessment can give significantly incomplete results (Suh et al., 2004).

If a process is shared by more than one product, as for example recycling of waste, which is usually done with several products at the same time, the environmental burden of the specific product should be allocated, if allocation is not done carefully the results could be affected negatively (Reap et al., 2008 1).

The data quality used in the assessment are affected from different aspects, some data can be unobservable in that moment, and the practitioner does not recognize the need to collect it. In some cases data are obtained from the persons not conducting the LCA and the quality is unknown, data can be outdated, they can be assumed because they are from similar processes, or averages are used (Reap et al., 2008, 2). The data is often collected from different sources as of the many processes in a life cycle to lower the time and cost, and to deal with the lack of data. This problem has been approached by common LCA databases, but also by new hybrid methods (Finnveden et al., 2009), which will be discussed in the next section.

The results are also affected by the fact that spatial variation, local uniqueness, temporal aspects and environmental dynamics are not taken in consideration (Reap et al., 2008, 1, Owens 1997). Economic, social aspect and risks are not part of a LCA (Baumann and Tillman, 2004), this can limit the LCA in the policy decision of sustainable production and consumption (Reap et al., 2008, 1).

2.1.2 Input-Output Analysis

Input-Output Analysis (IOA) is an economic analysis, a top down approach using monetary transactions between economic sectors to represent the interrelationships between processes leading to the production of goods and services (Grant 2009) from cradle (from raw material) to gate (until the product or service leaves the factory gate). IOA is an economic method developed by Wassily Leontief in the 1930s for which he later received a Nobel Price. The bases of an IOA are IO tables that are often published by world nations and are publicly available data of which today more than 100 countries are known to publish them, there are also organizations or communities that construct and publish their own tables e.g. OECD (number of countries 44) or the European Community (number of countries 27) (Eurostat 2011, OECD). An IO table consists of inputs and outputs of the countries industries, showing what is sold and bought by industries to provide goods or services (Murray and Lenzen, 2010). This is illustrated as sectors, where each sector is represented by one row and one column, inputs and outputs of an economy (Hendrickson et al., 2006). The data representing the sectors are highly aggregated, depending of IO table, a national economy can be represent as 60 (Eurostat 2011) sectors to 500 sectors (EIO-LCA), thus it is not highly specific for a single product (Eurostat 2011, Hendrickson et al., 2006). The data in the table is collected from various sources as tax data, surveys, government annually reports and others (Murray and Lenzen, 2010).

IO tables can be integrated with different data, social accounts or environmental data as GHG emissions (Murray and Lenzen, 2010). The IO model assumes that inputs and outputs of an industry are proportional, in this way integrating environmental data to the table is done by assuming that the amount of environmental intervention generated by an industry is proportional to amount of output of the industry (Suh and Huppes, 2005). The IOA with integrated environmental data has amongst other purposes been used for life cycle analysis (see Junnila, 2008, Mattila et al., 2010)

A life cycle approach based on U.S. IO tables, energy and environmental data called Economic Input-Output Life Cycle assessment (EIO-LCA) was developed by the Carnegie Mellon University in 1992. It is a model published online for free and has been used widely to account for life cycle analysis and carbon footprint in the U.S., as it can be done quickly and with minimal costs, for further details see the references (Lave et al., 1995, Weber et al., 2010, Hendrickson et al., 2006). It has been applied to different case studies as at regional level to indicate regional economic and environmental effects from the production of goods and service (Cicas et al., 2007), or environmental assessment of a chemical (Wright et al., 2008), or environmental impact of a service organization (Junnila 2006), or as a cross border model to be able to calculate energy intensities and GHG from the demand of imports (Norman et al., 2007). EIO-LCA is shown to be a valuable tool for products that are easily approximated from their sector but not for products that are new or that significantly differ from their sector average (Joshi 2000).

IOA has the advantage that there is no need to draw system boundary as it accounts for the impact in the full upstream supply chain and takes in consideration the sectors of the whole economy (Murray & Lenzen, 2010, Hendrickson et al., 1998, Lenzen 2001). IOA is also faced with different limitations as the calculations are based on the industrial sector the results will present the average product of that sector (Finnveden et al., 2009). Depending on how much the product differs from the sectors average or how detailed the sector data are, the results accuracy will be higher or lower. The IO data are aggregated by the national statistical agencies, some of the data are estimated, and emission data are usually calculated from statistical data leading to sampling, reporting and imputation errors. The aggregated data used in IO tables for different producers and products is not comprehensive enough and leads to a degrees of uncertainties, especially in products that are heterogeneous (Weidema et al., 2009, Lenzen 2001, Hendrickson et al., 1998). Some types of data are difficult to find, there is a general lack of environmental data (Lifset, 2009). IO tables are published every five years, or even less often due to the high amount of data needed, thus the data can be too old in cases where the economic situation has changed significantly, which can then lead to errors in the analysis (Hendrickson et al., 2006).

Other challenges with IOA come from that the single region assessment which assumes that the imported products are produced with same technologies and conditions as national ones and that foreign industries are perfectly homogenous, thus not including the environmental impact of imports and exports. The analysis does also take in consideration only the cradle to gate aspect not including the use phase, maintenance, decommissioning, demolition, disposal or recycling of the product. The assumption of the IO model that the inputs and outputs are proportional, implies that there are no capacity constraints or scale economies which causes errors (Lenzen 2001; Lifset 2009; Hendrickson et al., 2006). Uncertainties come also from the product price in which the appropriate price data could be hard to obtain for the specific year of the IO table (Williams et al., 2009).

2.1.3 Comparing LCA to IOA

The difference between the two assessment method begins with that the IO models a product system using economic flow databases with monetary economic national accounts covering the pre-consumption stage and LCA uses inventory databases with unit process data in physical units covering the complete life cycle (Rebitzer et al., 2004). It can be argued that IOA is more accurate than LCA as it captures more inputs and LCA is a more precise analysis hence the system boundary, but it is questionable how much of the impact is being ignored, and IOA can be more complete but not as precise due to the average data used for the sectors (Murray & Lenzen, 2010). IOA has shown to be a useful asset for LCA when used as a screening tool, hence it can give a first view of the product impacts making it easier to draw the system boundary (Lifset, 2009, Rebitzer et al., 2004). When conducting a comparison analysis, for products with similar materials and processes a LCA would give a comprehensive result, however if the products differ too much the results are less accurate due to the narrow system boundary. For the same case IOA is best suited for comparing aggregated products, for the ones that are very similar it is less accurate (Lave et al., 1995). Lenzen (2001) concludes that when comparing analysis of an IOA and LCA they give significantly different results which means that no one of the two methods is fully complete. They share also different sources of errors in unreliable measurements, estimates and assumptions, bias in source data, temporal, geographical and technological miscorrelation and lack of knowledge about the system (Lenzen, 2001). Also, IOA suffers from cut-off errors even if significantly lower than LCA, the cutoff is due to the excluding of capital goods, this is not an issues for short term effect studies. Aggregation uncertainties are significantly lower in the LCA than IOA but still do occur due to limited resources while performing the study some aggregated data are used. As the IO data are based on national accounts that group large amount of facilities into a single sector, the amount of effect the aggregation has on a result in IOA depends on whether the sector is representative of the product under consideration. Temporal uncertainty depends on how long time the material used in the study will not be changed. Williams argues as it is difficult to reduce this uncertainty, it is important to characterize it; through use of IO tables that change every five years and analyzing the significance of the time or through collecting of time-series process data. Geographic uncertainty is caused by the variations in production processes in different places (Williams et al., 2009).

Majeau-Bettez et al. (2011), analyzed quantitatively the IO and LCA databases to show the lack of harmonization between the two. The results show that in a LCA database some sectors of an economy are completely absent or represented in low amount resulting in that these upstream inputs are not captured. Their findings argue that the LCA and IO data sets are complementary for a hybrid approach. Disaggregating data for an IO table is efficient to a certain level but as the complexity in the study gets bigger it would be more efficient to use a LCA approach than an IOA approach. The main conclusion shows the need to have hybrid databases, as the dataset of the two approaches are very different (Majeau-Bettez et al., 2011).

2.1.4 Multi Regional Input Output Analysis

Environmental extended input output analysis (EE-IOA) has for long been used to measure environmental impact, even from a consumption perspective. With single region input output models the technological differences between countries can not be considered which leads to rather unsure results for the imported goods or for the goods that parts of the components come from other countries. For this problem it is recommended to use a Multi Regional Input Output model (MRIOA) as in this model different countries are distinguished with the trade flows between them. This is possible by combining domestic technical coefficient matrices with import matrices from all countries modeled into one coefficient matrix. (Wiedmann, 2009). A multi-region input output table consist of at least two regions or countries and shows their interconnection between their industries. In this way the relationship with different countries is represented taking in consideration also the technology differences, and showing the imports by each country for industry and final consumption use (Zhou, 2010). Data requirement is huge for a MRIOA, data is also not updated every year, time gaps are created between the data and data availability for some material and water use is often not available (Wiedmann et al., 2009). There are several models that can be used for a MRIOA, as the Global Resource Accounting Model (GRAM), Global Trade Analysis Project (GTAP) and EXIOBASE. GRAM disaggregates 52 countries and world regions into 48 economic sectors, 25 product groups and 1 service sector by using IO tables published by OECD. It was developed to represent the Europe's economic interrelations with the rest of the world (Giljum et al., 2008). GTAP has 129 regions and 57 commodities with dual reference years 2004 and 2007. It is a data base with complete bilateral trade information, transport and protection linkages (GTAP). EXIOBASE is a newly published database with 43 countries and Rest of the World with full trade matrices. It distinguishes 129 industries and products by country and covers 30 emitted substances and 80 resources by industry (EXIOBASE).

Peters 2007 dived MIRO into two approaches that study emissions embodied in consumption (EEC) and emissions embodied in trade (EET). EEC considers the individual consumption to study the final demand of consumers and is usually used for sub-national studies and EET considers total trade into a country whether it is consumed by industry or final demand and is usually used at national level studies. These two approaches will give different results when studied the final national demand because of imports that are required to produce exports. Depending if the imports have been further imported before, so if a third country is involved the results can be higher or lower regarding the amount of import a country has. The differences can be adjusted by reallocation and summation if necessary, if one wants to compare an arbitrary study to a national demand study. In this way it is important to be clear when using either of the methods (Peters, 2007).

MRIOA allows one to assess the environmental impacts in trade from different countries and can trade the environmental consequences of industry relocations to other countries, can also be used for forecast modeling, quantifies international supply chains and covers all indirect impacts caused by upstream production (Wiedmann et al., 2009). MRIOA can be used for sub-national levels by extending hybrid LCA to include global environmental impact, supply chains across regions, regional specific impacts or to study parts of the economy as household consumption. Studying different parts of the economy in a region one can place the causing on consumption, production or the consumption-production linkages causing environmental impacts. MRIOA studies have been used to evaluate the environmental impacts of a countries consumption, by studying the imports and exports from a consumer or producer perspective (Peters, 2007).

MRIOA has been used in the last years for many studies for environmental assessment for national accounting as in Andrew et al., 2009 by taking in consideration imports in a regions carbon footprint they concluded that imports can account for 40% of a nations total footprint. This shows how important imports can be for environmental accounting of a nation. MRIOA can also be used on a regional level in a country, Bertini and Paniccia, 2008, studied the pollutions origin and destination of it in the regions of Italy. It has been used to study trade in the world between countries and how trade can affect the releases of emissions negatively or positively, or to understand if the policies in climate change politics are fairly set. Ackerman et al., 2007, analyzed emissions embodied between Japan and United States of America (USA) which identified that one country shifted part of the carbon burden to the other one. When studying pollutions that are embodied in trade several studies have also identified that carbon leakage occurs (Peters and Hertwich, B 2008, Lenzen et al., 2010). Carbon leakage is a term used for emission reductions in Annex B countries that are offset by emission increases in non-Annex B countries, and can be quantified using MRIOA and a consumption approach (Peters 2008). In a regional study of Norway it was seen that there is a growth in imports from countries that are non-Annex B countries, and that almost a half of the countries footprint occurred in the developing countries (Reinvang and Peters, 2008). Apart from carbon leakage todays trend to move production where it is cheaper can lead that shifting of carbon-intensive productions to developing countries which have less strict policies for lowering of emissions in the atmosphere and environmental protection. The responsibilities, and not the total emissions of the country, would change if the allocation schemes were based on a trade approach (Zhou and Kojima, 2009). Comparing of producer and consumer accounting by using MRIOA and 87 world regions showed that a producer principle in which import are treated as they are produced domestically underestimated emissions for developed countries (Wilting and Vringer, 2007).

MRIOA is a valid methodology for environmental policy development as it can study environmental responsibilities and results of implementation of different tax regimes (Hoekstra and Janssen, 2005). Consumption approach, which also gives a basis for a different approach in climate change policy negotiations and development (Peters 2008). MRIOA has also been used to estimate household environmental impacts (Peters and Hertwich, C 2006) (Weber and Matthews, 2008) and the sustainability of supply chains from total consumption (Wilting 2008). MRIOA is recommended for estimating the Ecological footprint of production, consumption, imports and exports in an international supply chain (Turner et al., 2007). In Figure 5 the correlation between policies and MIROA can been seen. MRIOA is best suited for macro and meso level analysis, for micro product analysis it has too aggregated data. This analysis can be used for different policy strategies and programs as national climate negotiations but also for structural policies for carbon tariffs or carbon trading.

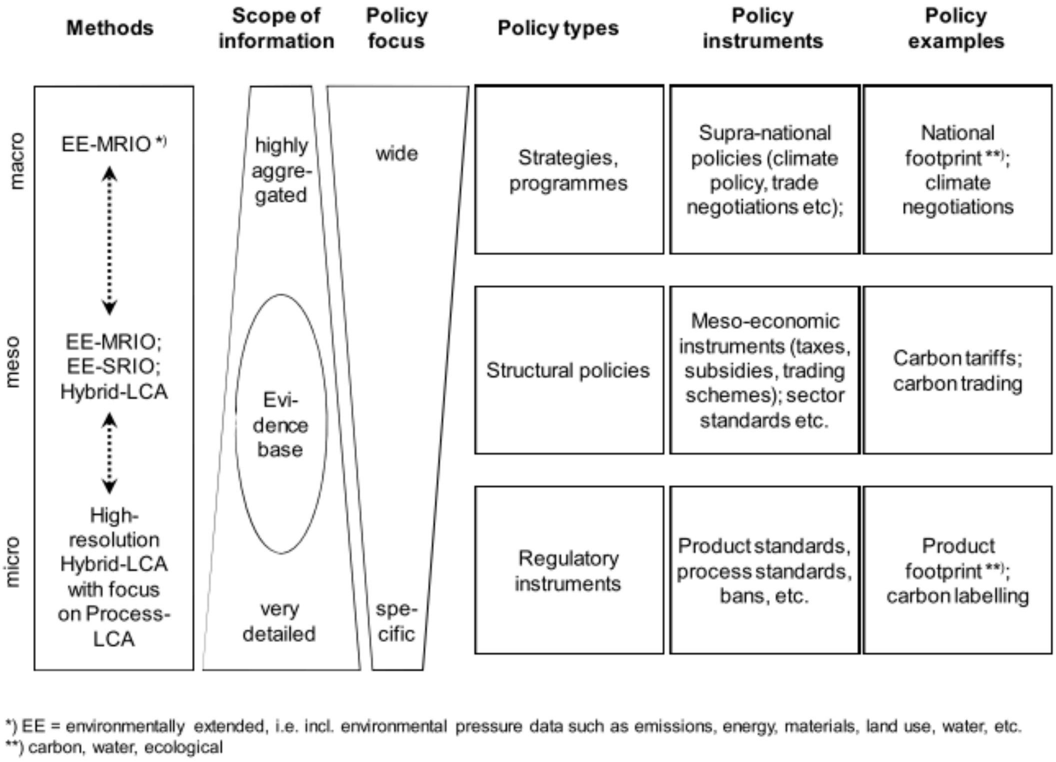

Figure 2.1: EIPOT-methods in relation to policy demands on different economic levels
(adapted from Femia and Moll 2005 and Wiedmann *et al.* 2006)

Figure 5. Environmental assessment methods and how they relate to policy demands on different economic levels.

MRIOA studies give one also the opportunity to use different analysis methods as Structural decomposition analysis (SDA) or Structural path analysis (SPA). SDA has been used to understand better the drivers behind change in a countries emissions, as in UK which showed among other results that consumer emissions have been growing (Baiocchi and Minx, 2010). SPA has been used to identify hot spot in the supply chain of meat product in UK, identifying also GHGs beyond farm gate which showed that CO2 emissions are an important part of emissions released in the agricultural sector. It was also shown that small processes contribute to 30% of emissions, which would probably be neglected in a LCA study as this 30% come from 3879 processes, which are too many to take in consideration in a LCA study and they would be cut off (Minx et al., 2008).

As IOA, MRIOA suffers from same errors and uncertainties. They can give significant error because they are heavily aggregated and this can give very different results depending on the model used (Lenzen et al., 2004). Very few studies until now have studied the uncertainties in MIROA but Lenze et al., 2010 used the Monte Carlo technique to study uncertainties which concluded that they can be found in; the fact that it is not possible to capture structural change of foreign IO data, divergence in prices, mismatches of sectors between countries, lack of import matrices that do not capture changes in import structure and choice of price conversion factors. Peters 2007 based on the experience with the GTAP database identified that the main challenges of MRIO are data with the issues of; currency, inflation, product differentiation, aggregation, periodic updating, averaging issues, trade statistics, system boundaries and international transportation (Peters, 2007).

2.2 Hybrid Analysis

To approach the disadvantages found in the IOA and LCA different hybrid methods have emerged combining these two methods in different models. Following three man hybrid approaches are discussed; Tiered hybrid analysis (also called; additive hybrid method (Forrest and Williams, 2010, Zhain and Williams, 2010, separative hybrid analysis (Williams 2004) economic balance hybrid LCA (Deng et al., 2011)), Integrated hybrid analysis (also called; Embedded hybrid analysis (Weidema et al., 2009) and Input-Output based hybrid analysis which separately in different articles are also called by the names Hybrid approaches, or Hybrid LCA (Stokes and Horvarth 2009, Crawford 2008). Bullard et al., (1978) combined LCA and IOA with the purpose to eliminate or minimize the truncation in LCA and aggregation errors in IOA in a new hybrid method for energy analysis. Showing this in a case study by calculating the energy cost of a coal-fired power plant that it is possible to successfully integrate IOA data with LCA and that all inputs do not have to be high detailed in order to get an accurate results (Bullar et al., 1978). Engelenburg et al., (1994) demonstrated the hybrid method with further improvements through a ten step approach applying them to a domestic refrigerator (Engelenbur et al., 1994). The approach was further improved by Wilting in 1996 through an eleven step method, and by analyzing the uncertainties it was concluded that to get more accurate results process data should be used as much as possible (Wilting, 1996). These approaches are all methods of a Tiered hybrid analysis in which the LCA data are used for use and end-of-life phases and some important lower-order upstream requirements of the functional unit and IOA is used for materials extraction and manufacturing (Suh et al 2004). The first Input-Output based hybrid analysis was published in Treloar (1997), where process data was incorporated to the IOA with the purpose to improve it. Treloar applied a hybrid method to the Australian residential building sector by extracting embodied energy paths from the IO table showing that IO data could be used for analysis of paths through the use of Structural Path Analysis (SPA) where process data are not available (Treloar 1997). Joshi (2000) used LCA data do disaggregate sector for which more detailed data where needed of an IOA table (Joshi 2000). Suh 2004, presented a model called Integrated hybrid analysis where both upstream and downstream cut-offs are accounted for to improve the limits of the LCA analysis by using IOA data through a matrix inversion method (Suh, 2004). These hybrid methods have since their first applications been applied to different case studies.

2.2.1 Tiered Hybrid Analysis

Tiered hybrid analysis (THA) uses process data from LCA for the use and disposal phase, and for some important upstream processes, while IO data covers the remaining processes (Suh and Huppes, 2005). The data used depends also on data availability, on to what degree the accuracy should be, the budget, labor and time (Suh et al., 2004).

Tiered hybrid analysis has been applied to overcome the methodological limitations of process LCA and IOA (Rowley et al., 2009; Deng et al., 2011) to reduce cut-off errors (Zhai and Williams, 2010), to remove system boundary (Peters A et al., 2010), to avoid truncation (Heinounen and Junnila, 2010), to conduct a Carbon Footprint analysis (Heinonen and Junnila, 2010) and to be able to incorporate data that is not available from other sources (Peters B et al., 2010; Forrest and Williams, 2010). It has been used in studies assessing products with geographical variation (Lenzen, 2004) and in comparative assessments studies (Wood et al., 2006). To test the methodology it has been compared both with process LCA studies (Stromman et al., 2006, Michelsen et al., 2008) and with IOA studies (Mattila et al., 2010). Methodological improvements, as applying the Leontief price model to estimate missing inventory items in respect to both physical and monetary flows have been dealt with in Stromman and Solli, 2008, which was then applied in Michelsen et al., 2008.

The advantages of the tiered hybrid analysis have been shown with various studies to result in a more complete assessment when compared to studies conducted by LCA or IOA (Lenzen 2004, Wood et al., 2006, Rowley et al., 2009, Zhai and Williams, 2010, Williams 2004, Mattila et al., 2010, Michelsen et al., 2008, Stromman and Solli, 2008). In Stromman and Solli (2008) the study concludes that almost 60% of some impacts would be missed with a LCA and Mattila et al., (2010) concluded that even if IOA for large parts gave similar results some impact categories were significantly underestimated or overestimated compared to tiered hybrid analysis (Stromman and Solli, 2008, Mattila et al., 2010). The analysis has the possibility to avoid truncation errors and take into account data not available for LCA (Peters A et al., 2010, Peters B et al., 2010). Having the possibility to import data from IO tables an assessment of more complex systems can be studied (Kofoworola & Gheewala, 2008). If compared, the results of an IOA and a LCA in an equal case assessment it could be argued that the results are correct to some degree in both of the studies as the end results could be similar, but when compared also with results from a tiered hybrid analysis it is shown that the assessment results are undervalued with 20% (Rowley et al., 2009). Tiered hybrid analysis can also be useful to identify the causes for differences in the results gained from a LCA and IOA, by given a third perspective (Rowley et al., 2009). The differences in the end result obtained by a hybrid analysis can lead also to a difference in the final policy recommendation, as shown by Deng in the assessment of a laptop computer in which the intensity of energy and carbon dioxide during manufacturing and use was quantified (Deng et al., 2011). Using the analysis there is the possibility to make a comparison study of same case scenarios with different geographical location by integrating data that were missing before (Forrest & Williams, 2010). As in LCA uses only process data, and IOA uses only monetary data, in a tiered hybrid analysis energy requirements can be determined in both physical and monetary units (Wilting 1996).

Tiered analysis suffers from double counting issues as the IO table covers all the processes in an economy, the processes covered by the LCA are present also in IO data. The issue to overcome double counting has been approached by Rowley et al., 2009, by calculating system incompleteness factors and deleting them from the IO data, in this way the IO data represents only the cut-offs from LCA and by Heinounen and Junnila, 2010 to avoid double counting of emissions (Rowley et al., 2009, Heinounen and Junnila, 2010). The disadvantages of the analysis method that are generally mentioned are the data; lack of available or accurate data (Wood et al., 2006, Zhai and Williams, 2010, Deng et al., 2011, Peters A et al., 2010), old data (Stromman and Solli, 2008, Zhai and Williams, 2010), use of average data (Michelsen et al., 2008), need to use data from different sources (Lenzen 2004), lack of common IO table database (Williams 2004), geographical differences make variation in data (Forrest), need to make assumptions because of lack of data (Kofoworola & Gheewala, 2008) and lack of detailed LCI database (Peters B et al., 2010). Wilting, 1996, argues that the data of an average product from an economic sector are not valid for a specific product (Wilting 1996). Depending on the data source the results could change significantly (Williams 2004). An important factor which is not considered in a tiered hybrid analysis is the technological change (Williams 2004). Making a comparison with previous studies of a products environmental assessment is difficult as previous studies generally use different inputs and analysis method (Heinounen and Junnila, 2010). The same problem arises if the results need to be complementary to previous studies, hence the methods are to different to be able to draw valid conclusions (Williams 2004). In general the model has still not been applied enough and can be uncertain (Heinounen and Junnila, 2010).The most valid uncertainties come from the data sources and data used, as old data, IO-data, data not from the specific geographical source, broad average data, data estimates (Stromman and Solli, 2008, Michelsen et al., 2008, Wood 2006, Zhai and Williams, 2010, Peters A et al., 2010, Peters B et al., 2010). Uncertainties which depend on model parameter, that are common with IOA and LCA return in the tiered hybrid analysis as; due to price, lifespam, geographical, temporal uncertainties, aggregation, assumptions as that local IO tables apply globally, variables as allocation, emission data uncertainties, truncation of LCA data issues give uncertain results (Peters A et al., 2010, Deng et al., 2011, Williams 2004, Lenzen 2004, Wilting 1996, Benders et al., 2012).

The issues that occurs with single region IO models which do not take into account the imports can be solved with a Multi Regional Input Output Analysis, where more than one country is presented in the table capturing trade between the countries in the table within the intermediate demand, are and results in a more detailed results (Wiedmann, 2009). Vringer et al., 2010 used multi regional tables in a tired analysis to assess the environmental impact of Dutch private consumption, analyzing the environmental impact of 350 consumption categories. In this way the data from imports could be taken in consideration. This study resulted in a more complete assessment compared both to a MRIO assessment and to a tiered hybrid assessment. The study found uncertainties in results from the LCA data and IO data used were not compatible as they were from different years, also a degree of double counting was detected (Vringer et. al 2010)

2.2.2 Integrated Hybrid Analysis

The integrated hybrid analysis consists of a matrix that includes four different parts, which are interconnected by physical and monetary systems, modeling LCA data, IO data, upstream and downstream cut-offs. In this way the IO data and LCA data are fully integrated and it is possible to model full feedback loops (Suh 2004). Suh (2004) demonstrates the model by applying it to a simplified product system (a toaster), introducing the possibility to use analytical tools, in this case SPA, to analyze the paths of the product system. SPA can also be used before conducting a hybrid analysis to determine the boundary between the two analysis, hence through the path analysis the most important paths are determined which can minimize the data requirement that comes with hybrid analysis (Suh et al., 2004). In other hybrid analysis the IO- and LCA data are summed to obtain the results wanted, in this way the data are not fully integrated which can lead to double counting, unable to model the interactive relationship between the both systems and analytical tools for LCA and IO are difficult to use (Suh, 2004). The difference between the tiered hybrid analysis and integrated hybrid analysis is the possibility to take in the downstream cut-offs, the discussion of the relevancy of downstream cut-offs can be found in (Peters and Hertwich, A 2006, Suh 2006), and the possibility to easier use analytical tools as SPA (Suh 2006).

As this method is recently developed it has been applied to few studies. One application has been to the life cycle of biodiesel to avoid methodological limitations of process LCA, using also the SPA to analyze the supply chain paths and identify the highest points of impact (Acquaye et al., 2011). In a different study a comparison of methods was conducted between the integrated hybrid analysis and the Input-Output hybrid analysis by studying the environmental impact of a wind power plant, taking into account multi-regional IO-data (Wiedmann et al., 2011). Ferraro and Nhambiu (2009) used the EIO-LCA model as bases for IO data in an Integrated hybrid analysis to be able to construct a hybrid computer model for the Portuguese economy. This model was then tested on a case study by assessing the Global Warming Potential (GWP) of manufacturing of crystal giftware. The case study was compared to a LCA and an EIO-LCA. Kondo and Nakamura (2004) developed a methodology called Waste Input Output (WIO), to be able to take into account the interdependence between the flow of goods and waste by applying the Leontief IO model to LCA waste management (Nakamura and Kondo, 2002). In the WIO model they were also able to take into account the cost assessment (Nakamura & Kondo, 2006). This model can be grouped as an integrated hybrid model as both physical and monetary flows are represented in a single technology matrix with both foreground processes and background economy (Suh and Nakamura, 2007).

When applying Integrated hybrid analysis one of the advantages is that no monetarization of physical flows is necessary and that it is possible to use physical units instead monetary (Wiedmann et al., 2011). The analysis shows a more complete assessment (Wiedmann et al., 2011), by integrating the IO data it is possible to take into account the higher upstream inputs and the data from Rest of the World (ROW) (Acquaye et al., 2011), and also economical data which leads to the possibility to assess the environmental contribution of the product but also at the same time the effects on economic activity and their correlation (Kondo & Nakamura, 2004, Nakamura and Kondo, 2002). Ferrao and Nhambiu (2009) showed that the model can overcome the limitations of an IOA and LCA by comparing a same case study with the LCA. The LCA underestimated the GWP for raw materials production, due to boundary truncations and EIO-LCA underestimated CO2 emissions due to specific inputs that in the aggregated data could not be presented (Ferraro and Nhambiu, 2009). Once the analysis is set up one can implement a wide range of alternative scenarios (Kondo & Nakamura, 2004).

As for the tiered hybrid analyses, the disadvantages found with data are consistent, the main problem is the lack of data (Wiedmann et al., 2011, Acquaye et al., 2011, Kondo & Nakamura, 2004), but also the variable data from different sources which are changing many time during a life cycle of a product are unsecure (Acquaye et al., 2011, Wiedmann et al., 2011), and the need to make different assumptions (Kondo & Nakamura, 2004). Material inputs that are not presented in the process matrix are neither taken from IO data, to avoid double counted data, but in this way some inputs can be missed if they are more then one (Wiedmann et al., 2011). Wiedmann et al., (2011) claims that the results of an Integrated hybrid analysis showing a higher result than an analysis done with LCA does not have to be solely due to a more complete assessment study, but could also be explained with different errors in the study and data as; errors in process input estimates, errors due to disaggregating the IO table, parametric and systematic error that may exist in the model used (Wiedmann et al., 2011). The uncertainties in the studies results come from inputs in the upstream matrix (Wiedmann et al., 2011, Acquaye et al., 2011), uncertainty in data variability and estimated data (Kondo & Nakamura, 2004). Comparing Input output based hybrid analysis and Integrated hybrid analysis, Wiedmann et al., (2011) drew general uncertainties that both studies are affected from; data uncertainties, allocation, assuming proportionally and homogeneity, sectoral aggregation, temporal aspects, representativeness of model data, monetary exchange rated (for multiregional models), price conversion (Wiedmann et al., 2011).

2.2.3 Input-Output Based Hybrid Analysis

In an Input-Output based hybrid analysis, to get a more detailed analysis, the sectors are disaggregated where available data from a LCA exists. A tiered hybrid analysis method is applied for the use and end-of-life stages because IOA does not cover them in a life cycle of a product system (Suh and Huppes, 2005). In Joshi (2000) three different IO based hybrid model are described, Model II, III and IV, which deal with the issues of heterogeneous products of a sector, double counting and aggregated data (Joshi, 2000).

The IO-based hybrid analysis has been applied to avoid the limitation of both IOA and LCA. In Treloar et al., (2004) a life-cycle energy study is conducted for eight different road designs to gain a higher degree of information than in an LCA study (Treloar et al., 2004). Other studies have also applied this hybrid method to overcome limitations of LCA (Facanha and Horvath, 2006); by including inputs not included in other process LCA studies (Crawford, 2009) (Murray et al., 2008) or to have a more fast and cost effective study (Joshi 2000), but also it has been applied to overcoming the issues of IOA as the lack of environmental impact data (Engstrom et al., 2007). Kim and Hur (2009) used IO-based hybrid analysis to be able to integrate working- and external environment for an environmental assessment (Kim & Hur, 2009), others used the analysis for comparison study of two battery systems (Lankey and McMichael, 2000) or 13 crop residue conversion technologies (Lu and Zhang, 2010), or for development of a decision-support tool for policymakers and managers (Stokes and Horvath, 2009). To evaluate the methodology it has been compared to LCA and IOA studies with a case study of two commercial office buildings (Crawford 2008) and a case study of 1,3-propanediol (PDO) (Urban et al., 2009).

When compared to Integrated hybrid analysis, IO-based hybrid analysis has many advantages while efficient it is less expensive, easier to implement, much less data processing and less complicated updating procedures, requires less effort to compile the model framework, national IO tables represent country-specific products and industry data is usually more current than data for specific processes (Wiedmann et al., 2011).

IO-based hybrid analysis has shown to be a more complete assessment both compared with IOA and LCA (Crawford 2009, Kucukvar & Tatari, 2011, Crawford 2008, Boyd et al., 2009, Engstrom et al., 2007, Facanha & Horvath, 2006) by improving system boundary completeness (Crawford 2008) and new data advantages as the possibility to have data for many generations and data that are specific to the processes, geographical location and time period of the study (Boyd et al., 2009). In Crawford (2009), assessing the life cycle of two wind turbines, it was concluded that half of the total embodied energy comes from the inputs that are excluded from process analysis, and that previous studies can be up to 78% incomplete (Crawford 2009). The IO-based hybrid analysis improves the accuracy of the traditional IOA studies by incorporating data from LCA that are more accurate (Weinzettel & Kovanda, 2009, Joshi 2000, Urban & Bakshi, 2009). In LCA there is no possibility to take in consideration economic data, for this reason IO-based hybrid analysis has shown to be a valid assessment method, but also for cases where environmental impact needs to be compared with the costs (Murrey et al., 2008). Comparison studies can easily and rapidly be conducted (Treloar et. al., 2004). IO-based hybrid analysis gives the possibility to consider both upstream and downstream effects, and in the cases where the environmental impacts data is available, the workload is small compared to LCA (Engstrom et al., 2007). Data uncertainty of IO data can be improved with LCA data (Boyd et al., 2009) and there is the possibility to cover imports of an economy (Engstrom et al., 2007).

The limitation found in the application of the IO-based hybrid analysis are the lack of specific and emissions data (Wiedmann et al., 2011, Kucukvar & Tatari, 2011, Kim & Hur, 2009, Weinzettel & Kovanda, 2009, Joshi 2000) and data that are assumed to be the same through the whole life cycle of a product (Wiedmann et al., 2011). The data are found to be unreliable because they are self reported and are subjected to measurement error and reporting requirement gaps (Lankey and McMichael, 2000). The use of IO data to account for missing process data is not reliable as the comparison of the equivalent data show that they do not provide a reliable representation, but it is better then not using any data at all to complete the system boundary (Crawford 2008). Estimations and assumptions contribute to lower data quality (Murrey et al., 2008, Lu & Zhang, 2010) and price variations can introduce errors in the analysis (Joshi 2000). IO-based hybrid analysis is difficulties to compare with other studies because of the complexity of the methods and data differences used (Urban et al., 2009). Assumptions and data uncertainties used in the model cause uncertainties in the results (Crawford 2008, Kucukvar & Tatari, 2011, Lankey and McMichael, 2000, Boyd et al., 2009, Kim, Lu, Murray et al., 2008), but also conversion from physical to monetary unit (Wiedmann et al., 2011). Estimation uncertainties are due to data collected from many different sources and time periods, normalized, aggregated and averaged to arrive at sector-level environmental indices (Joshi). The LCA input data results in parameter uncertainty due to imprecise, incomplete, or outdated measurements (Facanha & Horvath, 2006).

2.2.4 Comparison of the Hybrid Methods

To be able to analyze the application possibilities of the hybrid methods, the research question and the aim of the applied studies were analyzed. This was done by dividing the applied studies into different levels depending on the scope of the study by defining levels between micro, product level analysis and macro, economy wide analysis. Micro level analysis included cases as assessments of a product as batteries (Lantey & McMichael, 2000) or laptop computer (Deng et al., 2011) and macro level comprehends analysis as the assessment of socioeconomic and environmental analysis of a country. Meso level was defined as the sectorial level, which comprehends the level analysis of e.g. Swedish agriculture, waste life cycle strategies and forestry operations (Engstrom, 2007, Kondo & Nakamura 2004, Michelsen et al., 2008). Two level between these three were also distinguished: Micro-Meso and Meso-Macro. Micro-meso level is between the product analysis and sector analysis as an assessment of a typical biodiesel supply chain (Acquaye et al., 2011), case studies of commercial office buildings (Crawford 2008) or assessment of residential pools applied to nine different cities (Forrest & Williams, 2010). Meso-macro level is between sector analysis and economy wide analysis including analyzing carbon footprint of two metropolitan cities (Heinonen & Junnila, 2011) or environmental load of consumer good of the Dutch consumption (Vringer et al., 2010).

The studies which had the aim to compare two or more methods with each other were also distinguished and the studies which were applied only with the aim to demonstrate the new developed methodology though a case study resulting in given more weight to the methodological development rather to the choice of case study.

Table 1. The amount of articles applied on different levels out of total 40 articles. Micro: Product level Micro/ Meso: Middle level of product and Meso levels Meso: Sector level, basket of commodities etc. Meso/Macro: Middle level of Meso and economy wide levels Macro: Economy wide level Comparison: Comparison of two or more methodologies Demonstration: of methodology by applying to a case study.

	Micro	Micro/Meso	Meso	Meso/Macro	Macro	Comparison	Demonstration
All articles (40)	15	9	12	3	1	7	16
All articles %	37, 5%	22, 5%	30%	7, 5%	2, 5%	17, 5%	40%
IHA (7)	4	2	1	0	0	2	3
IHA %	57%	28, 6%	14%	-	-	29%	43%
IOBHA (14)	3	5	5	0	1	1?	6
IOBHA %	21, 4%	35, 7%	35, 7%	-	7%	7%	43%
THA (19)	8	2	6	3	0	2 – 5	5 -7
THA %	42%	10, 5%	31, 6%	15, 8%	-	26%	37%

The results show that the most applied studies are on a micro level, especially for the methods Integrated hybrid analysis and Tiered hybrid analysis, which show 57% and 42% of total applied studies respectively. These two methods have been developed to enhance the LCA, which is an analysis method that is product specific, it was expected that their main application would be on a product level. At the same time both of these methods show also one third of applications are on the sector level. By integrating the data of an IO table, the LCA a product analysis, could potentially gain in methodological improvement and be used on broader levels as an IO table gives the access to a broader range of data. The Input-Output based hybrid analysis is mostly applied on a meso and micro/meso level (35,7% each), showing that the possibility to integrate more detailed process data gives a methodology based on IO analysis a possibility to do a more detailed specific study than traditional IO analysis.

Around 40% of all articles are applied to demonstrate the development of the methodology through case studies, where the study seems to be applied with the aim for demonstrations purposes rather than for the specific sector or product. Very few articles have compared the methods with each other, only 17,5%. Mostly, the comparisons made are compared with previous LCA studies when available. In few cases the hybrid methods are compared to each other.

The hybrid methods take with them the advantages of the methods but also the disadvantages minus the resolved issues treated in the approach. There are common strengths and weaknesses for all hybrid methods and more specific ones found in the applied studies. All three hybrid analysis can be concluded to be more complete assessments than LCA and IOA. They also have in common as a strength;

- the use of mixed units,
- possibility to avoid truncation
- they extend the system boundary
- possibility to combine the economic and environmental analysis
- can help to identify the cause of differences between LCA and IOA based results and reduce the likelihood of drawing false conclusions about the relationship between the results

There are three main repeating weaknesses as can also be found as weaknesses in IOA and LCA, which are data issues, assumptions and uncertainties with others;

- Data issues: lack of data (specific data and emission data), variables, average data uncertainties, geographical errors, lack of national IO tables, different years of LCA and IO data, old emission data, data uncertainties (in price, lifespam, temporal), aggregated data, outdated measures, imprecise measures, reporting gaps, estimations, environmental data from different sources, adaptations, quality differences, truncation of LCA data
- Assumptions: imports as local, rest of the world assumptions, foreign industries homogenous, proportionality between monetary and physical flows
- Uncertainties: in national statistical data, imputation and balancing, allocation, assuming proportionally and homogeneity, concordance, sectoral and regional aggregation, temporal discrepancies, representativeness of model data, monetary exchange rates (for MRIO), price conversion

- Errors due to; process input estimates, disaggregating the IO table, parametric and systematic errors in the model
- Geographical, temporal, tax related variations in prices •Estimation of flow tables
- Source trade margins
- Differences in international tables
- Technological changes not considered

The data issues are a common problem for all the analysis methods, not only the accuracy and quality of the data but also the lack of available data especially environmental one and the time periods of data published or collected. The part of the problem could be faced with common databases for hybrid methods. There are emerging more IO databases in the past years, with environmental data and a multi-regional perspectives e.g. Global Trade Analysis Project (GTAP), ExioBase (GTAP 2012, Exiobase 2011), but a hybrid databases does not exists yet.

Tiered hybrid analysis and Integrated hybrid analysis can bee seen as a first and a second step in the way of improving the LCA accuracy of impact assessment. In the Tiered hybrid analysis the possibility to avoid truncation errors by taken into account monetary data from IOA, gives also the opportunity for more complex systems to be studied. It is also a rather fast methodology when one already has a LCA study ready and the user can determine the reliability of the results by moving the boundary between LCA and IOA data. Also possibility to avoid truncation errors, complete coverage of indirect requirements and overcome of double counting. An Integrated hybrid analysis can be seen as a even more complete analysis, a second step, as it fully integrates the IO and LCA data with their original units which do not need to be converted and both upstream and downstream inputs can be measured in this way. In this method it is also easier to take advantage of different analytical tools from IOA as SPA. But also it preserve process specificity and enables full feedback look to be modeled. Tiered hybrid analysis has been applied to many more studies than integrated hybrid analysis as tired hybrid analysis goes back to the 1978 and the integrated analysis is first mentioned 2006. This results also that more disadvantages are found. In Tiered hybrid analysis problems occurring is the overestimation of results, difficulty to compare with other studies, double counting, some processes are hard to match to IO sectors and difficulty to allocate the differences of the results compare with LCA. Due to the lack of applications of integrated hybrid analysis it is not easy to find specific problems. The Tiered hybrid analysis theoretically should be less accurate than the Integrated hybrid analysis, as it does not take in downstream effects, and in the Integrated hybrid analysis the data are fully integrated, but still there are no studies comparing these both models. The accuracy of the methods has not yet been analyzed.

In these two methods both economic and environmental assessments are merged into one method, which makes it also possible to easier take in consideration data from different countries. Many studies have used MRIO to assess the consumption and production systems in the international trade analyzing emissions embodied in trade (Ackerman, 2007) in supply chains (Wilting, 2008) and the effect of geographical location on emissions showing (Weber, 2008) it to be a reliable method to account for emissions from a consumption perspective (Wiedemann et. al., 2007, Wiedemann 2009). Both Tiered hybrid analysis and Integrated hybrid analysis have successfully used multi-regional tables as the basis for the IO data, which gives the possibility to take in consideration the part of the life cycle beyond national borders, which would be even more time consuming and costly if it had to be measured.

IOA, which is a economy wide assessment and in which there is no need to set the system boundary, uses publicly available data, thus is fairly quick with a low cost. This advantages is brought also with the Input-output based hybrid analysis as it is an improvement of the IOA by disaggregating the sectors with more detailed LCA data. This hybrid method has a smaller workload than a LCA or the other two hybrid methods, it is easier to update and to implement. It takes in consideration both up and downstream effects and the system boundary is complete. IO based hybrid analysis has succeeded to affront the problem of aggregated data in IOA by introducing more specific data from LCA studies, when they are available. This can also lead to more accuracy in a IO model when conducting specific product analysis, as the method is less time consuming it can maybe gain an further advantage to LCA in the future. But the hybrid method can only be conducted if LCA data exists for that specific product, and conversion from physical to monetary units causes data uncertainties. The overall use of IO data is not either reliable for specific product analysis.

As the hybrid applications are still not widely used, it is difficult to compare the results of hybrid studies with previous ones, as the methodologies and data used differ significantly with the previous ones which would be LCA or IOA studies. It is also difficult to use them as complementary studies for the same reason. This will be easier more the approaches are used. The only possibility when comparing is to use same case scenarios for methodology comparison.

3. Environmental Assessment of the Agri-food Sector in EU-25

3.1 Introduction

Two major studies on the EU level have identified the food sector as a significant contributor to environmental pressures. The EIPRO study concluded that three product areas of consumption contributed to 70-80% of environmental impact by various impact categories, and those are; food and drink, private transportation and housing (Tukker, 2006). The EEA study concluded both in the case of production and consumption that the agricultural and food sector was an significant contributor to GHG emissions. Four production industries are responsible for 75% of GHG emissions; i) agriculture, ii) the electricity industry, iii) transport services and iv) some basic manufacturing industries. Further four product groups were concluded to be responsible for 42% of GHG emissions; i) construction works, ii) food products, iii) products of agriculture, forestry and fisheries, and iv) electricity, gas and water services (European Environment Agency, 2013).

Thus the aim of this study is to analyze in a greater detail the agricultural sectors contribution to Global warming caused by the consumption of food products. The objective of this study is to identify the food products that have the greatest Global warming impact through their life cycle, identifying their environmental impact and evaluating the mitigation possibilities for the same. At the same time evaluating methodological possibilities and models to be applied for this purpose.

3.1.1 Scope

- To identify the environmental impact of food products through their life cycle by their overall volume used and economical value
- The focus lies on the life cycle impact of products by their final consumption in the EU-25 taking into account both household and government expenditure. All processes are taken into account; production, use and waste management. The impact of exports are not included.
- The year of reference is 2003, no future or past scenarios were included
- A top-down approach is used (Input-output analysis)
- Structural Path Analysis is used to study the linkages between the industry and products

To be able to analyze the Global warming of the food sector different models were assessed with this aim in focus and found that the E3IOT model is the most detailed model on the European Union (EU) level. This model was applied by using the CMLCA software to study the impact of global warming from food consumption products in EU-25. E3IOT is an Environmentally Extended Input-output (EEIO) model which is an update of the CEDA EU-25 model. It was developed by the Institute of Environmental Sciences (CML), University of Leiden and executed by TNO, CML, VITO and DTU for IPTS (Tukker et al., 2006), (Huppes et al., 2008).

3.1.2 The model E3IOT

The E3IOT model represents the economy of the countries in EU-25 (see Table 2) with the sectors disaggregated from a level of 35x35 sectors (IO table published by OECD) to a detail of 480x480 sectors.

Table 2. The countries in the European Union 25.

European union 25 (2004–2006)							
1	Austra	8	France	15	Lithuania	22	Slovenia
2	Belgium	9	Germany	16	Luxembourg	23	Spain
3	Cyprus	10	Greece	17	Malta	24	Sweden
4	Czech Republic	11	Hungary	18	Netherlands	25	United Kingdom
5	Denmark	12	Ireland	19	Poland		
6	Estonia	13	Italy	20	Portugal		
7	Finland	14	Latvia	21	Slovakia		

Each industry besides the value data of the product in euro has the corresponding emissions data correlated to that specific production. The approach of the database is to assess the environmental impacts of final consumption products through their entire life cycle, thus covers also the use and waste management stages which lack in other EU IO models. There is no other database model that covers the European consumption sectors in this great detail as E3IOT. In total 250 commodities and services are covered, which are bought directly by consumers with additional ones that are intermediates. The production and consumption of products has also corresponding environmental interventions, over thousand environmental interventions per every product/industry. To be able to analyze this large amount of environmental emissions they have been divided in eight impact categories. Impact analysis is an analysis method often used in LCA. Only impact categories that have established methodologies are taken in consideration in E3IOT, other more insecure ones as biodiversity were left out. The impact categories are:

1. abiotic depletion
2. global warming
3. ozone layer depletion
4. human toxicity
5. ecotoxicity
6. photochemical oxidation
7. acidification
8. eutrophication

With the data available it is possible to quantify the environmental impact by total product consumed or per euro spent.

To be able to construct the E3IOT database a large amount of data had to be used coming upon different problematics and adaptations.

Main data sources:

- OECD, Input-output tables, country level
- Eurostat, final expenditure studies
- Technology matrix, USA, CEDA 3.0
- LCA, processes database EcoInvent
- Environmental interventions matrix, USA, CEDA 3.0
- Environmental interventions tables, Western Europe
- and several other data sources

E3IOT was based on the CEDA 3.0 database because it has the most detailed sector division. The CEDA 3.0 represents the economical data of the U.S. that do not always correspond to the economy of EU. These data are in;

- the technology matrix, which is based on the US industry structure
- the environmental matrix, which uses US emission factors
- the classification of industry sectors, which based on the US Bureau of Economic Analysis (BEA), that do not always correspond to the European classification list of consumption products (COICOP)

Due to use of data from another economical structure (U.S. data) the model assumes similarity in production processes in the U.S. and Europe for most of the processes to be able to gain a higher detail process information. The technical coefficient has been changed to European standards for several key sectors as agriculture, energy mix for electricity generation. Other problems faced concerned the data compatibility involved the use and the waste phase, the imports had to be modeled and the lack of statistics for the whole EU-25 regarding final demand of consumer expenditures (for EU-15 there is).

The technology matrix had to be adapted based on the OECD 35x35 matrix to a 480x480 matrix, assuming that there would not be highly relevant differences between the structure of the production chain of a certain products between EU and US. Emissions from use phase and the waste phase were modeled only for relevant European products. Imported products were assumed to be made in Europe. Several adaptations of the emission data were conducted by matching different sets of data to be able to match the final demand of EU-25.

Two assumption have been made:

1. imported products and services are made with the same technology as in the EU-25
2. products produced in EU for export, consumed outside, have the same environmental intervention as imported products

To be able to assess the consumption of products, the production and waste matrixes are also modeled in the database as they are connected to the consumption activities. Thus the database has three technology matrixes: i) the production technology matrix, ii) the consumption of products technology matrix, and iii) the use of waste between disposal activities technology matrix.

- Production technology matrix: assumes that all products are produced with the same technology as in the EU (even if imported).
- Final consumption technology matrix: the products sold from consumer to consumer directly were not taken in consideration.
- Disposal activities technology matrix: the two disposal management sectors are the sanitary services, steam supply and irrigation systems (collection, landfill and incineration) and scrap (main recycling activities). With four recycling flows which are: paper, metals, glass and plastics. The productional waste is in the water supply and sewerage systems which combine both production activities and disposal activities because this is usually payed together in EU countries.

The emissions are based mostly on the European statistic and partly from U.S. data in the case of the structure of emissions. The emissions are presented per unit sales for every industry/product in euro, hence for the production and consumption. The emissions for households are in five consumption activities: car driving, heating, cooking, washing and use of pesticides. Emissions taken into account from car driving come from the sum of money spent on car, fuel, tiers and car insurance but specific taxes were not included. Heating and cooking considers the gas used by households, total energy use (water and room heating 89%, cooking 2%, electricity 10%), and the oil used for heating is treated as gas. Electricity is distributed over twelve products using electricity, and is not created as direct emissions from the household but from the production and waste of the same, the same goes for water use.

Due to lack of data and time some direct emissions have not been taken in consideration as; cigarettes, candles, paint etc or emissions from human and pet excretion. The links between electricity used in the household from the electricity firm or the waste of use of detergents have not been specified. Final demand is defined by the consumption expenditures defined by the sectors based on UNs Classification of Individual Consumption According to Purpose (COICOP) level 3 classifications with some changes which can bee seen in the Appendix 3. The government demand was calculated as an extrapolation of demand per private consumption category, thus due to lack of certain data this can underestimate various expenditures from the governmental channels. The classifications of the consumption products have been based from the various data used in the model from BEA and OECD which were adapted to the classification system of UN COICOP at a level 1, 2 and 3. Some products were adapted to fit best the classification from level 1 to 3, there are also products that have different classification as petrol or cars that were merged together. The full transformation list can be found in Appendix 3.

3.2 Material and Method

Method: Environmental extended Input-output analysis, and Structural Path Analysis
Model: E3IOT
Year: 2003
Software: CMLCA
Functional unit: total domestic final demand for products consumed in EU-25, including private household and final government consumption.
System boundary E3IOT: covers the life cycle of products from cradle-to-grave, including production of imported goods, production of goods in Europe, use and waste management of products. Production in Europe for exports is not included. 500 commodities and services, 250 directly bought and the rest as intermediates.
System boundary of the analysis: the analysis focuses on the sector (according to COICOP classification) Food and non-alcoholic beverages (44 products), even if the first analysis are done on the sectorial level of the whole economy to see the correlations. The sector Alcoholic beverages, tobacco and narcotics was not taken in consideration as it differs in policy development and production procedures. The sector Restaurants and hotels (eating and drinking places) not merged with the Food sector as it was not possible to separate the Food and non-alcoholic beverages sector and the Alcoholic beverages, tobacco and narcotics sector. This study will focus only on one impact category, Global warming.

Table 3. Emissions contributing to Global warming from E3IOT.

Emissions			
1	1,1,1-trichloroethane[air]	**13**	HCFC-123[air]
2	Carbon dioxide[air]	**14**	HCFC-124[air]
3	CFC-11[air]	**15**	HCFC-141b[air]
4	CFC-113[air]	**16**	HCFC-142b[air]
5	CFC-114[air]	**17**	HCFC-22 [air]
6	CFC-115[air]	**18**	HCFC-225ca[air]
7	CFC-12[air]	**19**	HCFC-225cb[air]
8	CFC-13[air]	**20**	Methane[air]
9	Dichloromethane[air]	**21**	Methyl Chloride[air]

Emissions			
10	Dinitrogen oxide[air]	**22**	methylbromide[air]
11	HALON-1211[air]	**23**	Tetrachloromethane[air]
12	HALON-1301[air]	**24**	Trichloromethane[air]

The input output analysis (IOA) (described in CH 2) uses IO tables in which the industries are inter-related and represents the outputs of an economy. The environmentally extended input output analysis (EEIO) uses IO tables that are extended with emissions causing impact on the environment. The IO model industries produce outputs by consuming other products/ industries in a fixed ratio. With this assumption it is possible to define the **A** matrix that is the domestic intermediate industry output in monetary values required to produce one unit of monetary output of another product flow. Then the sum of the industry output consumed by the intermediate industries by final consumer **x** can be calculated:

$$x = Ax + y \quad (1)$$

x = the total industry output

A = mxm matrix, domestic intermediate industry outputs in monetary values

y = the total final consumption of industry output

The total domestic industry output **x** required to satisfy final consumption is calculated by:

$$x = (I - A)^{-1} y \quad (2)$$

I = mxm identity matrix

The EEIO model is then calculated by assuming that the amount of environmental intervention generated by an industry is proportional to the amount of output of the industry, and that the identity of environmental interventions and the ratio between them are fixed. The matrix **B** is specified representing the direct environmental interventions for each sector. Then the total direct and indirect pollutant emissions and natural resources consumed by domestic industries to deliver a certain amount of industry output is calculated by:

$$m = B(I - A)^{-1} k \quad (3)$$

B = qxm matrix, shows the amount of pollutants emitted and natural resources consumed to produce one monetary unit of each industry's output

M = total domestic direct and indirect environmental intervention vector

k =any vector that shows net industry output of the system

(Tukker et al., 2006)

The total of direct plus indirect demand for each sector which represents the total supply of each industry can be calculated from:

$$x = (I - A)^{-1} k \quad (4)$$

x =the total supply vector

Then the emissions associated with the total supply vector are calculated:

$$m = Bx \quad (5)$$

In the E3IOT model the environmental interventions during production and the consumption and waste management phases of product are taken into account. Thus, the model has matrices for consumption activities (A_{22}) and post-consumer waste management (A_{33}). To be bale to record the relations between these three activities six linking matrices are specified (eq. 6). For each of the three activity groups a corresponding **B** matrix has been developed, resulting in the E3IOT model:

$$m = (B_1 B_2 B_3) \times \left[I - \begin{bmatrix} A_{11} A_{12} A_{13} \\ A_{21} A_{22} A_{23} \\ A_{31} A_{32} A_{33} \end{bmatrix} \right]^{-1} k \quad (6)$$

(Tukker et al., 2009)

Structural Path Analysis (SPA) was developed by Waugh 1950 but firstly applied in 1984 by Defourny and Thorbecke. In the SPA the Leontief inverse expands the direct requirements matrix which results in an analysis of the linkages between the final consumption and production. In this way it is possible to study the impacts caused by emissions from industry to product through different paths the product passes, upstream in a supply chain. By disaggregation of the product by every path the contribution can be illustrated showing the total environmental impact from the demand. Usually it does not have to be the industry or the final product consumed with the highest impact, linkages between can also have significant contributions (Minx et al., 2008), thus to be bale to analyze mitigation possibilities in a given production a SPA can identify the hot spots for improvement.

3.3 Results

Figure 6. illustrates the share of the environmental impact categories caused by the consumption of products in EU-25. As can be seen the impact category Global warming is responsible for 35% of the total share and is the most contributing environmental impact category. The second and third categories with the highest share are contributing with more then a half impact in comparison with Global warming, these are Human toxicity (17%) and Eutrophication (15%).

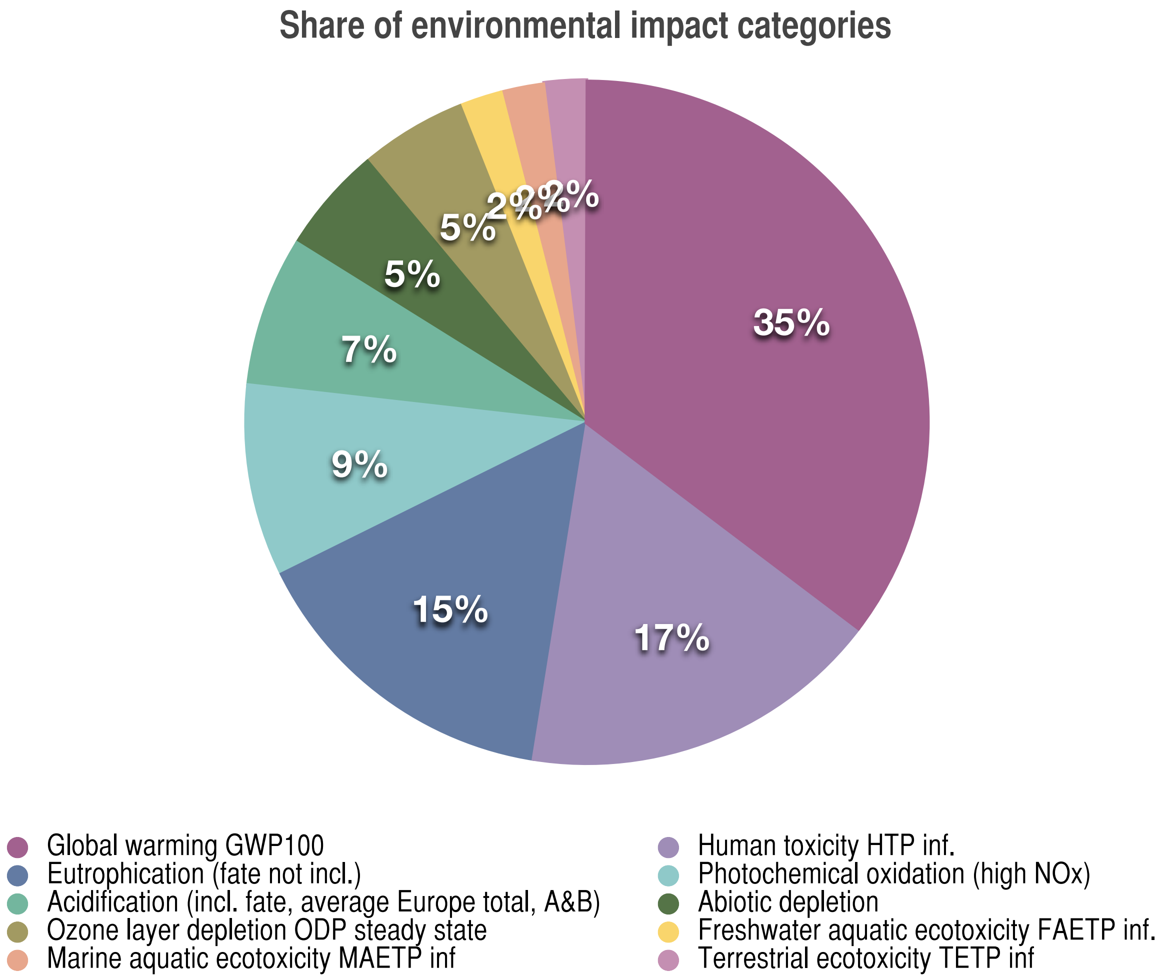

Figure 6. Share of impact categories caused by the consumption in the EU-25.

The significance of the contribution of Global warming compared to the other impact categories is clearly demonstrated, thus the identification of mitigation possibilities from different sectors would be crucial. Hence, Global warming was chosen as the single environmental impact category to be studied and all the results that follow consider only this impact category. The emissions causing Global warming considered in the E3IOT database are 24 in total (see previous Table 3 for detail). Out of all emissions Carbon dioxide contributes with 71% and represents a significant share from the consumption of products in EU-25, see Figure 7. Following two are Methane and Dinitroxen oxide, that contribute with a share of 10% and 8% correspondingly. By grouping together these three emissions they cover almost 90% of all emissions released.

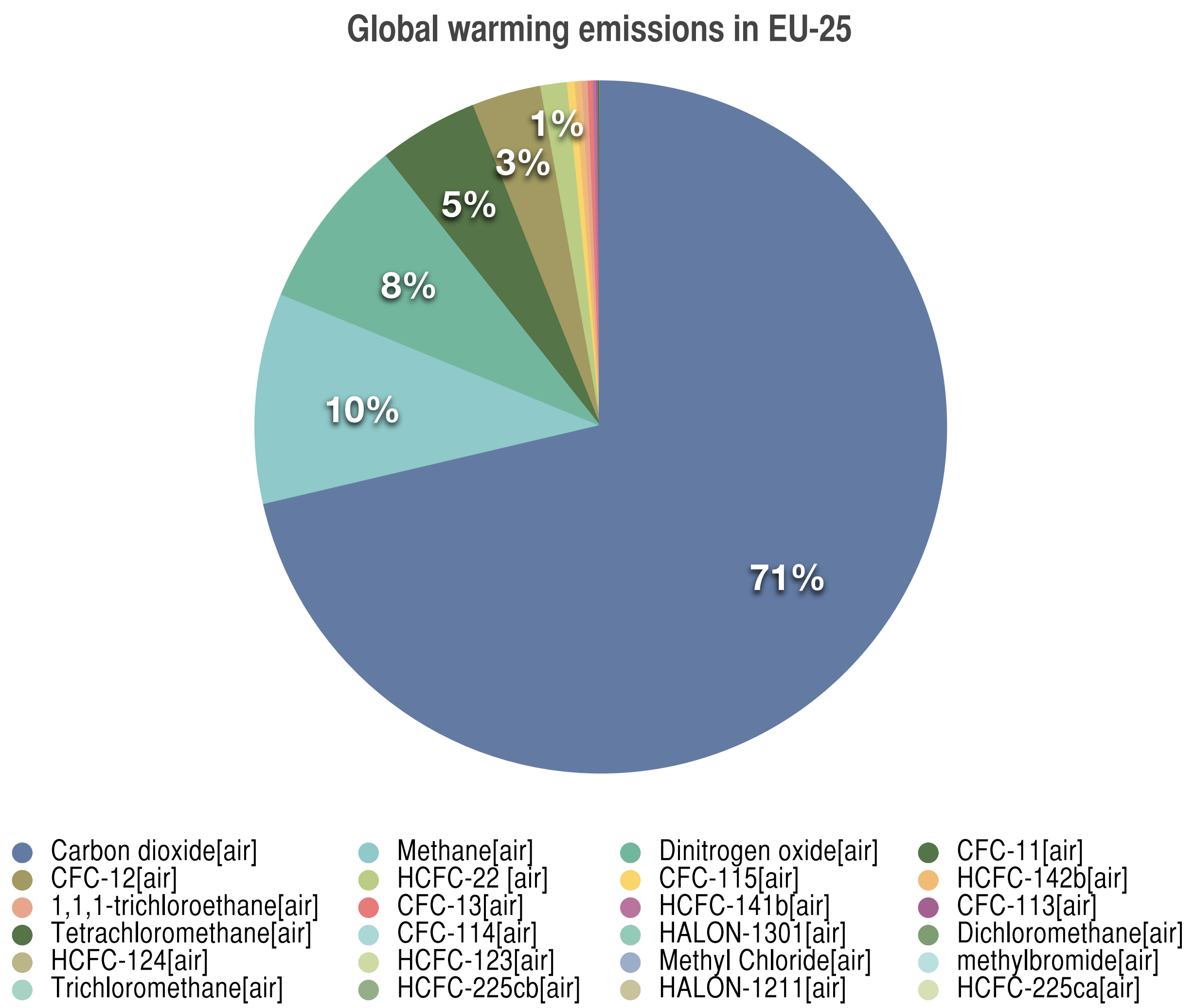

Figure 7. Share of emissions causing Global warming from the overall consumption in EU-25.

Figure 8 illustrates the distribution of the impact caused from the sectors (level 1 in COICOP) of the European economy from final household consumption to Global warming. Household, which also implies car driving, contributes alone with 41% out of the total (2 000 out of total 4 930 million tonCO2eq) final consumption of products. Following is the Food sector (Food and non-alcoholic beverages), which contributes with 25% in total (1 210 million tonCO2eq). The sector Alcoholic beverages, tobacco and narcotics which is separated in the classification COICOP was also separated from the Food sector in the analysis. The Restaurants and hotel sector which includes products from food and beverages consumed in catering, hotels, restaurants etc. contributes with an other 7% (347 million tonCO2eq). As the sectors Food and Alcoholic beverages are separated, the Restaurants and hotel sector was also kept separated in further analysis of the consumption of food products. But it can bee seen that the Alcohol sector which contributes with only 1% (76 million tonCO2eq) of the share, would probably not take a high share of the Restaurant sector as well. If we would merge Food and Restaurant sectors they would have a share of 35% (1 560 million tonCO2eq), and further with the alcohol sector of a total 36% (1 630 million tonCO2eq) impact. This implied that the minimum impact from the agricultural industry is 25% and a maximum up to 36%.

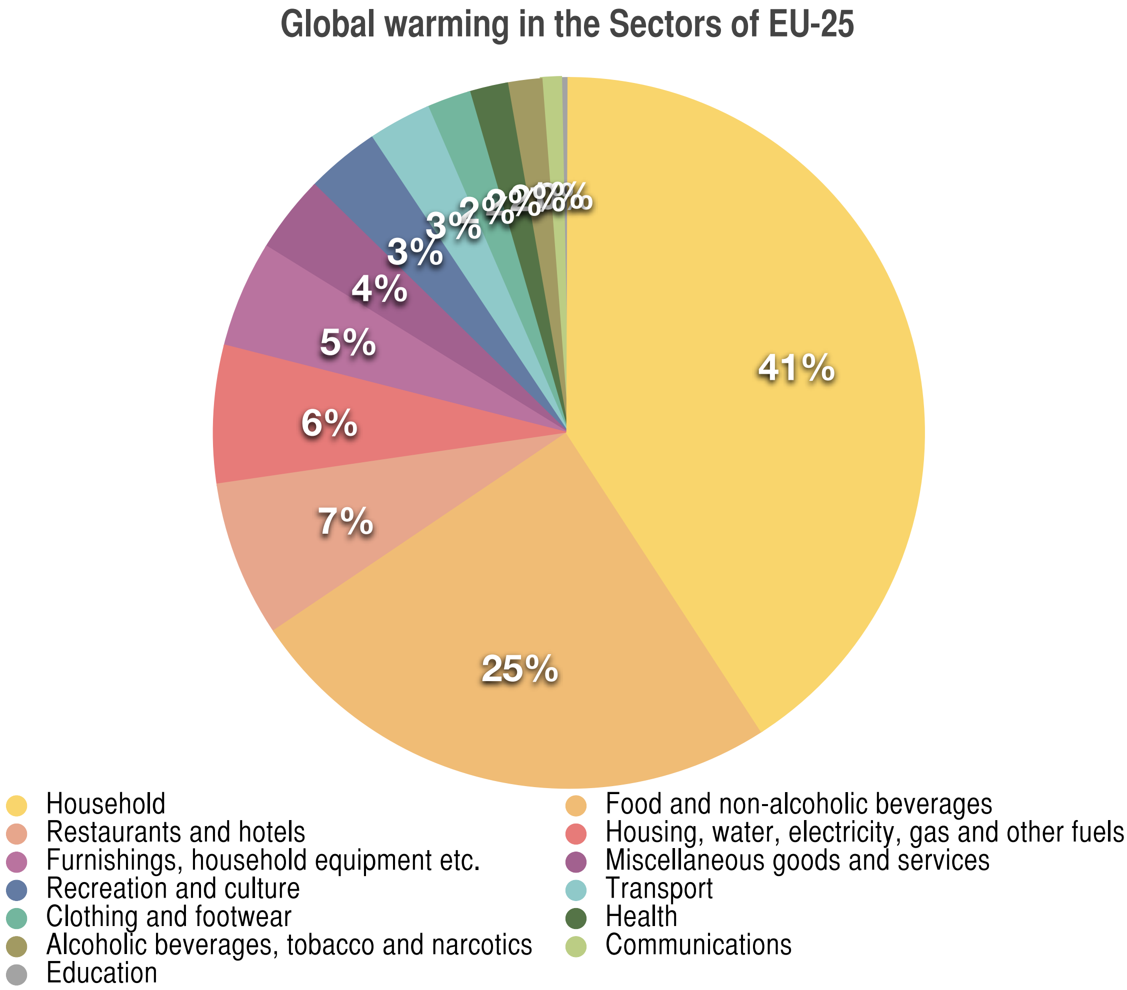

Figure 8. Share of the contribution from the sectors level 1 to Global warming.

With this result it is concluded that the agricultural industry has a significant impact to Global warming. The contribution of the sectors Household and Food have a significantly smaller share of economical value than in impact value. The Household sector has an share of 18 % (447 000 million euro out of total 2 000 000 million euro) and food sector of 17% (417 000 million euro out of total 2 000 000 million euro). This is illustrated also in the Figure 9, where it can be concluded that the value per euro of impact CO2eq is much greater from these two sectors than from the remaining ones. In fact, the Household sector has an value of 4.47

million tonCO2eq/euro and Food 2.90 million tonCO2eq/euro, where the remaining sectors have a range from 1.5 and lower million tonCO2eq/euro.

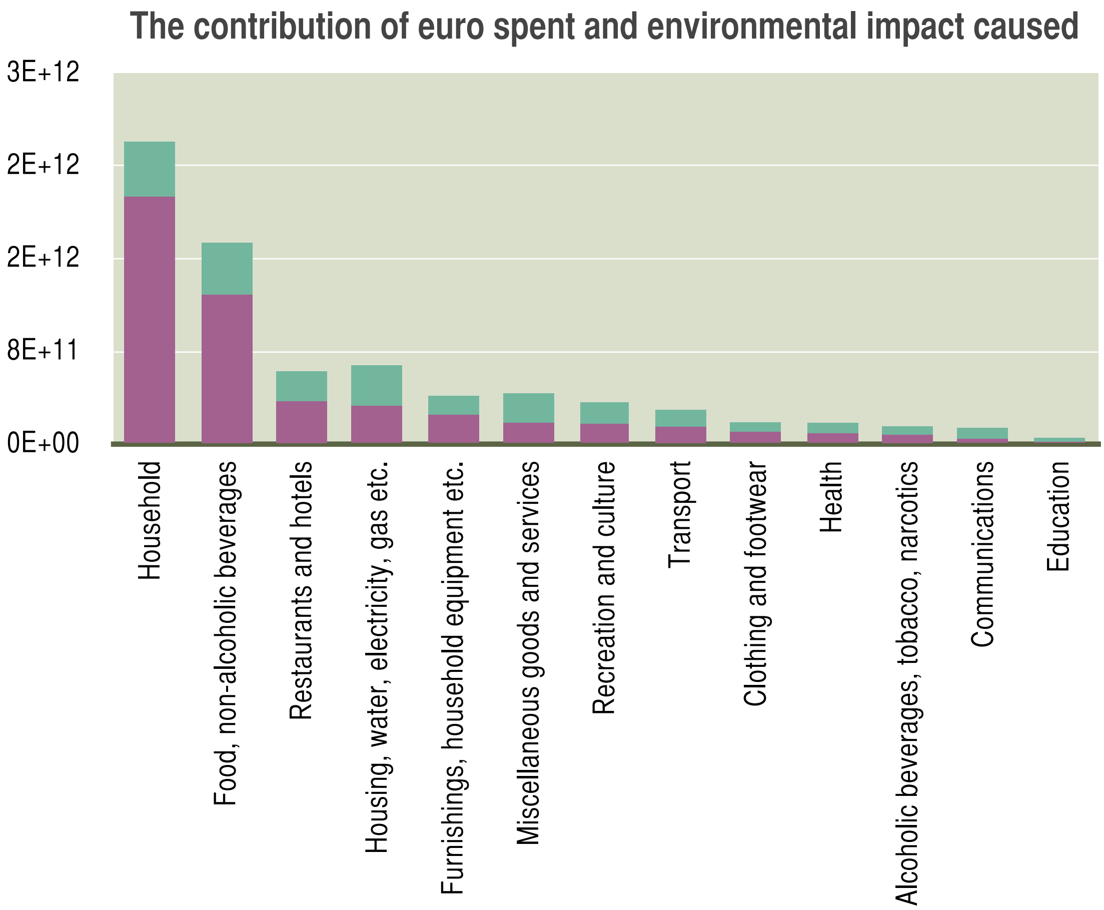

Figure 9. The contribution of euro spent and the environmental impact caused by million tonCO2eq per sector in EU-25.

In the next part of the results the Food sector is analyzed in greater detail. This sector is divided in Level 2 sectors by COICOP classification to a total of 11 sub-sectors. Figure 10 shows the share of Global warming impact in the sub-sectors from the Food and non-alcoholic beverages sector.

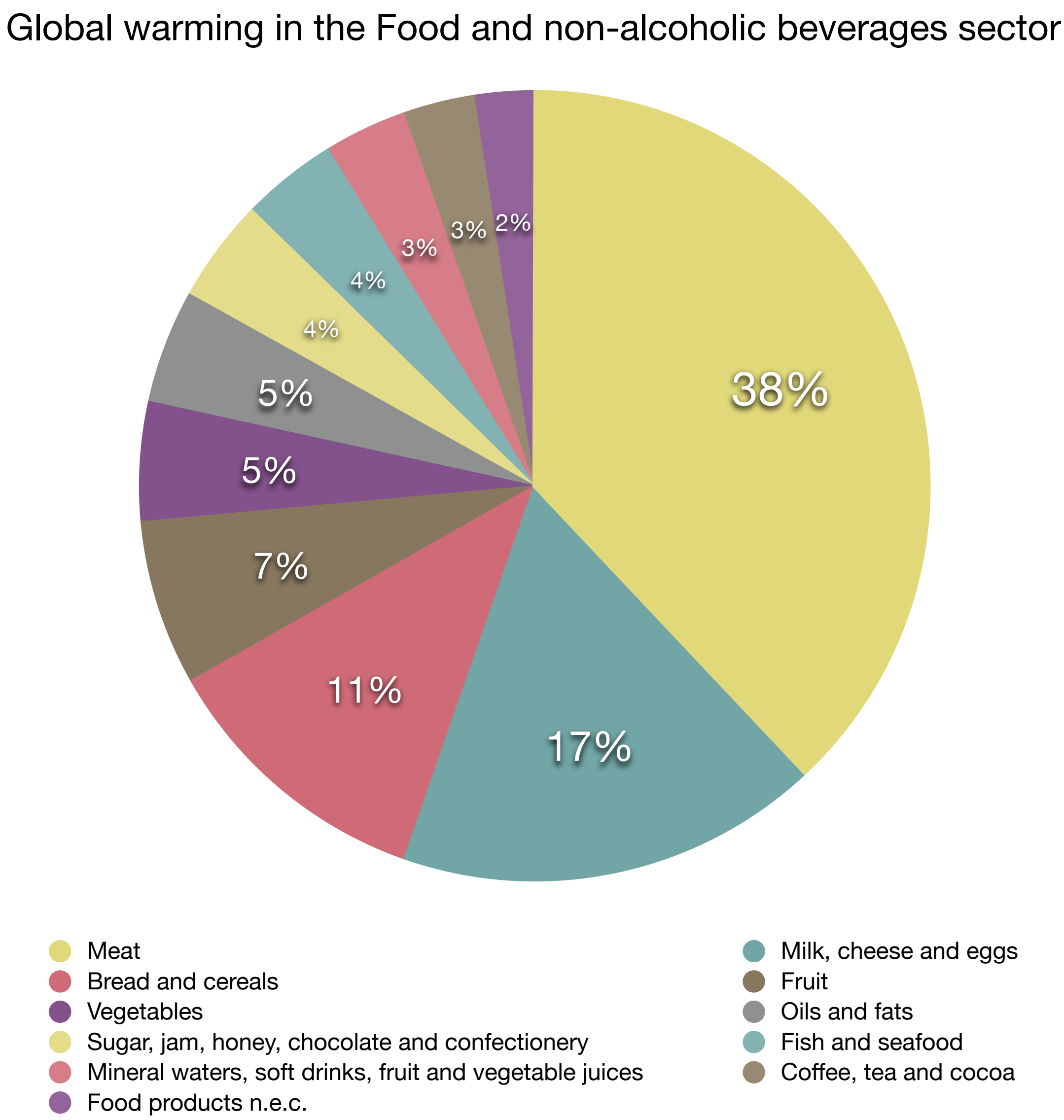

Figure 10. Share of contribution from the Food and non-alcoholic beverages sector to Global warming emissions.

There is a significant differences between the sub-sectors in their overall impact. The three main sectors which contribute above 10% from the whole Food sector (1 000 million tonCO2eq) are; i) Meat 38% (460 million tonCO2eq), ii) Milk, cheese and eggs 17% (209 million tonCO2eq) and iii) Bread and cereals 11 % (138 million tonCO2eq). As few as two sub-sectors of the whole food sector cover 55% (700 million tonCO2eq) together, Meat and Milk, cheese and eggs sub-sectors. These two will be analyzed in further detail in the following results. The remaining 9 sub-sectors have an impact of 45% together with a small contribution per grouping.

Table 4. The Food an non-alcoholic beverages sub-sectors per total euro spent from consumption, the impact caused in million tonCO2eq per euro spent, and a total impact of million tonCO2eq per grouping.

Food and non-alcoholic beverages							
Order	Sector	Value (million euro)	Value (%)	million tonCO2eq/ euro	Order	million ton CO2eq	Order
1	Meat	115,590	28%	4	1	460	1
2	Bread and cereals	72,270	17%	2	10	138	3
3	Milk, cheese, eggs	66,689	16%	3	5	209	2
4	Vegetables	30,300	7%	2	9	59	5
5	Fruit	25,361	6%	3	3	82	4
6	Sugar, jam, honey, etc.	22,414	5%	2	7	51	8
7	Fish and seafood	21,970	5%	2	6	51	7
8	Mineral waters, soft drinks, etc.	21,430	5%	2	11	41	9
9	Oils and fats	16,465	4%	3	2	56	6
10	Food products n.e.c.	13,668	3%	2	8	30	11
11	Coffee, tea and cocoa	11,200	3%	3	4	35	10
	Total	417,357	100%	-	11	1,213	11

The value of the sectors in euro show a similar trend, (Table 4) in which the Meat sector has the highest value per year followed by Bread and cereals and Milk, cheese, eggs. The top five sector that contribute to the impact of Global warming are also the top five (not in same order) contributing sector of euro spent. This means that the sector causing most impact have a high economical value. Although a different trend can bee seen when looking at the impact caused per euro spent (million tonCO2eq/euro). In this aspect we can see that Meat, Fruit and Milk have a high contribution (in top 5) per euro, meaning that if consumption would increase in this grouping the Global warming emissions would rise. Instead Bread and Vegetable sectors have a quite smaller contribution per euro spent. This would indicate if these grouping were consumed in a higher extend and at the same proportion decreased from the previous three, the Global warming emissions would decrees. Certainly the amount of nutrition and calories would have to be taken in consideration if one would argue that a change in diet would benefit the climate, this would have to be further analyzed.

The Meat sub-sector is divided into four consumption products: Meat packing plants (Bovine meat and Pig meat), Miscellaneous livestock (Mutton, goat and other meat), Poultry slaughtering and processing (Poultry) and Sausages and other prepared meat products (Bovine and Pig meat) which are presented in Table 5. Bovine and pig meat are the primary meat sorts that contribute to the sub-sector of Meat as they contribute to products Meat packing plants (45%) and Sausages and other prepared meat products (19%) with a share of 64% in total in comparison to Poultry with 32% and Miscellaneous livestock with 3%.

Table 5. The products from the Meat sub-sector per total impact (million tonCO2eq), their value in euro consumed, and by the impact per euro spent.

Meat					
Products	**million ton CO2eq**	**% impact**	**Value (million euro)**	**% value**	**million tonCO2 eq./euro**
Meat packing plants	209	45.5%	49,900	43.17%	4.17
Poultry slaughtering and processing	146	31.8%	41,000	35.47%	3.54
Sausages and other prepared meat products	90	19.5%	20,900	18.08%	4.25
Miscellaneous livestock	15	3.3%	3,790	3.28%	3.98
Total	460	100.0%	1.16E+05	100.00%	-

This two sorts of meat have also a higher contribution per euro spent than Poultry and Miscellaneous livestock. This indicates that substituting to different types of meat consumed, from bovine and pig to poultry and other meat would lower the million tonCO2eq in the atmosphere.

The Milk, cheese and eggs sub-sector is divided into 6 consumption products which are demonstrated in the Table 6. Two products show significant contribution in comparison to the others, those are; Fluid milk 42% and cheese 35% which contributes to 77% together out of the whole milk, cheese and eggs sub-sector. These two products have also the highest contribution per euro spent but are also the most valuable products in euro. Fluid milk and cheese products would be hard to replace with similar products to consume. In this case a further more detailed analysis, which analyses hot-spots of the supply chain would be needed to be able to define possible mitigation possibilities.

Table 6. The products from the Milk, cheese and eggs sector per total impact (million tonCO2eq), their value in euro consumed, and by the impact per euro spent.

Milk, cheese and eggs					
Products	**million tonCO2eq**	**% Impact**	**Value (million euro)**	**% value**	**million tonCO2 eq./euro**
Fluid milk	88	42.0%	27,400	41.1%	3.18
Natural, processed, and imitation cheese	73	34.8%	21,800	32.7%	3.32
Poultry and eggs	22	10.6%	6,870	10.3%	3.21
Dry, condensed, and evaporated dairy products	20	9.7%	8,270	12.4%	2.45
Creamery butter	5	2.5%	2,060	3.1%	2.48
Dairy farm products	1	0.4%	289	0.4%	2.86
Total	209	100.0%	6.67E+04	100.0%	-

The Table 7 illustrates the environmental impact over the top ten products out of the total 44 products in the Food sub-sectors. The full list of all products in the EU-25 can be seen in Appendix 1. The results show that the 5 main contributing products come from the sub-sectors of the two (previously analyzed) sectors; Meat and Milk, cheese and eggs. The first 3 products come from the Meat sector and contribute together to a total of 37% in comparison to the total 44 products (440 million tonCO2eq) and the following 2 come from the Milk, cheese and eggs sector and contribute together with a 13% (160 million tonCO2eq). These top 5 products contribute with a share of 50% (1 200 million tonCO2eq) out of the total 44 sectors from Food products and non-alcoholic beverages. There economical value is also high with a total of 39 % out of 44 sectors which shows the high consumption value from these two sectors in the EU-25. The sausages and other prepared meat products have the highest contribution per euro (4.25) , even if their value is some what lower, they have a resulting high contribution. The top products from the Milk sector on the other hand, have a lower contribution per euro (3.18-3.32) but have a high value sector which results in top five impact sectors.

Table 7. The 10 highest contributing products to Global warming emissions from the Food and non-alcoholic beverages sector, beginning with the highest first, with their total economical value and the impact per euro spent.

The products in the Food and non-alcoholic beverages sector									
Products	million ton Co2eq	% impact	Order Co2	Value (million euro)	% value	Order euro	million tonCO2 eq/euro	Order Co2/euro	Sub-sectors
Meat packing plants	209	17.28%	1	49,900	11.96%	1	4.17	2	Meat
Poultry slaughtering and processing	146	12.07%	2	41,000	9.82%	2	3.54	6	Meat
Sausages and other prepared meat products	90	7.40%	3	20,900	5.01%	6	4.25	1	Meat
Fluid milk	88	7.27%	4	27,400	6.57%	3	3.18	14	Milk, cheese and eggs
Natural, processed, and imitation cheese	73	6.04%	5	21,800	5.22%	5	3.32	10	Milk, cheese and eggs
Edible fats and oils, n.e.c.	56	4.60%	6	16,300	3.91%	9	3.39	8	Oils and fats
Vegetables	53	4.34%	7	18,000	4.31%	8	2.89	18	Vegetables
Bread, cake, and related products	39	3.21%	8	27,400	6.57%	4	1.39	41	Bread and cereals
Bottled and canned soft drinks	37	3.06%	9	18,400	4.41%	7	1.99	34	Mineral waters, soft drinks, fruit and vegetable juices
Fruits	37	3.03%	10	9,960	2.39%	16	3.66	5	Fruit
Total of top 10 products	826	68.31%	10	251,060	60.15%	10	-	10	Total of top 10 products
Total of all 44 products	1,209	100%	44	417,357	100%	44	-	44	Total of all 44 products

Edible fats and oils are the sixth highest contributor, with a share per euro spent of 3.39 and a value at 9 place. Bread, cake and related products have one of the lowest contribution out of all products per euro spent (1.39 on 41 place) but as a high consumed product with a 6.57% they arrive high in contribution to Global warming. A similar trend is seen also for Bottled and canned soft drinks. Fresh vegetable and fresh fruit are the remaining two products in top ten. Vegetables have a low contribution per euro (2.89) but are consumed with a total of 4.31% and contribute with a share of 4,34%. Where Fruits have a high contribution per euro (3.66) and are consumed with a lower value of 2.39% but contribute also highly with a share of 3%. This indicated that the supply chain of fresh fruits cause a higher impact on Global warming then fresh vegetables.

The Food sectors was further analyzed using SPA analysis, which gives the possibility to analyze the linkages of products from the industry per Global warming emissions. The three most important emissions were chosen, Carbon dioxide, Methane and Dinitrogen oxide. For every emission the paths were analyzed with path length maximum 3 and with the contribution boundary of 1%. The contributions lower then 1% were not considered significant in this analysis. The full analysis can be found in Appendix 2 for all three analyses.

Analyzing Carbon dioxide with a boundary level of 1% the results derived in total 10 paths. The contribution from the Food industry did not result in any contribution (see Appendix 2).

When analyzing the emission Methane with SPA, the results showed 15 products that contribute with 1% or more. Out of these 15, 7 products come from the Food sector and from Agricultural industry, which is shown in Table 8, with a share of 20% out of total 32%.

Table 8. The results of SPA for Methane, extrapolated only the contributions from the Food industry.

Industry	Product	Contribution (%)	Paths (no.)
Meat animals	Meat packing plants	10%	3
	Sausages and other prepared meat products	1%	3
	Total	11%	
Poultry and eggs	Poultry slaughtering and processing	5%	3
	Poultry and eggs	1%	2
	Total	6%	
Dairy farm products	Natural, processed, and imitation cheese	1%	3
	Fluid milk	1%	3
	Total	2%	
Miscellaneous livestock	Miscellaneous livestock	1%	2
	Total	1%	

The highest contribution of methane to Global warming from the Food sector comes from the Meat animal industry, in total 11%, with the main contribution from product Meat packing plants (10%). The second most contribution comes from the Poultry and eggs industry with 6%, with Poultry slaughtering and processing products contributing with 5%. And the remaining industries contribute with a share of 2% from Dairy farm products and 1% share from Miscellaneous livestock.

In the SPA results from the analysis of Dinitrogen oxide, two main contributors can be distinguished ;the industries Vegetables 12% and Fruits 10% (see Table 9). The remaining industries from the food sector contribute additionally to 3%. In total 25 % of total 26% (additional 1% comes from Tobacco industry) of the Dinitrogen oxide emissions is caused by the Food industry.

Table 9. The results of SPA for Dinitrogen oxide, extrapolated only the contributions from the Food industry.

Industry	Product	Contribution (%)	Paths (no.)
Vegetables	Vegetables	9%	2
	Frozen fruits, fruit juices, and vegetables	1%	3
	Potato chips and similar snacks	1%	3
	Eating and drinking places	1%	3
	Total	12%	
Fruits	Fruits	5%	2
	Roasted coffee	3%	3
	Frozen fruits, fruit juices, and vegetables	1%	3
	Wines, brandy, and brandy spirits	1%	3
	Total	10%	
Food grains	Cereal breakfast foods	1%	3
	Prepared flour mixes and doughs	1%	3
	Total	2%	
Oil bearing crops	Edible fats and oils, n.e.c.	1%	3
	Total	1%	

Fresh vegetables and fruits can be distinguished as the highest contributors of Dinitrogen oxide as Vegetables contribute to 9% and Fruits 5%.

3.4 Discussion and Conclusion

Several conclusions can be drawn from the results gained by analyzing the impact of Global warming caused from the consumption in the EU-25. First the food sector shows to be a significant contributor to the Global warming and is an important impact category to analyze for mitigation possibilities. The sub-sectors of the food sector show different trends among them, here follows a summary of the five most contributing sub-sectors;

- Meat; has the total highest impact compared to all other sectors. But also per euro spent. The meat sub-sector has also has the highest economical value. The bovine and pig meat are the primary sort of meat that contribute with the highest share, both by impact value, compared to a little bit less of poultry meat and miscellaneous livestock, which have a high contribution per euro but are not consumed in the same extent. This trend is also confirmed by comparison of the meat products to the other 44 products in the Food sector. The meat industry contributes significantly to one emission, Methane, from the products Meta packing plants, Sausages and other prepared meat products, poultry slaughtering and processing and Miscellaneous livestock with an total of 17% .
- Milk, cheese and eggs; is the third most economically valuable sector and is the second most contributing impact sector, but with lesser impact compared to meat. The two most contributing products are milk and cheese, which are also the highest in value consumed in euro. These two products and Poultry and eggs have also a small share to the emissions Methane, 1% each.
- Bread and cereals; is the third sector per contribution grouping of environmental impact due to its high consumption. It is the second most valuable sector but the contribution per euro is low (1.91 compared to meat 3.98). It is the 41 lowest of all food products. Bread and cereals products contribute to the Dinitrogen oxide with 3% from the Vegetable and Food grains industry.
- Fruit; the sub-sector is the forth most contributing sector, with a rather high impact per euro (3.22 compare to meat 3.98), and the fifth sector by economical value. This sector contributes also to the Dinitrogen oxide emission with Fresh fruits and Frozen fruits, fruit juices and vegetables (in total 6%).
- Vegetables; is the fifth sector by impact contribution, with a slighter more economical value then fruit sector per year, but with a much less impact per euro spent (1.95 compared to fruit 3.22). The vegetable products contribute to a total of 10% to Dinitrogen oxige from fresh vegetables (9%) and Frozen fruits, fruit juices and vegetables (1%).

This does not mean that the other sectors are irrelevant, as the food products in different aspects can not be replaced one by the other due to variety in diets, and a full supply chain analysis would be necessary per products to spot supply chain mitigation possibilities. Most of the products have a small contribution per product but as a sector the agriculture is second most contributing sector. IOA has demonstrated to be a valid methodology for a first overview analysis, which can then identify sectors or products to identify for further more detailed analysis or for further economical assessment.

With a SPA it is possible to analyze specific linkages between the industry and product per emissions. The Meat and Poultry and eggs industries are the most contributing industries to Methane emissions. The same result could be drawn from the total contributing from sub-sectors to Global warming. In this way the importance to focus on these sectors for mitigation purposes could be identified. These sectors would also need a further detailed analysis to identify hot spots from the supply chain. This could not be done for two reasons; one is that the E3IOT model is based on an aggregated EU-25 countries, the second reason is that the database is not detailed enough. More the IO table is disaggregated and more data is available there is a higher possibility for a more detailed analysis. A model on a country level with this type of detail would also give the possibility to identify more accurate mitigation possibilities and policy strategies. Even with this results policy recommendations could be based. A SPA identified also the Fruit and Vegetable production as an significant contributor to the Dinitrogen oxide emissions. This shows the importance of linkage analysis, but also an importance of a further detailed analysis as LCA.

This approach relies on US data for resource use and emissions for many sector which gives some uncertainties in the results. It can be a clear method for a first step analysis and identification of products which are in the top of environmental impact to then be used for more detailed analysis. It does not exist still a detailed country based model, or a more accurate one than E3IOT, thus to get more accurate results one would have to use LCA. Further analysis is necessary to identify the hot spots in the supply chains of products to evaluate the economical cost of mitigation, technological cost, but also the social aspect as diet change.

The agricultural industry and consumption of product relay on many different factors for mitigation. If we reduce production and availability of products the import will increase and may be substituted by more impact products. A MRIO analysis is needed to evaluate the impact from import and export. The change of diet is one possibility, consuming less impact products as vegetables instead of meat. In this case nutritional and calorie value has to be considered but also social aspects as tradition and habits. A study analyzing environmental impact of diet in the EU show that a change in diet would decrease marginally the overall impact (Tukker et al., 2009). This analysis focuses not only on global warming but on all impact categories in E3IOT, even so probably the result would be rather similar. A third possibility is to study the hot-spots in the supply chain and decrease even if small contribution but on many places along the chain.

It was possible to analyze the correlation of economical value and Global warming impact per product and sub-sector with the E3IOT model. The environmental cost of impact and the mitigation cost would have to be appointed to the source, to then be able to be further fairly distributed. Food products have a shared responsibility of mitigation both by producer and consumer, but also from institutions, political and social structures. The possible mitigation will depend on the environmental damage caused, but also an economic and social cost. In this analysis the highest contributing product groups were identified and their corresponding value. For further analysis it would be necessary to estimate the economical cost of mitigation per product, but also the possibilities of changes in consumption.

4. Environmental Assessment of the Supply Chain of Buffalo Milk in Italy

4.1 Integrated Hybrid Analysis Applied

From the impact assessment of consumption in EU-25 of food products (in previous chapter) two groupings of food were shown to be the most contributing to Global warming; Meat and Milk, cheese and eggs. The aim of this analysis is to assess the food sector in Italy and the impact it has on the Global warming. Also concluded was that IOA is a good starting analysis to get an overview of the sector, and in this case a more complete analysis was chosen to be able to define the hot-spots and mitigation possibilities in specific supply chains. In previous chapters of the methodological review it was concluded that Integrated hybrid analysis is the most complete analysis method. Hence, the aim of this study is to assess the possibility of applying the Integrated hybrid analysis method to the Italian food sector; the supply chains in the sector Meat and Milk, cheese and eggs.

4.1.1 Introduction

Integrated hybrid analysis combines two different systems (LCA and IOA) and due to there different structures some adaptations are made in order to be able to fully integrate them. Differences between the two assessment methods are that LCA does not have:

- annual transaction records available
- quantities are in physical units
- concerns the direction of physical flows instead of that of money flows
- contains use and end-of-life stages
- primarily concerns the function of a system and more

Due to these differences some adaptations are necessary. A commodity by commodity IO table is used because a commodity rather then the industry is more known to the LCA practitioners and due to the aggregation of commodities in an industry output. The IO technology coefficient matrix should include domestic and imported capital goods, and domestic and imported current products, by assuming that the imported products and capital goods are the same as the domestic ones. The prices in the IO table should be adapted to current price levels. The relationship from LCA processes in producing and consuming functional flows are referred as supply and demand relationship between the processes. Assumption of steady state is made to assume that processes are operated under complete steady-state conditions (Suh, 2004).

4.2 The Model

The model is made of four different matrixes, a LCA matrix with the process data, an IOA matrix with the monetary economic data, an upstream cut-off by process matrix and a downstream cut-off by functional flow matrix.

The upstream cut-off matrix is calculated by dividing the total bill of goods for the inputs that are not covered by a process in a process-based system during the period of steady state approximation by the total unit operation time of each process.

$$C^u = \tilde{Z}_*^{u\hat{\hat{g}}} - 1$$

(1)

$\tilde{Z}^u{}_*$ - Total amount of the cut-off commodity flows by processes during the period of steady-state approximation in monetary terms

$(C^u)_{ij}$ - Shows the amount of cut-off of input-output commodity i to process j during the unit operation time, in monetary terms.

The downstream cut-off matrix is calculated by dividing the annual sales of functional flow (in physical units that are relevant to each functional flow) by the production of each total commodity.

$$C^d = \tilde{Z}^d{}_*(\hat{g}_{***})^{-1}$$

(2)

$\tilde{Z}^d{}_*$ - Annual sales of functional flows from processes to input-output industries in relevant physical units.

g_{***} - Total domestically produced and imported current and capital goods

$(C^d)_{ij}$ - Shows the amount of cut-off flows of functional flow i to input-output commodity j per unit of monetary value of its output, in relevant physical units.

$$\begin{bmatrix} \widetilde{A}_* & -C^d \\ -C^u & I - A'_{***} \end{bmatrix} \begin{bmatrix} \tilde{g} \\ g_{***} \end{bmatrix} = \begin{bmatrix} \tilde{f} \\ f_{***} \end{bmatrix}$$

(3)

A'_{***} - Commodity-by-commodity input-output technology coefficient matrix that includes domestic and imported current products and capital, with prices updated to current levels, and excluding the portion of commodity flows already covered by the process-based system.

g_{***} - Total production for domestic and imported current products and capital, with prices updated and with commodity flows already covered by the process based system subtracted.

f_{***} - Final demand for domestic and imported current products and capital, with prices updated and with commodity flows already covered by the process based system subtracted.

Equation (3) shows that the amount of functional flow and input-output commodity produced, minus the amount used in the process-based system and in the input-output based system is equal to the amount delivered to the final consumers.

Units:

$\widetilde{A}_*$ - LCA technical coefficient matrix - Various physical units per unit operation time for each process

A'_{***} - Input-output technical coefficient matrix - Monetary units per unit output for each input-output commodity in monetary terms

C^u - Monetary units per unit operation time for each process

C^d - Various physical units per unit of output for each input-output commodity in monetary terms.

Rearranging (3) gives:

$$\begin{bmatrix} \tilde{g} \\ g_{***} \end{bmatrix} = \begin{bmatrix} \tilde{A}_{*} & -C^{d} \\ -C^{u} & I - A'_{***} \end{bmatrix}^{-1} \begin{bmatrix} \tilde{f} \\ f_{***} \end{bmatrix}$$

(4)
for a non-singular square matrix.

Based on the linearity assumption we can further write:

$$\begin{bmatrix} \tilde{x} \\ x \end{bmatrix} = \begin{bmatrix} \tilde{A}_{*} & -C^{d} \\ -C^{u} & I - A'_{***} \end{bmatrix}^{-1} \begin{bmatrix} \tilde{y} \\ 0 \end{bmatrix}$$

(5)
Which shows the amount of unit operation time by processes and the amount of commodities by input-output based system for an arbitrary final demand for functional flow $\tilde{y}$.
The environmental intervention produced during this time is calculated by:

$$\bar{q} = \begin{bmatrix} \tilde{B} & B'_{***} \end{bmatrix} \begin{bmatrix} \tilde{x} \\ x \end{bmatrix}$$

(6)
$\bar{q}$ - Environmental intervention produced by the hybrid system

$\tilde{B}$ - Environmental intervention by processes matrix

B'_{***} - Environmental intervention by input-output commodities matrix

By combining the equation (5) and (6) the integrated hybrid model is obtained:

$$
\begin{aligned}
\bar{q} &= \begin{bmatrix} \tilde{B} & B'_{***} \end{bmatrix} \begin{bmatrix} \tilde{A}_{*} & -C^{d} \\ -C^{u} & I - A'_{***} \end{bmatrix}^{-1} \begin{bmatrix} \tilde{y} \\ 0 \end{bmatrix}, \\
&= \bar{B}\bar{A}^{-1}\bar{y}
\end{aligned}
$$

$\bar{(\ )}$ - Indicates integrated hybrid matrices and vectors.

(7) Gives the total amount of environmental intervention resulting from the interaction between the functional flow based system and the commodity-based system in both directions, in one consistent mathematical structure **(**Suh, 2004).

4.2.1 Cut-off Upstream Matrix

The cut-off upstream matrix (Cu) refers to parts of life cycle that are not taken into calculation in a LCA study because there environmental impact is thought to be negligible, but studies show significant parts of the environmental impact may be missed due to this. In a Integrated hybrid analysis the part that is cut-off from the LCA study is added in monetary terms as purchases from within the economy from the IO table. The upstream matrix is modeled with the purpose to model the upstream inputs from the IO system not covered by the process system. It is derived by dividing the total bill of goods for the inputs that are not covered by LCA-study by the total unit operation time of each process (Suh, 2004). As a result the matrix will present the amount of cut-off of IO commodity to that process during the unit operation time in monetary terms. In Wiedmann et al., 2011 and Acquaye et al., 2011 the application of the Cu is derived by 1) matching all processes and sectors 2) for every input the unit cost of the process is multiplied by the total amount of value from process data 3) and double counted data are deleted.

4.2.2 Cut-off Downstream Matrix

The Cut-off downstream matrix (Cd) is modeled with the purpose to show that the functional flows produced by the processes which are supplied not only within the process based system but also outside the system. The values modeled in Cd corresponds to purchases from the economic sectors on the functional unit of the LCA study. LCA practitioner collects all the data for the processes investigated by a demand and the functional unit until the system boundary is reached. These processes may feedback onto other processes. The system boundary is far most relevant process. IOA shows all the flows between all sectors. System boundary includes all economic transaction in an economy. The IOA table represents all feedbacks within the industry aggregation used. For each economic sector it is required to determine the quantity the sector purchases from each LCA process. Cd is the purchases of IO sector from the LCA study eg. manufacturing sector purchases electricity and additional purchases from sectors in the economy. Then each sector needs to be subtracted from the economy (IO table) to avoid double counting (Suh, 2006). Peters & Hertwich (2006) argue that for standard practitioners a Tiered hybrid analysis (THA) is adequate, because the data requirement to construct a Cd is to big for the results gained, but more studies need to be conducted to show the relevance of Cd. Cd is set to zero in THA. Cd could be modeled for only functional unit or if arbitrary demand exists for every process needed. In the case of arbitrary demand in a LCA study, where a demand is on any process not only on functional unit. If Cd is modeled just for the functional unit, if places the demand on functional unit only, the environmental impact is very small from this cut off. Contribution of Cd will depend on the magnitude of the economic sales of the product (Suh, 2006). When constructing a product system two information sources are used. Bill of goods (upstream) and sales information (downstream). Especially the sales data show the distribution structure at the product at hand providing necessary data to compile the Cd. The only way to precisely identify the significance of Cd in a product life cycle is to compile the matrix and obtain the full picture (Peters and Hertwich, 2006). But in practice compiling needs to be in balance which what is gained. The downstream matrix is calculated by taking the annual sales of functional flow per production of each total commodity, in physical units (Suh, 2004). The application of the matrix is not well documented in literature, out of the articles applied or it is not mentioned in the article, or the matrix is set to 0, and only one study has applied Cd but has not explained in the article how it has been modeled. In Wiedman et al. (2011), the Electricity from wind power is only used for demonstration purpose as Cd, which they assumed is used only by one sector, Transmission of electricity, and in the IO table the Electricity by wind power was set to zero.

4.3 Data Analysis

Integrated hybrid analysis has been applied in very few cases until now, as explained in more detail previously. In the scientific articles the applied methodology has not been given added information if compared with the scientific article of Suh (2004) in which the model is explained. Hence, the application of this methodology is new and due to this a case study has been chosen to test the possibility of applying the method to the food supply chain with the aim to study the impact of the Global warming with the most possible completeness.

CMLCA is a the only software available that has the possibility to model an Integrated hybrid analysis. CMLCA is a free software tool that has been developed by the Leiden University, the Institute of Environmental Science with the principles of LCA and IOA in mind. CMLCA is a flexible software that can be adapted to different needs, and allows one to perform an IOA and a LCA analysis with hybrid analysis. But it is still a software in progress and has not been tested in many different case studies except for teaching purposes. While testing different databases and data options the adaptations to CMLCA has always been taken in consideration.

4.3.1 LCA Data

With the aim to identify environmentally friendly livestock models of the Italian agricultural sector the Project "SOS ZOOT", in the contest of the Sub-Project "VIAAI" (2010-2012) different LCA studies of several Italian farms were conducted by the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and the Agricultural Research Council (CRA). This was done for three different supply chains; mozzarella cheese, prosciutto di Parma and milk. Several farms for every supply chain were assessed to be able to obtain a medium result which will then define the national value. In this study only the mozzarella di bufala study was taken in consideration as a first case study. The LCA assessment was conducted by the standard ISO LCA and ILCD Handbook methodology to 2 buffalo farms in the area "Mozzarella di bufala campana-DOP" production area (Caserta, Italy) using an attributional approach (Pirlo et al., 2012). For this case study the supply chain of buffalo milk was assessed.

4.3.1.1 Buffalo Milk

System boundary: cradle to farm gate (Figure 1). Transport of input material included. Waste treatment, buildings and equipments have been excluded.
Functional unit: 1 kg of Normalized Buffalo Milk (LBN)
Allocation: an economical allocation was performed for all the co-products generated (veals, fattening bulls or replacement heifers, culled cows).
Impact categories: the CML 2001 impact assessment methodology has been used to evaluate the environmental burden of milk production. (Pirlo et al., 2012)

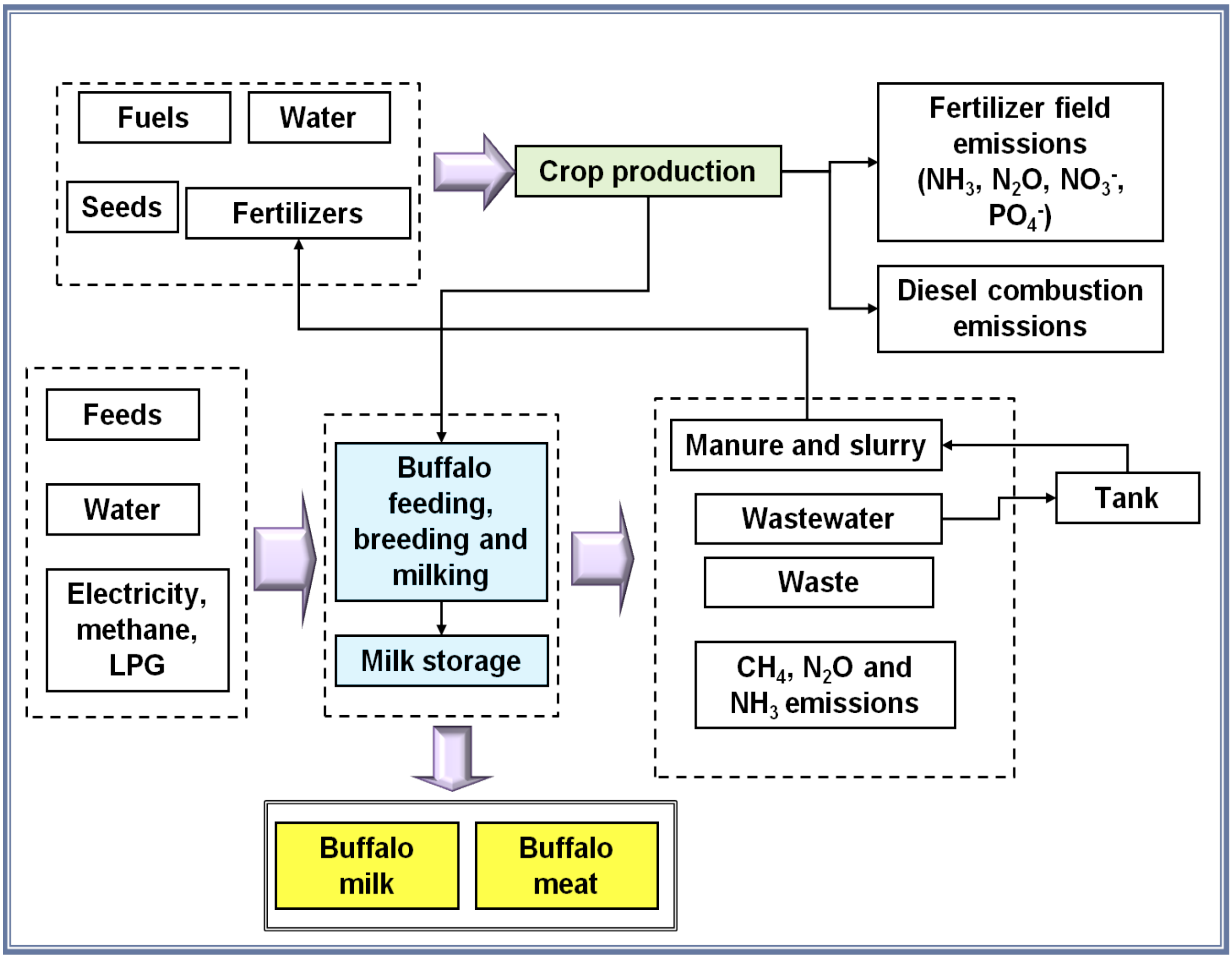

Figure 11. The system boundary of the LCA study of 1kg of Normalized Buffalo Milk.

In the Table 10 and 11 the part of the results regarding the GHG emission are only presented as it is the scope of this research.

Table 10. The impact from Farm A and Farm B on Global warming. (Pirlo et al., 2012).

Impact category	Farm A	Farm B
Global warming (kg Co2 eq./kg LBN	4.80	4.96

Table 11. The impact from emissions; CH4, N2O and CO2 contributing to Global warming from Farm A and Farm B. (Pirlo et al., 2012).

Impact category	Main emissions	Farm A	Farm B	Main sources
Global warming (kg Co2 eq./kg LBN	CH 4	2.25	2.36	Enteric fermentation and manure management
	N2O	1.92	2.24	Chemical and organic fertilizer use
	CO2	0.557	0.278	Diesel consumption during agricultural field work processes

Compatibility with CMLCA

The LCA studies are constructed in the program Simapro. To be able to be imported to the CMLCA program they have to be exported with the data format Ecospold. Ecospold is a data exchange format widely used for LCI data exchange and is based on XML and related technologies. While Ecospold and CMLCA have different ID systems when importing a study the ID matching has to be set off. In this case the flows between datasets will only be matched on the basis of the names, and if it is present with CO2 and carbon dioxide they will not be matched, in this case the matching can be done manually (Heijungs, 2012). The exporting from Simapro does not allow one to separate projects from each other, as if one does a unique study with different numbers of case studies (as in this case different number of farms), it is not possible to export only one study. As thus, this has to be taken in consideration before constructing a study if the aim is to export it further.

4.3.2 IO Data

Several amount of databases were evaluated for the purpose to be applied then in this case study using the Integrated hybrid analysis.

Table 12: IO databases of the European and Italian economies evaluated in this study.

Database	Year	No. of Countries	Emissions	Total sectors	Agri & Food
ISTAT	2008	1 IT	no	59	2
EUROSTAT	2006	27 (EU)	no	60	2
AgroSam	2000	27 (EU)	no	98	40
E3IOT	2003	25 (EU-merged)	1200	478	44
EXIOBASE	2000	43	30	129	25

4.3.2.1 National IO Table: Italy

The source of the national IO table for Italy can be obtained from EUROSTAT (EUs IO database) or the national statistical agency ISTAT (Istituto nazionale di statistica). National IO data consist of a national IO table but without the environmental extension with 59 economical sectors. The most recent published year is 2008. The national environmental research institute ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) has extended the national IO table with Greenhouse emissions for the year 2008 with also an integration with further three sectors according to NACE rev. 1; NACE 10 carbon (Mining of coal and lignite; extraction of peat), NACE 11 (Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction, excluding surveying) and gas and NACE 13 (Mining of metal ores), by using emissions data from the National Accounting Matrix including Environmental Accounts (NAMEA). These three sectors were divided into national and imported data from German and Norwegian data as the Italian data was not representative enough, but all other sectors are assumed to have used the Italian technologies. The emission integrated are the Greenhouse gases CO2, CH4 and N2O. As is common for national IO tables, also the Italian one has an aggregated agricultural and food sector, separated as one sector each with total two.

Compatibility with CMLCA

The data from the database are in a xls format which is not compatible with CMLCA. The import of data is best made with tab delimited data. Due to this all data form the table had to be transformed to tab delimited data. With this option also Industries, Alternatives, Totals and Emissions need to be separated and imported one by one. Alternatives in CMLCA represent the external demand to a system final demand.

Convert the data:

- Open the database in Excel
- Save the data as a cvs file
- Open the file in Notepad
- Replace all ; with tab
- Save as txt

When the data has been converted to txt for every part: Industries, Alternatives (Final demand) and Totals, the import can be done.

Strengths

The national IO table is accessible and free, from the website of ISTAT or EUROSTAT. With the collaboration of the Research centre ENEA it was also possible to obtain the national IO table extended with environmental emissions, though not yet published for public.

Limitations

The national IO table presents the agricultural sectors as one sector, and the food sector as one. The data of the whole sector are aggregated into one number value which would request a high amount of data availability to disaggregate. To be used for a specific supply chain it would be needed to disaggregate this value further to obtain a representative value for that specific chain. Further the aggregated emission data requires the same disaggregation which is not available for the Italian supply chains of agriculture and food.

Conclusion

The national IO table for Italy is not specific enough to be used with the purpose of analyzing specific agricultural and food sectors as is the purpose of this research.

4.3.2.2 AgroSAM Model

Social accounting matrix (SAM) is a comprehensive matrix that shows all transaction and transfers between different production activities, factors of production and institutions within an economy. SAM is represented in the form of a matrix where each row represents the inputs and each column represents the outputs of the economy. The difference between a SAM and an IO table is that SAM additionally shows final consumption expenditure, capital formation and trade with intermediate consumption and value-added which represents the income. In this matter SAM is an extended IO table that represents circular flow of income at macro level. The basic data of a SAM are from Supply and Use tables or IO tables which usually represent the agricultural sector highly aggregated, mostly as two industries, agriculture and food. The aim of the AgroSAM database was to obtain a database with a disaggregated agricultural sector for the EU-27 by using national SUT and the Common Agricultural Policy Regionalised Impact (CAPRI) model database. The resulting database which is still not published was obtained by the IPTS-JRC research center for research purposes.

Strengths

AgroSAM database in total defines 98 industries, 97 commodities and 20 institutions and taxes (Compensation of employes, Subsidies, Households see Table 14 for further details) with also Rest of the World. The AgroSAM database has the agricultural and food sector disaggregated from two sectors to 40 sectors in total, see Table 13. The agricultural sector is disaggregated in 30 rows and the food sector in 10. This represents a database with the most detailed agricultural sector available per nation.

Table 13. The agricultural and food sectors in AgroSAM.

	Agricultural sector
1	Production of other wheat
2	Production of durum wheat
3	Production of barley
4	Production of grain maize
5	Production of other cereals
6	Production of paddy rice
7	Production of rape seed
8	Production of sunflower seed
9	Production of soya seed
10	Production of other oil plants
11	Production of other starch and protein plants
12	Production of potatoes
13	Production of sugar beet
14	Production of fibre plants
15	Production of grapes
16	Production of fresh vegetables, fruit, and nuts
17	Production of live plants
18	Other crop production activities
19	Production of fodder crops
20	Set aside
21	Production of raw milk from bovine cattle
22	Production of bovine cattle, live
23	Production of swine, live
24	Production of raw milk from sheep and goats
25	Production of sheep, goats, horses, asses, mules and hinnies, live

26	Production of eggs
27	Production of poultry, live
28	Production of wool and animal hair; silk-worm cocoons suitable for reeling
29	Production of other animals, live, and their products
30	Agricultural service activities
	Food sector
31	Production of other food
32	Processing of sugar
33	Production of vegetable oils and fats, crude and refined; oil-cake and other solid residues, of vegetable fats or oils
34	Dairy
35	Production of meat of bovine animals, fresh, chilled, or frozen
36	Production of meat of swine, fresh, chilled, or frozen
37	Production of meat of sheep, goats, and equines, fresh, chilled, or frozen
38	Meat and edible offal of poultry, fresh, chilled, or frozen
39	Production of beverages
40	Production of prepared animal feeds

AgroSAM gives also the opportunity for different types of analysis of the EU agricultural sector and the CAP policy as compared to an SUT EU national table it contains data on; subsidies, taxes and other, see Table 14 for further details.

Table 14. The Alternatives of Agrosam.

1	Compensation of employees
2	Operating surplus, gross
3	Trade and transport margins
4	Other taxes on production
5	Other subsidies on production
6	Value added type taxes (VAT)
7	Taxes and duties on imports excluding VAT
8	Taxes on products, except VAT and import taxes
9	Subsidies on products
10	Property income
11	Current taxes on income, wealth, etc.
12	Social contributions and benefits
13	Other current transfers
14	Adjustment for the change in net equity of households in pension funds reserves
15	Corporations
16	General government
17	Households
18	Rest of the world
19	Gross fixed capital formation
20	Changes in inventories
21	Gross capital formation

Compatibility with CMLCA

In CMLCA only a symmetric table can be used, due to this the AgroSAM would have to be converted from a SUT table to a IO table. This would cause the loss of detail and also some sectors would have to be aggregated to make it symmetrical.

The data from the database are in a xls format which is not compatible with CMLCA. The import of data is best made with tab delimited data. Due to this all data form the table had to be transformed to tab delimited data. With this option also Industries, Alternatives, Totals and Emissions need to be separated and imported one by one.

Convert the data:

- Open the database in Excel
- Save the data as a cvs file
- Open the file in Notepad
- Replace all ; with tab
- Save as txt

When the data has been converted to txt for every part: Industries, Alternatives (Final demand) and Totals, the import can be done.

Limitations

The AgroSAM consists of all EU-27 countries and ROW but they are not interconnected, as thus can not be used for a multi regional national analysis, meaning that imports and exports can not be traced. AgroSAM database is not an environmental extended table, thus has no emissions data. For this research the evaluation of the possibility to extend the national Italian table with Greenhouse gases was done. There is the possibility to have the GHG compatible with AgroSAM for all the industries except the agriculture and food as those are compatible with NACE rev. 1 and at the same time those are also available from NAMEA. The main issue is to allocate the emissions for the disaggregated sectors, which are 40 (food and agricultural production). As the disaggregation of these sectors was based on the CAPRI database and further adapted with other data sources the emissions would have to be adopted based on this disaggregation method. Due to lack of time and lack of knowledge in this specific matter this was not possible.

Conclusion

AgroSAM would be a valid database to use with CMLCA both for hybrid analysis but also for other IO analysis which are available but lack of emissions data is a limitation.

For this hybrid analysis it is a valid database as it gives one the opportunity to have the detailed agricultural sector and it would be more easy to allocate data for the analysis but without an extension of environmental emissions it is not valid for this research purpose.

4.3.2.3 E3IOT Model

The E3IOT model is explained in detail in the CH 3, here follows a summary. The E3IOT model represents the economy of the countries in EU-25, aggregated together, with 480x480 sectors. The approach of the database is to assess the environmental impacts of final consumption products through their entire life cycle, hence covering also the use and waste management stages. In total the E3IOT database covers 250 commodities bought directly and additional ones indirectly with over thousand environmental interventions which are possible to analyze through 8 impact categories. Base year is 2003.

Compatibility with CMLCA

The E3IOT database is in the lca format, which is compatible with CMLCA, thus there is no need for adjustments.

Strengths

E3IOT model has the Food sector disaggregated into 44 products, with 11 sub-sectors. This high detailed is compatible with this research purpose as the Meat sub sector and the Milk, cheese and egg sector are further disaggregated into 4 and 6 products correspondingly.

Limitations

The E3IOT model is aggregated into 25 European countries, in which case this mean value of the European countries would not be representative for the Italian agricultural sector. The E3IOT database has a cost of 1000 euro for academic license and 3500 euro for non-academic license.

Conclusion

The E3IOT database is a highly disaggregated database for the agricultural and food sector which gives one the possibility to do number of analysis, but due to its aggregation of countries it is not representative for the Italian sector.

4.3.2.4 Exiobase Model

Exiobase is a Mutli-regional EEIO databse (and SUT) which covers 43 countries in total and the rest of the World. It is based on SU tables for every country which are then linked in a multi regional trade matrices. This gives the possibility to study and trace both export and import of every country by country. For every industry 30 emissions are available. Exiobases base year is 2000. The database covers 129 industries of which the agricultural and food sector covers 25 industries (forestry, fish production and tobacco was not taken in consideration) (see Table 15 for further detail).

Table 15. The Agricultural and food sectors from the Exiobase database.

1	Cultivation of paddy rice
2	Cultivation of wheat
3	Cultivation of cereal grains nec
4	Cultivation of vegetables, fruit, nuts
5	Cultivation of oil seeds
6	Cultivation of sugar cane, sugar beet
7	Cultivation of plant-based fibers
8	Cultivation of crops nec
9	Cattle farming
10	Pigs farming
11	Poultry farming
12	Meat animals nec
13	Animal products nec
14	Raw milk
15	Wool, silk-worm cocoons
16	Processing of meat cattle
17	Processing of meat pigs
18	Processing of meat poultry
19	Production of meat products nec
20	Processing vegetable oils and fats
21	Processing of dairy products
22	Processed rice
23	Sugar refining
24	Processing of Food products nec
25	Manufacture of beverages

Compatibility with CMLCA

The Exiobase database is in the LCA format, which is compatible with CMLCA, thus there is no need for adjustments.

Strengths

One of the strongest arguments for the Exiobase database is the possibility to model exports and imports of a country, which gives additional information per product/industry. There is no need for adjustments of data as it is compatible directly with CMLCA software. The agricultural sectors are also highly disaggregated, as meat from cattle and pigs is separated and can be isolated, which is not the case in E3IOT. The emissions can be aggregated as for E3IOT and the Global warming can be studied as one indicator, even if the number of emissions are only three (Carbon dioxide, Nitrous oxide and Methane), those are the three most important emissions also for the agricultural sector as seen in the previous analysis. Waste sector also covered.

Limitations

The Exiobase database is still not published, but indicated by the website it should have been published first week of February 2013. It will cost 1500 euro.

Conclusion

The Exiobase potentially would be the best match for this type of analysis as it is highly disaggregated for the sector that is studied, and it contains country data. But it is still not available.

4.4 Discussion and Conclusion

Due to lack of time and data availability the application of the Integrated hybrid analysis was not completed and the final results could not be presented, nevertheless various results can be drawn. Application of the Integrated hybrid analysis has various limitation, partly due to scarce applications and partly due to data availability. Theoretically, the Integrated hybrid analysis seems to be the most complete methodology available for environmental assessment as it integrated cut off data from the LCA. Two main problem were encountered: Cu and Cd matrices and data availability.

The Cu and Cd matrices, as the whole methodology have been applied in few case studies and as those they are still discussable. Even if Cu matrix is clear, depending on the data one uses it will need adjustments. Cd matrix is the matrix that has not still been completely applied, and as such the importance of it is questionable. Further research is needed to draw any conclusions on its significance.

Data availability is another problem. Regarding process data it is clear that one for applying an Integrated hybrid analysis has to have a complete LCA study, which per se is time consuming. On the other hand the IOA data is usually known to be more easily available. Thus, for this case study the IO data was lacking. This is due to two problem; IO data is to aggregated for the agricultural and food sector and IO tables lack emission data. More tables are integrating emissions data and understanding the importance of such. Even on the EU level, as we could see with AgroSAM, the importance of disaggregating the agricultural sector is being done as the sector has a huge economical importance in the region. In the case of Italy, it was not possible to find a database with emission data, and disaggregated agricultural sector on a country level, but with the database Exiobase this kind of analysis will be possible.

The Integrated hybrid analysis is an analysis method which has the potential to complete environmental impact assessment results and gives the opportunity to have more reliable data which can be based for mitigation spotting in the supply chain and policy development. For further research it would be needed to apply the Cd matrix to assess the significance of it and with such results the methodology could be further stabilized. The hybrid methods are still new, and not tested enough. Due to this, there is still a lack of comprehensive understanding of uncertainties in the results.

5. Conclusion

To foster a more sustainable production and consumption and to comply with the environmental goals set by the EU the agricultural sector has to deal with the mitigation of Global warming emissions. Two comprehensive studies have shown the agricultural and food sector to be in the top sectors contributing to GHG emissions, and with further analysis in this study this has been confirmed. To be able to set strategic policies in dealing with this issues a further understanding of the sector is crucial. As shown in this study both methodological and availability of data are still an issue. Nevertheless, two approaches of methodologies for assessment are available, a bottom up approach and a top down approach. A top down approach covers the whole economy, is a rather fast method and certain data bases are available. With the aim to analyze specific sectors, as in this case the agricultural sector, the lack of data is shown. This is due to two specific reasons: one is that there is still lack of environmental data and the other is that IO tables used for this type of analysis are highly aggregated. Nevertheless, an IO table of the whole EU-25 is available and gives one the possibility to analyze the agricultural sector in a detail not yet available.

From these results, by analyzing the Global warming emissions contributing from the agricultural sector and the value of the sector five groupings of products were brought to attention. First is the Meat sector with the highest impact per groping and also the highest economical value. Second is the Milk, cheese and eggs sector with a high impact and slightly less economical value in which two product groups could be identified as the most contributing both in economical value and in environmental impact; milk and cheese. The third sector is Bread and cereals which have a high environmental impact due to its total high consumption as the contribution per euro is rather low. The Fruit and Vegetable sectors differ in the matter that the fruit sector has a high impact per euro and is high in total economical value where the vegetable sector has a much less impact per euro spent. With this analysis it was possible to identify the food sectors with high value and high environmental impact. In this case the value means the cost the consumer pays for that product and the environmental impact through the whole life cycle. The policy recommendation from these results is to prioritize these five sectors in mitigation strategies. But further research would be needed to draw specific product oriented recommendations. First, a country specific approach would be needed to be able to orient most adoptable recommendations as the agricultural practices differs significantly between the EU countries. The methodological possibilities to do a specific sectorial analysis is still limited due to data availability and methodological development. An Integrated hybrid analysis is recommended, as it would potentially be a methodology which could give further insight in the sector on a country level and on a more detailed level.

The sustainable consumption and production policies recommend that the market should be reoriented towards sustainable practices, engage retailers and food producers to produce and choose more environmental friendly choices, with more information to the consumers, support changes of dietary and support for niche practices. It has also been shown previously that the consumers in EU need more knowledge and information about environmental products and what effect they have globally. To be able to compile with this, data availability would be the first issue to solve, only in this way it is possible to gain more information to be able to reorient both practices and consumers for more sustainable choices.

The agricultural farm businesses differ from other enterprises as it is usually small business or in many cases family owned small farms, which can not afford to bear the cost of the pollution. At the same time many markets are artificial in which case the CAP influences the end price of a product. Adding additional cost on production could also inhibit the competitiveness on the market. Nevertheless, the governments give high priority to the sector with the aim to maintain self-sufficiency and production (Baldock, 1992). The sector as such makes it difficult to apply the same type of measures as for other sectors in the economy. The policies, even PPP, have to be adjusted and adopted for the agricultural sector to not give a negative trade off in the economy. The agriculture pollution is second generation and more difficult to control at the same time there are certain environmental management difficulties when it comes to pollution controlling policies. When comparing the cost of environmental protection to the production cost it has been shown to be relatively small for the agricultural sector. The abatement cost in European countries and US for the agriculture has also shown to be low compared to other industries. The direct pollution abatement expenditures are small in pollution-intensive industries and in the agricultural sector. The pollution abatement costs related to production costs are also small in the food sector when compared to pollution intensive industries (Tobey and Smets, 1996). This would mean that there is a window of opportunity for mitigation in the agricultural sector with a small cost. Hence, the applied analysis of GHG emissions in the agricultural sector could point out the possible hot spots which could further serve as a base for the policy instruments as Ecolabel, Integrated product policy, Eco-Management and Audit Schemes etc..

This research gives a deeper insight in environmental assessment on a sectorial level, which methodological issues are needed to be dealt with and which results could be obtained. A further research possibility would be needed to contribute to methodological development of more detailed studies as Integrated hybrid analysis, and more detailed IO tables with environmental emissions. This study shows the correlation between the value of consumed products in euro in EU-25 and the correlation it has with the environmental impact. Further economical analysis is recommended for the estimate of the economical and social cost of the mitigation possibilities. In this way a balances approach including social, environmental and economical dimensions would be achieved.

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Appendix 1

The full list of all 44 products in the Food and non-alcoholic beverages sector, by total COeq impact, by their economical value, and their impact per euro.

The products in the Food and non-alcoholic beverages sector									
Products, Level 3	**million ton Co2eq**	**% impact**	**Order Co2**	**Value (million euro)**	**% value**	**Order euro**	**kgCO2eq/ euro**	**Order Co2/ euro**	**Level 2**
Meat packing plants	209	17.3%	**1**	49,900	11.96%	**1**	4.17	**2**	Meat
Poultry slaughtering and processing	146	12.1%	**2**	41,000	9.82%	**2**	3.54	**6**	Meat
Sausages and other prepared meat products	90	7.4%	**3**	20,900	5.01%	**6**	4.25	**1**	Meat
Fluid milk	88	7.3%	**4**	27,400	6.57%	**3**	3.18	**14**	Milk, cheese and eggs
Natural, processed, and imitation cheese	73	6.0%	**5**	21,800	5.22%	**5**	3.32	**10**	Milk, cheese and eggs
Edible fats and oils, n.e.c.	56	4.6%	**6**	16,300	3.91%	**9**	3.39	**8**	Oils and fats
Vegetables	53	4.3%	**7**	18,000	4.31%	**8**	2.89	**18**	Vegetables
Bread, cake, and related products	39	3.2%	**8**	27,400	6.57%	**4**	1.39	**41**	Bread and cereals
Bottled and canned soft drinks	37	3.1%	**9**	18,400	4.41%	**7**	1.99	**34**	Mineral waters, soft drinks, fruit and vegetable juices
Fruits	37	3.0%	**10**	9,960	2.39%	**16**	3.66	**5**	Fruit
Frozen fruits, fruit juices, and vegetables	36	3.0%	**11**	12,000	2.88%	**12**	2.97	**16**	Fruit
Roasted coffee	35	2.9%	**12**	11,200	2.68%	**13**	3.13	**15**	Coffee, tea and cocoa
Potato chips and similar snacks	25	2.1%	**13**	12,700	3.04%	**10**	1.93	**36**	Bread and cereals
Prepared fresh or frozen fish and seafoods	24	2.0%	**14**	9,220	2.21%	**17**	2.53	**24**	Fish and seafood
Cereal breakfast foods	23	1.9%	**15**	9,210	2.21%	**18**	2.42	**28**	Bread and cereals
Poultry and eggs	22	1.8%	**16**	6,870	1.65%	**21**	3.21	**13**	Milk, cheese and eggs

The products in the Food and non-alcoholic beverages sector									
Products, Level 3	**million ton Co2eq**	**% impact**	**Order Co2**	**Value (million euro)**	**% value**	**Order euro**	**kgCO2eq/ euro**	**Order Co2/ euro**	**Level 2**
Candy and other confectionery products	21	1.7%	**17**	10,500	2.52%	**15**	1.99	**35**	Sugar, jam, honey, chocolate and confectionery
Dry, condensed, and evaporated dairy products	20	1.7%	**18**	8,270	1.98%	**19**	2.45	**27**	Milk, cheese and eggs
Prepared flour mixes and doughs	18	1.5%	**19**	6,120	1.47%	**23**	2.96	**17**	Bread and cereals
Cookies and crackers	17	1.4%	**20**	10,700	2.56%	**14**	1.58	**39**	Bread and cereals
Canned fruits, vegetables, preserves, jams, and jellies	17	1.4%	**21**	7,610	1.82%	**20**	2.17	**33**	Sugar, jam, honey, chocolate and confectionery
Canned and cured fish and seafoods	15	1.3%	**22**	6,850	1.64%	**22**	2.21	**31**	Fish and seafood
Miscellaneous livestock	15	1.3%	**23**	3,790	0.91%	**26**	3.98	**3**	Meat
Food preparations, n.e.c.	12	1.0%	**24**	5,270	1.26%	**25**	2.18	**32**	Food products n.e.c.
Frozen specialties, n.e.c.	9	0.8%	**25**	3,700	0.89%	**27**	2.52	**25**	Food products n.e.c.
Frozen bakery products, except bread	9	0.8%	**26**	3,610	0.86%	**28**	2.57	**22**	Bread and cereals
Commercial fishing	8	0.7%	**27**	5,900	1.41%	**24**	1.41	**40**	Fish and seafood
Greenhouse and nursery products	6	0.5%	**28**	12,300	2.95%	**11**	0.502	**44**	Vegetables
Sugar	6	0.5%	**29**	1,650	0.40%	**35**	3.83	**4**	Sugar, jam, honey, chocolate and confectionery
Ice cream and frozen desserts	6	0.5%	**30**	2,110	0.51%	**31**	2.7	**21**	Sugar, jam, honey, chocolate and confectionery
Dehydrated fruits, vegetables, and soups	6	0.5%	**31**	2,450	0.59%	**30**	2.3	**29**	Fruit
Creamery butter	5	0.4%	**32**	2,060	0.49%	**32**	2.48	**26**	Milk, cheese and eggs

The products in the Food and non-alcoholic beverages sector									
Products, Level 3	**million ton Co2eq**	**% impact**	**Order Co2**	**Value (million euro)**	**% value**	**Order euro**	**kgCO2eq/ euro**	**Order Co2/ euro**	**Level 2**
Flour and other grain mill products	4	0.3%	**33**	1,230	0.29%	**37**	3.37	**9**	Bread and cereals
Flavoring extracts and flavoring syrups, n.e.c.	4	0.3%	**34**	3,030	0.73%	**29**	1.27	**42**	Mineral waters, soft drinks, fruit and vegetable juices
Canned specialties	4	0.3%	**35**	1,890	0.45%	**33**	1.82	**37**	Food products n.e.c.
Tree nuts	3	0.3%	**36**	951	0.23%	**38**	3.52	**7**	Fruit
Pickles, sauces, and salad dressings	3	0.3%	**37**	1,840	0.44%	**34**	1.73	**38**	Food products n.e.c.
Macaroni, spaghetti, vermicelli, and noodles	3	0.2%	**38**	1,300	0.31%	**36**	2.26	**30**	Bread and cereals
Salted and roasted nuts and seeds	2	0.2%	**39**	779	0.19%	**39**	2.82	**20**	Food products n.e.c.
Chocolate and cocoa products	1	0.1%	**40**	544	0.13%	**40**	2.54	**23**	Sugar, jam, honey, chocolate and confectionery
Dairy farm products	1	0.1%	**41**	289	0.07%	**41**	2.86	**19**	Milk, cheese and eggs
Oil bearing crops	1	0.0%	**42**	165	0.04%	**43**	3.29	**11**	Oils and fats
Manufactured ice	0	0.0%	**43**	187	0.04%	**42**	1.06	**43**	Food products n.e.c.
Miscellaneous crops	0	0.0%	**44**	2.14	0.00%	**44**	3.25	**12**	Food products n.e.c.
Total	1,209	100.0%		417,357	100.00%				

Appendix 2

Structural Path Analysis of Carbon dioxide.

Alternative = [A1] k2					
	Elementary flow = [E407] Carbon dioxide[air]				
Value (kg)	Contribution (%)	Path length	Path (1)	Path (2)	Path (3)
6.13E+11	17	1	[I832] C_(Driving with) motor vehicles and passenger car bodies		
2.23E+11	6	1	[I735] C_(Household heating with) heating equipment, except electric and warm a furnaces		
1.56E+11	4	2	[I811] C_(Washing with) household laundry equipment	[I410] Electric services (utilities)	
1.16E+11	3	2	[I810] C_(use of) Household refrigerators and freezers	[I410] Electric services (utilities)	
9.45E+10	3	2	[I815] C_(use of) Electric lamp bulbs and tubes	[I410] Electric services (utilities)	
5.42E+10	2	2	[I809] C_(use of) Household cooking equipment	[I410] Electric services (utilities)	
7.89E+10	2	2	[I818] C_(use of) Household audio and video equipment	[I410] Electric services (utilities)	
2.29E+10	1	2	[I509] C_New residential 1 unit structures, nonfarm	[I31] New residential 1 unit structures, nonfarm	
2.82E+10	1	2	[I832] C_(Driving with) motor vehicles and passenger car bodies	[I193] Petroleum refining	
2.33E+10	1	3	[I924] C_Eating and drinking places	[I446] Eating and drinking places	[I410] Electric services (utilities)
1.41E+12	40				

The total Structural Path Analysis of Methane.

Alternative = [A1] k2					
	Elementary flow = [E639] Methane[air]				
Value (kg)	**Contribu tion (%)**	**Path length**	**Path (1)**	**Path (2)**	**Path (3)**
2.04E+09	10	3	[I530] C_Meat packing plants	[I52] Meat packing plants	[I3] Meat animals
1.08E+09	5	3	[I532] C_Poultry slaughtering and processing	[I54] Poultry slaughtering and processing	[I2] Poultry and eggs
8.82E+08	4	3	[I735] C_(Household heating with) heating equipment, except electric and warm a furnaces	[I412] Natural gas distribution	[I25] Crude petroleum and natural gas
5.17E+08	2	2	[I735] C_(Household heating with) heating equipment, except electric and warm a furnaces	[I25] Crude petroleum and natural gas	
4.71E+08	2	3	[I832] C_(Driving with) motor vehicles and passenger car bodies	[I193] Petroleum refining	[I25] Crude petroleum and natural gas
1.31E+08	1	1	[I832] C_(Driving with) motor vehicles and passenger car bodies		
2.64E+08	1	2	[I480] C_Poultry and eggs	[I2] Poultry and eggs	
1.48E+08	1	2	[I482] C_Miscellaneous livestock	[I4] Miscellaneous livestock	
1.37E+08	1	2	[I832] C_(Driving with) motor vehicles and passenger car bodies	[I961] Sanitary services, steam supply, and irrigation systems	
3.10E+08	1	2	[I891] C_Water supply and sewerage systems	[I413] Water supply and sewerage systems	
1.29E+08	1	2	[I924] C_Eating and drinking places	[I961] Sanitary services, steam supply, and irrigation systems	
1.51E+08	1	3	[I531] C_Sausages and other prepared meat products	[I53] Sausages and other prepared meat products	[I3] Meat animals
1.27E+08	1	3	[I534] C_Natural, processed, and imitation cheese	[I56] Natural, processed, and imitation cheese	[I1] Dairy farm products
2.21E+08	1	3	[I537] C_Fluid milk	[I59] Fluid milk	[I1] Dairy farm products
1.17E+08	1	3	[I924] C_Eating and drinking places	[I446] Eating and drinking places	[I961] Sanitary services, steam supply, and irrigation systems
6.73E+09	32				

The total Structural Path Analysis of Dinitrogen oxide.

Alternative = [A1] k2					
	Elementary flow = [E492] Dinitrogen oxide[air]				
Value (kg)	Contribution (%)	Path length	Path (1)	Path (2)	Path (3)
1.18E+08	9	2	[I490] C_Vegetables	[I12] Vegetables	
6.54E+07	5	2	[I488] C_Fruits	[I10] Fruits	
4.36E+07	3	3	[I570] C_Roasted coffee	[I92] Roasted coffee	[I10] Fruits
1.16E+07	1	3	[I544] C_Frozen fruits, fruit juices, and vegetables	[I66] Frozen fruits, fruit juices, and vegetables	[I10] Fruits
1.53E+07	1	3	[I544] C_Frozen fruits, fruit juices, and vegetables	[I66] Frozen fruits, fruit juices, and vegetables	[I12] Vegetables
1.04E+07	1	3	[I547] C_Cereal breakfast foods	[I69] Cereal breakfast foods	[I6] Food grains
7.09E+06	1	3	[I548] C_Prepared flour mixes and doughs	[I70] Prepared flour mixes and doughs	[I6] Food grains
1.76E+07	1	3	[I562] C_Wines, brandy, and brandy spirits	[I84] Wines, brandy, and brandy spirits	[I10] Fruits
1.66E+07	1	3	[I571] C_Edible fats and oils, n.e.c.	[I93] Edible fats and oils, n.e.c.	[I15] Oil bearing crops
8.61E+06	1	3	[I574] C_Potato chips and similar snacks	[I96] Potato chips and similar snacks	[I12] Vegetables
1.00E+07	1	3	[I576] C_Cigarettes	[I98] Cigarettes	[I9] Tobacco
1.12E+07	1	3	[I924] C_Eating and drinking places	[I446] Eating and drinking places	[I12] Vegetables
3.36E+08	25				

Appendix 3

The COICOP classification and the corresponding to the E3IOT classification.

COICOP level 3 to E3IOT	
COICOP	E3IOT
CP01 Food and non-alcoholic beverages	
CP011 Food	
CP0111 Bread and cereals	141401 Flour and other grain mill products (0.014140818)
	141402 Cereal breakfast foods (0.148264155)
	141403 Prepared flour mixes and doughs (0.087404288)
	141801 Bread, cake, and related products (0.351540178)
	141802 Cookies and crackers (0.150596261)
	141803 Frozen bakery products, except bread (0.051839784)
	143100 Macaroni, spaghetti, vermicelli, and noodles (0.026823087)
	143201 Potato chips and similar snacks (0.169391394)
CP0112 Meat	10302 Miscellaneous livestock (0.027445845)
	140101 Meat packing plants (0.444496691)
	140102 Sausages and other prepared meat products (0.183634311)
	140105 Poultry slaughtering and processing (0.344423085)
CP0113 Fish and seafood	30002 Commercial fishing (0.246649578)
	140700 Canned and cured fish and seafoods (0.418332309)
	141200 Prepared fresh or frozen fish and seafoods (0.335018069)
CP0114 Milk, cheese and eggs	10100 Dairy farm products (0.003503536)
	10200 Poultry and eggs (0.084238529)
	140200 Creamery butter (0.034014348)
	140300 Natural, processed, and imitation cheese (0.329458714)
	140400 Dry, condensed, and evaporated dairy products (0.122121796)
	140600 Fluid milk (0.426663101)
CP0115 Oils and fats	20600 Oil bearing crops (0.008935445)
	142900 Edible fats and oils, n.e.c. (0.991064548)
CP0116 Fruit	20401 Fruits (0.515446663)
	20402 Tree nuts (0.025184182)

COICOP level 3 to E3IOT	
COICOP	**E3IOT**
	141000 Dehydrated fruits, vegetables, and soups (0.064829923)
	141301 Frozen fruits, fruit juices, and vegetables (0.394539207)
CP0117 Vegetables	20501 Vegetables (0.623405159)
	20702 Greenhouse and nursery products (0.376594841)
CP0118 Sugar, jam, honey, chocolate and confectionery	140500 Ice cream and frozen desserts (0.076321371)
	140900 Canned fruits, vegetables, preserves, jams, and jellies
	141900 Sugar (0.064942539)
	142002 Chocolate and cocoa products (0.023473006)
	142005 Candy and other confectionery products (0.47997722)
CP0119 Food products n.e.c.	20503 Miscellaneous crops (0.000212936)
	140800 Canned specialties (0.154869363)
	141100 Pickles, sauces, and salad dressings (0.120050237)
	141302 Frozen specialties, n.e.c. (0.278073221)
	142004 Salted and roasted nuts and seeds (0.051085841)
	143000 Manufactured ice (0.013385337)
	143202 Food preparations, n.e.c. (0.382323027)
CP012 Non-alcoholic beverages	
CP0121 Coffee, tea and cocoa	142800 Roasted coffee (1)
CP0122 Mineral waters, soft drinks, fruit and vegetable juices	142200 Bottled and canned soft drinks (0.881588519)
	142300 Flavoring extracts and flavoring syrups, n.e.c. (0.118411519)
CP02 Alcoholic beverages, tobacco and narcotics	
CP021 Alcoholic beverages	
CP0211 Spirits	142104 Distilled and blended liquors (1)
CP0212 Wine	142103 Wines, brandy, and brandy spirits (1)
CP0213 Beer	142101 Malt beverages (1)
CP022 Tobacco	150101 Cigarettes (0.910631835)
	150102 Cigars (0.039997313)
	150103 Chewing and smoking tobacco and snuff (0.049370896)
CP03 Clothing and footwear	
CP031 Clothing	

COICOP level 3 to E3IOT	
COICOP	E3IOT
CP0311 Clothing materials	
CP0312 Garments	180101 Women's hosiery, except socks (0.027149329)
	180102 Hosiery, n.e.c. (0.014808634)
	180400 Apparel made from purchased materials (0.958042085)
CP0313 Other articles of clothing and clothing accessories	190301 Textile bags (0.055777196)
	320500 Rubber and plastics hose and belting (0.043645717)
	340301 Leather gloves and mittens (0.053493917)
	340302 Luggage (0.485309273)
	340303 Women's handbags and purses (0.176803425)
	340304 Personal leather goods, n.e.c. (0.12204241)
	340305 Leather goods, n.e.c. (0.062928118)
CP0314 Cleaning, repair and hire of clothing	720201 Laundry, cleaning, garment services, and shoe repair (1)
CP032 Footwear including repair	
CP0321 Shoes and other footwear	320200 Rubber and plastics footwear (0.274766684)
	340100 Boot and shoe cut stock and findings (3.92388E-05)
	340201 Shoes, except rubber (0.710636556)
	340202 House slippers (0.014557583)
CP0322 Repair and hire of footwear	720201 Laundry, cleaning, garment services, and shoe repair (1)
CP04 Housing, water, electricity, gas and other fuels	
CP041 Actual rentals for housing	
CP0411 + 0421Actual + imputed rentals	110101 New residential 1 unit structures, nonfarm (0.696100533)
	110102 New residential 2–4 unit structures, nonfarm (0.016210359)
	110105 New additions & alterations, nonfarm, construction (0.200902522)
	110108 New residential garden and highrise apartments construction
	110501 New farm residential construction (0.010042819)
CP0412 Other actual rentals	
CP042 Imputed rentals for housing	
CP0421 Imputed rentals of owner-occupiers	
CP0422 Other imputed rentals	

COICOP level 3 to E3IOT	
COICOP	E3IOT
CP043 Maintenance and repair of the dwelling	
CP0431 Materials for the maintenance and repair of the dwelling	30001 Forestry products (0.028255796)
	110105 New additions & alterations, nonfarm, construction (0.412729979)
	110108 New residential garden and highrise apartments construction
	110400 New highways, bridges, and other horizontal construction
	110501 New farm residential construction (0.020631758)
	120101 Maintenance and repair of farm and nonfarm residential structures
	200903 Wood products, n.e.c. (0.025373567)
	290202 Polishes and sanitation goods (0.039592773)
	310103 Products of petroleum and coal, n.e.c. (0.000684617)
	361100 Concrete products, except block and brick (0.000149201)
	361500 Cut stone and stone products (0.005223604)
	361600 Abrasive products (0.003095152)
	361900 Minerals, ground or treated (0.003121573)
	362200 Nonmetallic mineral products, n.e.c. (0.001922522)
	370103 Steel wiredrawing and steel nails and spikes (0.000100245)
	370402 Primary metal products, n.e.c. (0.000862571)
	381000 Nonferrous wiredrawing and insulating (0.001079379)
	400901 Prefabricated metal buildings and components (0.000271205)
	410100 Screw machine products, bolts, etc. (0.00144228)
	410202 Crowns and closures (0.00028053)
	410203 Metal stampings, n.e.c. (0.013132056)
	420500 Miscellaneous fabricated wire products (0.004101485)
	420700 Steel springs, except wire (0.000540855)
	420800 Pipe, valves, and pipe fittings (0.018162165)
	421000 Metal foil and leaf (0.005396895)
	421100 Fabricated metal products, n.e.c. (0.012971976)
CP0432 Services for the maintenance and repair of the dwelling	110105 New additions & alterations, nonfarm, construction (0.47508949)
	110108 New residential garden and highrise apartments construction
	110400 New highways, bridges, and other horizontal construction

COICOP level 3 to E3IOT	
COICOP	E3IOT
	110501 New farm residential construction (0.023749018)
	120101 Maintenance and repair of farm and nonfarm residential structures
	300000 Paints and allied products (0.005524442)
	730102 Services to dwellings and other buildings (0.034190536)
CP044 Water supply and miscellaneous services relating to the dwelling	
CP0441 Water supply	680301 Water supply and sewerage systems (1)
CP0442 Refuse collection	
CP0443 Sewerage collection	680301 Water supply and sewerage systems (1)
CP0444 Other services relating to the dwelling n.e.c.	120101 Maintenance and repair of farm and nonfarm residential structures
CP045 Electricity, gas and other fuels	
CP0451 Electricity	680100 Electric services (utilities) (1)
CP0452 Gas	680202 Natural gas distribution (1)
CP0453 Liquid fuels	80001 Crude petroleum and natural gas (1)
CP0454 Solid fuels	30001 Forestry products (0.985126019)
	70000 Coal (0.014874019)
CP0455 Heat energy	
CP05 Furnishings, household equipment and routine maintenance of the house	
CP051 Furniture and furnishings, carpets and other floor coverings	
CP0511 Furniture and furnishings	190200 House furnishings, n.e.c. (0.15135251)
	220101 Wood household furniture, except upholstered (0.250328094)
	220102 Household furniture, n.e.c. (0.007881532)
	220103 Wood television and radio cabinets (0.000175554)
	220200 Upholstered household furniture (0.150289163)
	220300 Metal household furniture (0.052809946)
	220400 Mattresses and bedsprings (0.076625079)
	230100 Wood office furniture (0.054506969)
	230400 Wood partitions and fixtures (0.055123914)
	230500 Partitions and fixtures, except wood (0.077471085)
	230600 Drapery hardware and window blinds and shades (0.048375957)

COICOP level 3 to E3IOT	
COICOP	E3IOT
	230700 Furniture and fixtures, n.e.c. (0.063232832)
	270406 Chemicals and chemical preparations, n.e.c. (0.011827315)
CP0512 Carpets and other floor coverings	170100 Carpets and rugs (1)
CP0513 Repair of furniture, furnishings and floor coverings	720205 Watch, clock, jewelry, and furniture repair (1)
CP052 Household textiles	170900 Cordage and twine (0.013357579)
	171001 Nonwoven fabrics (0.047079116)
	171100 Textile goods, n.e.c. (0.002420142)
	190100 Curtains and draperies (0.249501914)
	190302 Canvas and related products (0.051451411)
	190303 Pleating and stitching (0.091845058)
	190304 Automotive and apparel trimmings (0.207062528)
	190305 Schiffli machine embroideries (0.005816363)
	190306 Fabricated textile products, n.e.c. (0.33146584)
CP053 Household appliances	
CP0531 Major household appliances whether electric or not	400300 Heating equipment, except electric and warm a furnaces
	540100 Household cooking equipment (0.310840547)
	540200 Household refrigerators and freezers (0.295354933)
	540300 Household laundry equipment (0.23607558)
	540500 Household vacuum cleaners (0.130271554)
CP0532 Small electric household appliances	490300 Blowers and fans (0.251800627)
	540400 Electric housewares and fans (0.748199344)
CP0533 Repair of household appliances	720204 Electrical repair shops (0.601195335)
	730101 Miscellaneous repair shops (0.398804694)
CP054 Glassware, tableware and household utensils	320300 Fabricated rubber products, n.e.c. (0.127206743)
	320400 Miscellaneous plastics products, n.e.c. (0.530492306)
	320600 Gaskets, packing, and sealing devices (0.009566479)
	350100 Glass and glass products, except containers (0.147111669)
	350200 Glass containers (0.010598158)
	360701 Vitreous china table and kitchenware (0.00712075)
	360702 Fine earthenware table and kitchenware (0.038900796)

COICOP level 3 to E3IOT	
COICOP	E3IOT
	360900 Pottery products, n.e.c. (0.086033382)
	500300 Scales and balances, except laboratory (0.042969793)
CP055 Tools and equipment for house and garden	
CP0551 Major tools and equipment	420300 Hardware, n.e.c. (0.051065445)
	430200 Internal combustion engines, n.e.c. (0.129018113)
	440002 Lawn and garden equipment (0.459724039)
	470401 Power-driven handtools (0.360192418)
CP0552 Small tools and miscellaneous accessories	420100 Cutlery (0.08996322)
	420201 Hand and edge tools, except machine tools and handsaws
	420202 Saw blades and handsaws (0.020656876)
	540700 Household appliances, n.e.c. (0.112058766)
	550100 Electric lamp bulbs and tubes (0.059132583)
	550200 Lighting fixtures and equipment (0.061666202)
	550300 Wiring devices (0.001281541)
	580100 Storage batteries (0.120671123)
	580200 Primary batteries, dry and wet (0.112161882)
	621100 Instruments to measure electricity (0.363019913)
CP056 Goods and services for routine household maintenance	
CP0561 Non-durable household goods	640800 Non durable household goods / Brooms and brushes (1)
CP0562 Domestic services and household services	730107 Miscellaneous equipment rental and leasing (0.39757058)
	730109 Other business services (0.60242945)
CP06 Health	
CP061 Medical products, appliances and equipment	
CP0611 Pharmaceutical products	290100 Drugs (1)
CP0612 Other medical products	
CP0613 Therapeutic appliances and equipment	630200 Ophthalmic goods (1)
CP062 Out-patient services	
CP0621 Medical services	770100 Doctors and dentists (1)
CP0622 Dental services	770100 Doctors and dentists (1)

COICOP level 3 to E3IOT	
COICOP	E3IOT
CP0623 Paramedical services	770303 Other medical and health services (1)
CP063 Hospital services	770200 Hospitals (1)
CP07 Transport	
CP071 Purchase of vehicles	
CP0711 Motor cars	590100 Truck and bus bodies (0.017051812)
	590301 Motor vehicles and passenger car bodies (0.982948184)
CP0712 Motor cycles	610500 Motorcycles, bicycles, and parts (1)
CP0713 Bicycles	610500 Motorcycles, bicycles, and parts (1)
CP0714 Animal drawn vehicles	
CP072 Operation of personal transport equipment	
CP0721 Spares parts and accessories for personal transport equipment	320100 Tires and inner tubes (0.270157158)
	590302 Motor vehicle parts and accessories (0.264070034)
	620101 Search and navigation equipment (0.465772808)
CP0722 Fuels and lubricants for personal transport equipment	310101 Petroleum refining (0.956679463)
	310102 Lubricating oils and greases (0.043320574)
CP0723 Maintenance and repair of personal transport equipment	500100 Carburetors, pistons, rings, and valves (0.00034386)
	750002 Automotive repair shops and services (0.999656141)
CP0724 Other services in respect of personal transport equipment	750001 Automotive rental and leasing, without drivers (0.772618115)
	750003 Automobile parking and car washes (0.227381885)
CP073 Transport services	
CP0731 Passenger transport by railway	650100 Railroads and related services (1)
CP0732 Passenger transport by road	650200 Local and suburban transit and interurban highway passenger transportation (1)
CP0733 Passenger transport by air	650500 Air transportation (1)
CP0734 Passenger transport by sea and inland waterway	650400 Water transportation (1)
CP0735 Combined passenger transport	
CP0736 Other purchased transport services	650301 Trucking and courier services, except a (0.866854548)
	650302 Warehousing and storage (0.052801792)
	650702 Arrangement of passenger transportation (0.080343686)
CP08 Communications	

COICOP level 3 to E3IOT	
COICOP	E3IOT
CP081 Postal services	780100 Postal Service (1)
CP082 Telephone and telefax equipment	560300 Telephone and telegraph apparatus (0.587319493)
	560500 Communication equipment (0.412680537)
CP083 Telephone and telefax services	660100 Telephone, telegraph communications, and communications
CP09 Recreation and culture	
CP091 Audio-visual, photographic and information processing equipment	
CP0911 Equipment for the reception, recording and reproduction of sound and pictures	560100 Household audio and video equipment (1)
CP0912 Photographic and cinematographic equipment and optical instruments	630300 Photographic equipment and supplies (1)
CP0913 Information processing equipment	510102 Calculating and accounting machines (0.042248808)
	510103 Electronic computers (0.911695838)
	510400 Office machines, n.e.c. (0.040780559)
	570300 Other electronic components (0.005274826)
CP0914 Recording media	510104 Computer peripheral equipment (0.900186479)
	560200 Prerecorded records and tapes (0.077994458)
	580600 Magnetic and optical recording media (0.021819023)
CP0915 Repair of audio-visual, photographic and information processing equipment	720204 Electrical repair shops (1)
CP092 Other major durables for recreation and culture	
CP0921 Major durables for outdoor recreation	200703 Mobile homes (0.191118285)
	590200 Truck trailers (0.105328918)
	600100 Aircraft (0.35056299)
	610100 Ship building and repairing (0.031527299)
	610200 Boat building and repairing (0.118340604)
	610601 Travel trailers and campers (0.054752003)
	610603 Motor homes (0.069000885)
	610700 Transportation equipment, n.e.c. (0.079368994)
	Aircraft and missile equipment, n.e.c.

COICOP level 3 to E3IOT	
COICOP	E3IOT
CP0922 Musical instruments and major durables for indoor recreation	640200 Musical instruments (1)
CP0923 Maintenance and repair of other major durables for recreation and culture	600200 Aircraft and missile engines and engine parts (1)
CP093 Other recreational items and equipment, gardens and pets	
CP0931 Games, toys and hobbies	640301 Games, toys, and children's vehicles (0.699104667)
	640302 Dolls and stuffed toys (0.300895333)
CP0932 Equipment for sport, camping and open-air recreation	130500 Small arms (0.070952073)
	130600 Small arms ammunition (0.050067332)
	640400 Sporting and athletic goods, n.e.c. (0.878980577)
CP0933 Gardens, plants and flowers	100000 Chemical and fertilizer minerals (0.002296754)
	270201 Nitrogenous and phosphatic fertilizers (0.102948613)
	270300 Pesticides and agricultural chemicals, n.e.c. (0.784476638)
	270401 Gum and wood chemicals (0.110277966)
CP0934 Pets and related products	20202 Feed grains (0.044866133)
	141501 Dog and cat food (0.847443819)
	141502 Prepared feeds, n.e.c. (0.107690044)
CP0935 Veterinary and other services for pets	770304 Veterinary services (1)
CP094 Recreational and cultural services	
CP0941 Recreational and sporting services	40001 Agricultural, forestry, and fishery services (0.016110748)
	720203 Portrait photographic studios, and other miscellaneous personal
	760202 Bowling centers (0.027859969)
	760203 Professional sports clubs and promoters (0.05584963)
	760204 Racing, including track operation (0.080283143)
	760205 Physical fitness facilities and membership sports and recreation clubs (0.267300397)
CP0942 Cultural services	660200 Cable and other pay television services (0.227540806)
	670000 Radio and TV broadcasting (0.026463781)
	730108 Photofinishing labs and commercial photography (0.037678562)
	760101 Motion picture services and theaters (0.077751115)
	760102 Video tape rental (0.060408786)

COICOP level 3 to E3IOT	
COICOP	E3IOT
	760201 Theatrical producers (except motion picture), bands, orchestras and entertainers (0.061818223)
	760206 Other amusement and recreation services (0.508338749)
CP0943 Games of chance	760206 Other amusement and recreation services (1)
CP095 Newspapers, books and stationery	
CP0951 Books	260301 Book publishing (1)
CP0952 Newspapers and periodicals	260100 Newspapers (0.503876328)
	260200 Periodicals (0.496123642)
CP0953 Miscellaneous printed matter	260400 Miscellaneous publishing (0.395500779)
	260501 Commercial printing (0.077155985)
	641100 Signs and advertising specialties (0.527343214)
CP0954 Stationery and drawing materials	240400 Envelopes (0.025368275)
	240701 Paper coating and glazing (0.054759901)
	240702 Bags, except textile (0.135219827)
	240705 Stationery, tablets, and related products (0.02379423)
	240706 Converted paper products, n.e.c. (0.13530454)
	250000 Paperboard containers and boxes (0.033196159)
	260602 Blankbooks, looseleaf binders and devices (0.047256708)
	260700 Greeting cards (0.349269092)
	270402 Adhesives and sealants (0.048908401)
	640501 Pens, mechanical pencils, and parts (0.089883037)
	640502 Lead pencils and art goods (0.045710895)
	640503 Marking devices (0.001263473)
	640504 Carbon paper and inked ribbons (0.002999866)
	640700 Fasteners, buttons, needles, and pins (0.007065566)
CP096 Package holidays	
CP10 Education	770401 Elementary and secondary schools (0.201347798)
	770402 Colleges, universities, and professional schools (0.561932087)
	770403 Private libraries, vocational schools, and educational services,
	770600 Job training and related services (0.05318784)
CP11 Restaurants and hotels	

COICOP level 3 to E3IOT	
COICOP	E3IOT
CP111 Catering services	
CP1111 Restaurants, cafés and the like	740000 Eating and drinking places (1)
CP1112 Canteens	740000 Eating and drinking places (1)
CP112 Accommodation services	720101 Hotels (0.682494998)
	720102 Other lodging places (0.317505002)
CP12 Miscellaneous goods and services	
CP121 Personal care	
CP1211 Hairdressing salons and personal grooming establishments	720300 Beauty and barber shops (1)
CP1212 Electrical appliances for personal care	540700 Household appliances, n.e.c. (1)
CP1213 Other appliances, articles and products for personal care	240500 Sanitary paper products (0.25427708)
	290201 Soap and other detergents (0.233120933)
	290300 Toilet preparations (0.512602031)
CP123 Personal effects n.e.c.	540700 Household appliances, n.e.c. (1)
CP1231 Jewellery, clocks and watches	620700 Watches, clocks, watchcases, and parts (0.090925545)
	640101 Jewelry, precious metal (0.368748248)
	640102 Jewelers' materials and lapidary (0.27588132)
	640104 Silverware and plated ware (0.01640165)
	640105 Costume jewelry (0.059547469)
	720205 Watch, clock, jewelry, and furniture repair (0.188495725)
CP1232 Other personal effects	
CP124 Social protection	770301 Nursing and personal care facilities (0.439092368)
	770700 Child day care services (0.140400663)
	770800 Residential care (0.121291235)
	770900 Social services, n.e.c. (0.299215674)
CP125 Insurance	700400 Insurance carriers (1)
CP126 Financial services n.e.c.	700100 Banking (0.802764535)
	700200 Credit agencies other than banks (0.191717997)
	730303 Accounting, auditing and bookkeeping, and miscellaneous
CP127 Other services n.e.c.	700300 Security and commodity brokers (0.11528682)

COICOP level 3 to E3IOT	
COICOP	E3IOT
	710201 Real estate agents, managers, operators, and lessors
	720202 Funeral service and crematories (0.020505538)
	730103 Personnel supply services (0.009031426)
	730106 Detective and protective services (0.007483176)
	730200 Advertising (0.002162393)
	730301 Legal services (0.11632745)
	730302 Engineering, architectural, and surveying services (0.042751342)
	770501 Business associations and professional membership
	770502 Labor organizations, civic, social, and fraternal associations
	770503 Religious organizations (0.081806332)
	770504 Other membership organizations (0.058183663)