POSTER SESSION F

Sustainable diets and behaviour

The role of LCA in sustainable food procurement by a city

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ABSTRACT
Life cycle assessment (LCA) can identify the potential for the environmental optimization of production processes of single products. The method however reaches its limit, if several hundreds or thousands of products should be assessed at once. This can be overcome by combining LCA data for single products with environmental data linked to purchase statistics.

Keywords: environmental impact, environmental product information, environmental product declaration, carbon footprint

1. Introduction

Life cycle assessment (LCA) has proved to be a powerful tool for the environmental optimization of production processes of single products. However, it is difficult to apply detailed LCA studies to investigate several hundreds or thousands of products at once. The city of Zurich centrally organizes the procurement of about 1000 different food products for about 10’000 people in hospitals, retirement homes and other public institutions. A general aim of its policy is to reduce the environmental impacts of the governmental activities. LCA has proved to be a suitable method in order to assist this goal.

2. Goal and scope

The total environmental impact of food purchases centrally organized by the city have been evaluated applying LCA data for single products and combining them in a simplified manner with the total purchase statistics. The methodology has been developed in a study accounting for the embodied greenhouse gas emissions of Switzerland (Jungbluth *et al.* 2007).

3. Life cycle inventory analysis

A total balance of embodied emissions due to the purchases has been made. The analysis of the purchases is based on data on the estimated quantity of ordered food products. These data are linked with life cycle assessment (LCA) data of food products and product groups (ecoinvent Centre 2007, Jungbluth *et al.* 2010). Figure 1 shows an example of the life cycle inventory and impact assessment for the purchases of dairy products. Rough assumptions have been made concerning transports, packages and distribution according to the methodology developed for assessing impacts of food purchases (Jungbluth 2000a, b). Most of the impacts stem from the agricultural production of milk.

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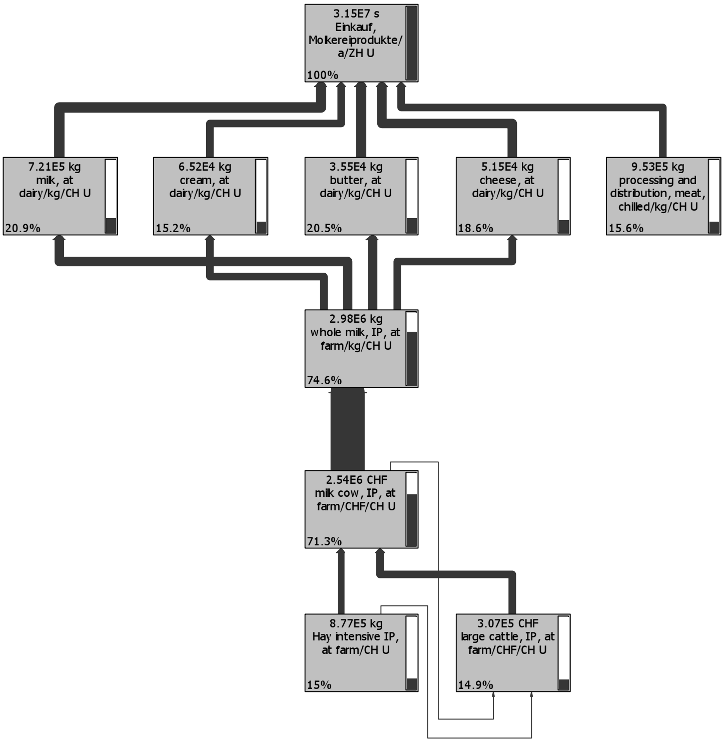

Figure 1: Unit process raw data for annual purchases of dairy products and LCIA with the ecological scarcity method

4. Impact Assessment

The impact assessment has been made for the cumulative energy demand (Frischknecht *et al.* 2007), the greenhouse gas emissions (GWP-global warming potential) (Solomon *et al.* 2007) and for environmental impacts based on the ecological scarcity method 2006 (Frischknecht *et al.* 2009). Figure 2 shows the shares of weight, value and environmental impacts for the different categories of food purchases. The evaluation on the basis of the ecological scarcity method highlights the importance of meat and dairy products for the overall impacts. Surprisingly, further products have also been identified as highly relevant, e.g. purchases of coffee. The results show differences between total environmental impacts and energy demand or GWP only.

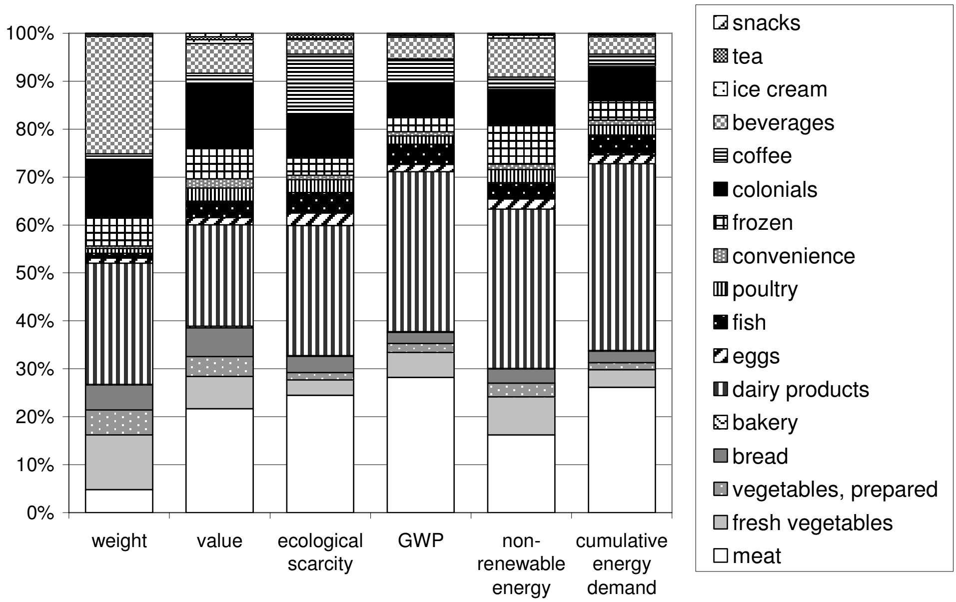

Figure 2: Share of different indicators for the food purchases of Zurich

5. Conclusions

Results of LCA case studies have been used to propose relevant issues to be considered in the call for tender of different product groups. In addition, suggestions for the reduction of environmental impacts are given to the persons responsible for food storage and preparation in the different institutions. Thus, LCA has been used in different ways to optimize the environmental performance in a large institution.

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Lifecycle greenhouse gas emissions and land use of different protein-rich products in Dutch menus

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ABSTRACT
This paper focuses on the impact on greenhouse gas emissions and land use when people's main source of proteins shifts from meat to alternative protein-rich products. Lifecycle greenhouse gas emissions and land use of protein-rich products that are prepared in different types of Dutch menus were calculated. The results show that a shift to a vegan menu reduces annual greenhouse gas emission in the Netherlands by 6 Mton CO_2eq per year, which amounts three percent of the annual Dutch greenhouse gas emission. The reduction of the land use is about 12,500 km^2 per year. Also eating chicken instead of beef or lamb reduces the greenhouse gas emissions and land use.

Keywords: protein-rich products, greenhouse gas, land occupation, vegetarian, food consumption

1. Introduction

According to Steinfeld *et al.* (2006), the global meat and dairy production chains (including land use change) are responsible for approximately eighteen percent of the global anthropogenic greenhouse gas emissions (excluding land use change and forestry) . We explored the general presumption that a shift of the consumption from animal proteins to vegetable proteins leads to a reduction of greenhouse gas emissions and land use. We compared the lifecycle greenhouse gas emissions and land use of several omnivorous and vegetarian menus We focused on the protein-rich components of the menus and assumed all other components are the same in all menus.

2. Methods

2.1 Dutch consumption and menus

First, environmental effects are calculated at the Dutch menu level. More specific: what is the environmental effect of the average consumption of protein-rich food products in the Netherlands? The next question asked is, what is the environmental impact of changing the menu, a shift from the consumption of animal protein to vegetable proteins?

The standard menu is the average consumption of protein-rich products per person per day, compiled from the 1998 results of the Dutch food consumption survey (Voedingscentrum, 1998). The other menus are defined so that the nutritional content (*e.g.* protein, iron, calcium, vitamin B components) sufficiently resemble the omnivorous menu based on the guidelines of the Dutch Food Centre (Voedingscentrum, 2008). We defined eight menus 1) an omnivorous menu, 2) a vegetarian menu (without meat and fish), 3) a vegan menu (without animal proteins) and 4) a menu without dairy products, 5) six days omnivorous and one day per week vegetarian , or 6) six days omnivorous and one day per week vegan , 7) six

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days omnivorous and one day per week no dairy products, and 8) six days omnivorous and one day per week omnivorous with 25% meat substitutes (Table 1).

We selected 34 protein-rich products for the assembly of the menus. Among these products are the most consumed meat products in the Netherlands: pork as fresh meat or processed in all kinds of assembled products, chicken as fresh meat and beef as minced beef from Dutch dairy cows, imported beef from extensive farming systems in Ireland and Brazil and beef from Dutch intensive farming systems. Dairy products, such as fresh milk and cheese, are included,. In the category of fish products, a selection from wild and farmed fish is made based on consumption statistics. This includes, for instance, salmon from aquaculture and wild herring, shrimps and mussels from fisheries.

The last group of products are meat substitutes (such as vegetarian burgers), which are mostly assembled products containing a wide range of food ingredients. Besides ingredients like vegetables, grains and starch, they also contain limited quantities of animal proteins like chicken-egg protein, milk protein or cheese.

Table 1: Average intake of protein-rich products in the Netherlands from different sources per menu (g protein-rich products per person per day).

	Meat (g/pppd)	**Fish (g/pppd)**	**Dairy (g/pppd)**	**Egg (g/pppd)**	**Vegetable (g/pppd)**	**Total (g/pppd)**
Menus (all days):						
Average (VCP[a])	109	10	410	14	0.4	544
Omnivorous (RGV[b])	59	34	524	14	0	631
vegetarian	0	0	524	28	92	644
vegan	0	0	0	0	623	623
no dairy	86	34	0	14	498	632
One day per week:						
no dairy	109	10	352	14	55	540
no meat	93	10	410	14	16	544
hybrid meat	95	10	410	14	15	544
vegan	93	9	352	12	78	543

[a] VCP = Dutch food consumption survey 1998 (Voedingscentrum, 1998)
[b] RGV-menu meets the guidance of the Dutch Food Centre (Voedingscentrum, 2008)

2.2 Calculation tool

The lifecycle greenhouse gas emissions and land use of 34 protein-rich products were calculated according an attributional Life Cycle Analysis (LCA) (Guinee, 2002) For animal products, the production of feed components, the transport and processing of feed, the feed conversion rate and manure management are taken into account. If several co-products are produced during the same stage, the upstream greenhouse gas emissions and land use are allocated according to their economic value.

2.3 Environmental indicators

Two environmental indicators are analyzed in this paper:

a. Greenhouse gas emissions are expressed in kg carbon dioxide equivalents, based on the most recent GWP-100 factors(1 kg N_2O = 298 kg CO_2eq and 1 kg CH_4 = 25 kg CO_2eq). The calculations of greenhouse gas emissions are based on IPCC modeling (IPCC, 2006; Brandes *et al.*, 2007) and lifecycle assessment methods are based on PAS-2050 (BSI, 2008) and other carbon footprint studies (Blonk and Luske, 2008; Blonk *et al.*, 2008). Emissions from fertilizer application and production, enteric fermentation, manure management and application, use of peat lands, fossil fuel combustion and production and materials for packaging are taken into account. Not taken into account are emissions from land conversion or land occupation because the methodology for allocating emissions to certain products is still under development. Moreover greenhouse gas background emissions from natural areas and emissions from capital goods or means of transport are not taken into account.

b. Land use worldwide and in the regions South America and Southeast Asia is expressed in m^2*year. This indicator is chosen to reflect the growing conversion of land for agricultural practices worldwide in general and in South America and Southeast Asia as a representative figure of land use in regions where biodiversity is highly threatened.

2.4 Data gathering

Data on the production chains of the protein-rich products are obtained from Dutch national information guides and databases (LEI, 2008; PPO, 2006), international literature, FAO data on fertilizer use (FAO, 2002) and yields and directly from companies in the food chain. Data from companies were often the only available recent source for information on processed (vegetarian) products. Specific data about the menu of vegetarians are not available.

3. Results

3.1 Separate protein rich products

The lifecycle greenhouse gas emissions and land use show a wide range between and within the product categories meat, dairy, eggs, fish and meat substitutes. In general, animal protein from intensive farming systems (pork and chicken) score relatively low in environmental burden compared to animal protein from extensive farming due to a lower feed conversion rate.

Beef, lamb, and dairy products have the highest lifecycle greenhouse gas emissions and land use per kg of protein (minimally 30 kg CO_2eq per kg protein). This is mainly caused by the relatively high greenhouse gas emissions from enteric fermentation. Pork has an average score of 24 kg CO_2eq per kg protein and the score of chicken meat is 12 kg CO_2eq per kg protein. The scores of the meat substitutes range from 6 to 20 kg CO_2eq per kg protein, and the scores of fish products from 5 to 40 kg CO_2eq per kg protein. In other words: if meat products are replaced with (vegetable) meat substitutes, on average a decrease in greenhouse gases can be expected. However, the size of the reduction is highly dependent on the specific substitution.

The lifecycle land use of protein rich products shows a wide range: for instance, the score of Brazilian beef is more than 400 m^2*year per kg meat, while for Dutch chicken it is 5.4 m^2*year per kg meat .

Despite this broad range, it can be stated that less land is used for the production of vegetable proteins than for the production of the same amounts of meat proteins. However The amount of land used for soy cropping varies in meat products in between 0 (Brazilian Beef) and 3.4 (Dutch Chicken) m2/kilogram product and for vegetarian products in between 0 and 3.0 m2/kg product in case of tofu, with an average value of 1.6 m2/kg.

3.2 Menus

The protein-rich product content of the average menu of Dutch citizens has a lifecycle greenhouse gas emission score of 1.7 kg CO_2eq per per person per day and a lifecycle land use score of 3.1 m^2 *year per person per day (Figure 1). More than half of the greenhouse gas emissions (54%) is caused by the consumption of meat products, with dairy consumption also making a major contribution (41%).

Land occupation of the protein-rich products in this menu is mainly (61%) situated in the most vulnerable regions for loss of biodiversity: South America and South East Asia.

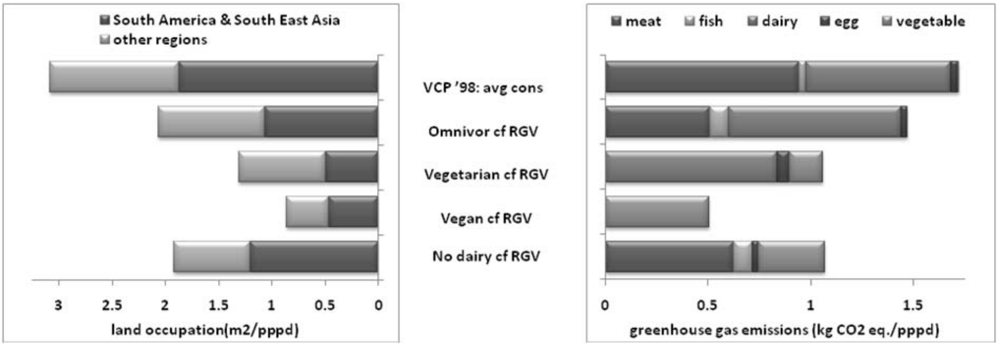

Figure 1: Land occupation (left hand side) and greenhouse gas emissions (right hand side) due to intake of protein rich products in different menus according the guidance of the Dutch Food Centre (RGV) compared to the average Dutch consumption (conform food consumption survey VCP in 1998 and abbreviated as avg cons)

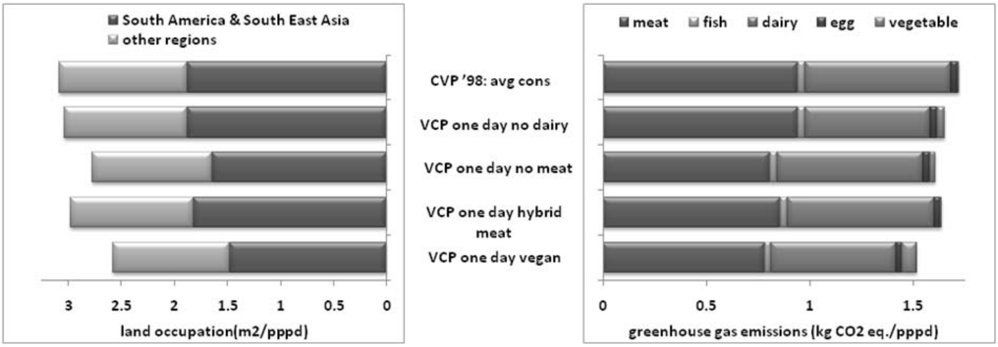

Figure 2: Land occupation (left hand side) and greenhouse gas emissions (right hand side) due to intake of protein rich products in different menus where one day per week the intake of protein rich products is changed from the level of the average Dutch consumption (conform food consumption survey VCP in 1998 and abbreviated as avg cons)

A considerable reduction in greenhouse gas emissions and land use from the level of the recent average menu can be achieved with a menu that meets the consumption guidelines from the Dutch Food Centre. An omnivorous menu compiled according to these guidelines reduces greenhouse gas emissions and land occupation with respectively 14% and 33% (Figure 1, omnivore conform RGV). This reduction can mainly be attributed to less meat consumption (see also Table 1). Compared to this omnivorous menu excluding protein from animal sources in the menu reduces greenhouse gas emissions and land use even further (Figure 1, vegan conform RGV). A vegetarian menu or a menu without dairy protein both reduces the greenhouse gas emissions from the level of the omnivorous menu with 27% - 28%.

A change to a vegetarian menu has more impact on land use (reduction of 37%) whereas a menu without dairy has a lot less reducing effect on land use (7%). A menu without any animal protein (vegan menu) has the lowest contribution to greenhouse gas emissions and land use. Although land use in South America and Southeast Asia with a vegan menu is comparable to a vegetarian menu. This is because in a vegan menu, protein from egg and dairy is replaced mainly by protein from soy grown in South America.

Of the less extreme menus, the most promising option is six days omnivorous and one vegan day per week. This gives a potential reduction of 12% and 16% for respectively greenhouse gas emissions and land occupation (Figure 2). The other menus only give small reductions, about 5% reduction in greenhouse gas emissions and 1-4% for land occupation. One exception is six days omnivorous and one day per week no meat that reduces land use with 10%.

4. Discussion

The lifecycle greenhouse gas emissions and land use of extensively produced meat are larger than those of intensively produced meat. This provokes the question how important these environmental indicators are in deciding whether the extensively produced meat is more sustainable than intensively produced meat. The problem is the importance of other aspects like animal welfare in comparison with the carbon footprint If several sustainability indicators would be combined in a single score, the ranking may change.

Blonk Milieu Advies is developing a website at which up to date information can be gathered about environmental effects of food products to keep up with the fast development of agri-food production chains.

The environmental effects of animal by-products and alternatives to animal by-products deserve investigation. The discussion about consumption and environment has focused on the consumption of meat, but meat makes up on average only half of an animal's live body weight. Slaughter by-products are used for a wide variety of applications: in food, pharmaceuticals, the oleochemical industry, fertilizers, feed components, etc. Altering meat consumption therefore affects other industries and applications, and withdrawal can lead to unforeseen environmental effects.

It is estimated that only 50% of the lifecycle greenhouse gas emissions of food production and consumption, including storage and preparation, is accounted for by the protein-rich components of the diet. Substitutes for protein products are probably interrelated on a dietary level with the replacement of many other products and the average menu of a vegetarian differs in many respects from the average menu of a meat consumer. Data on the average menu of vegetarians were scarce.

Finally, exploring how changes in consumption patterns can alter the environmental effects of protein production raises the question of the environmental potential of optimizing current animal production chains. Answering this question is the first step towards meeting the challenge of making food production more sustainable.

5. Conclusions

Dairy and meat products both contribute substantially to the global greenhouse gas emissions and land use for protein consumption in the Netherlands. Replacing animal proteins with vegetable proteins reduces the lifecycle greenhouse gas emissions of consumption. The extent of the reduction depends on the choice of vegetable alternatives. If everybody in the Netherlands would eat only vegetable proteins (vegan menu) a reduction of 6 Mton CO_2eq per year can be achieved (3% of total Dutch greenhouse gas emissions). A vegan menu also reduces the area of land needed to produce protein products by 12,500 km^2*year.

The amount of soy and other vegetable commodities from South America or Southeast Asia to compose a more vegetable-based menu differs little from the amount needed for the average (omnivore) menu in the Netherlands. Hence, it is important to stimulate more sustainable crop growing practices, for example by selective sourcing of crop commodities in the production chains of both animal and vegetable products. With regard to animal welfare issues, the absolute numbers of animals kept in animal husbandry systems will decrease if less meat is consumed. A vegetarian menu however includes dairy products and eggs, and so the number of chickens and calves that are needed to produce the desired amount of eggs and milk (in systems where animal welfare level is judged to be very low) will increase. A vegan menu has no relation to meat production and alternatives would have to be found for animal by-products, such as their use in pet food or non-food applications.

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Comparative environmental analysis of a food purchase at a municipal market and a hypermarket in a retail park

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ABSTRACT

This project studies the final stage of the agri-food chain: the retail. The environmental relevance of this final stage has risen in recent decades with the tertiarization of Western economies, where the service sector accounts for 70% of GDP and, consequently, metabolic flows in absolute terms have become more relevant. However, there are few environmental studies of the activities of this sector since it has been assumed that the resulting impacts were insignificant in relation to agricultural and industrial activities. Likewise, most of these studies are qualitative and therefore there is a lack of quantitative data. In this context, the present paper aims to obtain numerical data on the metabolic flows of a purchase in a municipal market and a hypermarket in a retail park and their resulting environmental impacts, and develops strategies for improving the environmental performance of the traditional retail sector.

Keywords: agri-food retail, environmental impact, LCA, industrial ecology

1. Introduction

The service sector is the one that carries the greatest economic weight in western countries, where it represents approximately 70% of GDP (Eurostat, 2007). However, metabolic flows in this sector have been studied very little until now, as it was assumed that the impacts derived from service activities were similar between them and of little importance in relation to agricultural and industrial activities. That is why there has been environmental concern and more policies have been generated in these latter sectors, especially in industrial area, for which policies have been focalised mainly on atmospheric emissions and the ultimate disposal of waste (Farreny, 2008).

Therefore, although the service sector has not traditionally represented one of the economic sectors with the greatest environmental impact, the tertiarization of recent decades has generated a sector where, given its current market importance, the magnitude of flows of energy and materials has increased, along with, therefore, the associated impact. On the other hand, the consumption of energy and materials varies depending on the type of services considered (transport, tourism, catering, etc.), and a quantitative characterisation of these flows by each type can provide a qualitative view of the impacts associated to the same.

1.1. Agri-food retail facilities

The food trade is one of the most important commercial branches of the service sector as it represents an essential type of service for human living. Traditionally, there used to be

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municipal markets and small businesses located within the urban network, but in recent decades department stores and retail parks have started appearing, a concept forged in North America in the 1930s and that expanded to other continents from the 1960s (Escudero, 2008). 2006 estimates for Western Europe suggested there were almost 1,400 hypermarkets selling food, concentrated in 700 retail parks (Guy, 2006).

1.2. Precedents/Antecedents

In the field of services and, specifically, the commercial sector, several studies have looked qualitatively at environmental impacts, and this has also been the case for the food trade sector itself. However, these studies have been limited to qualitative descriptions and proposing guides to good practice or preventative measures, such as the *Guia de gestió dels residus i de l'energia als mercats municipals* (DIBA, 2009); and, therefore, there has been a lack of quantitative studies in the sector.

1.3. Aims

In this context, the main aim of this study is to quantify the overall environmental impact associated to a standard purchase in two types of commercial establishment: a municipal market, as a standard establishment located in the urban nucleus, and a retail park, as an establishment located on the urban periphery, applying life cycle assessment methodology.

2. Methodology

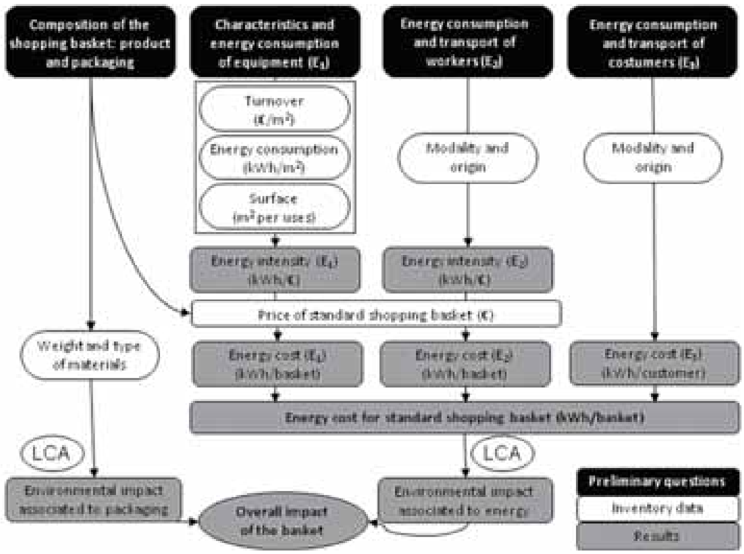

Figure 1: Methodological structure of the project.

Of all the periods of the lifecycle of food products, this project will focus its analysis on those that are related with retail trade. However, the study focuses on two vectors: the energy vector, which calculates the energy consumption associated both to establishment consumption and the transport of workers and customers; and the waste vector, which studies the quantity and type of waste generated as packaging. The study works in two phases, the first involves quantifying the flows for the vector, on the basis of an MEFA (Eurostat, 2001); and the second involves quantifying the associated impact, working with an LCA (ISO 14040, 2006) (Figure 1).

2.1. Study System

The analysis was made in two study systems that are representative of the food trade sector but that also offer differing social and environmental characteristics. On the one hand, for the municipal market system (S_m), five markets were chosen that are located geographically in the study area, the province of Barcelona, and that are representative of the different types of municipal market and where quantitative studies had not been performed previously. On the other hand, the retail park system (S_{rp}), for which we selected a retail park located in Sant Boi de Llobregat (Barcelona), representative of this type of commercial format and with similar structural and functional characteristics to other European retail parks.

2.2. Functional unit

In order to obtain the potential impact of the energy and waste vectors associated to a system, a functional unit was defined: a standard shopping basket, which contains the following purchases: lean meat (150 g), minced meat (400 g), boiled ham (125 g), cheese (125 g), eggs (half a dozen), sliced cod (250 g), clams (500 g), apples (4), courgettes (3), green beans (300 g), potatoes (1 kg) and almonds (90 g).

This basket was determined on the basis of the Consumer Price Index (CPI) of the National Statistical Institute (INE), based on the Continuous Survey of Family Budgets (ECPF), which makes it possible to work out how families consume and in what quantity. Secondly, we worked on the basis of the quantities for a balanced diet of 2,300 kcal (Pinto and Carbajal, 2003) to determine the units of each product. And finally, the quantities of these products were adjusted to those that cannot be purchased in bulk in a retail park and can only be purchased in packs of units or certain quantities.

2.3. Inventory

In relation to the energy vector, the consumption by the establishment for the retail park data was available on the energy intensity for 2006 in the study by Farreny et al. (2008). However, for the municipal markets, energy consumption was estimated on the basis of the calculations made by the Institut Cerdà (DIBA, 2009). And energy consumption by transport, both of workers and customers, was measured using the methodology used in the study by Farreny et al. (2008).

For the waste vector, we first filled the standard shopping basket at a municipal market and in a retail park in the area in order to sort out the packaging of each of the selected products and weight it using analytical scales, differentiating between primary packaging, pertaining to the product itself like polystyrene tray, and secondary packaging, which is added by the customer in order to transport purchases like plastic bag. Secondly, the weight data was unified by type of material and by commercial establishment.

2.4. Environmental tools: Life cycle assessment (LCA)

Having characterised the flows of study, energy and packaging, what followed were the stages of classifying and characterising the methodology for the life cycle assessment (LCA) (ISO 2006). The classification enabled the association of each environmental load to one or more impact categories, while the characterisation made way for the overall impact, which was worked out by multiplying each load by a characterisation factor associated to each impact category (ISO 2006). The classification and characterisation stages observed the CML 2 Baseline 2000 (Guinée et al., 2001) methodology. The selected midpoint impact categories and their units are as follows: abiotic depletion potential (ADP, kg Sb eq.), acidification potential (AP, kg SO_2 eq.), eutrophication potential (EP, kg PO_4^{3-} eq.), global warming potential (GWP, kg CO_2 eq.), ozone layer depletion potential (ODP, kg CFC-11 eq.) and human toxicity potential (HTP, kg 1.4-DB eq.).

The ecoinvent 2.0. database was used as a source of information to calculate the impact of the energy production associated to the quantified consumptions flows (Dones *et al.*, 2007) and the impact of the materials of the inventoried packaging flow (Hischier, 2007).

3. Results and discussion

3.1. Energy consumption

The energy consumption of a standard basket is higher for a purchase in a retail park (11.10 kWh) than at a municipal market (0.57 kWh) at a ratio of 20 to 1, which is reduced to 5 to 1 when excluding the transport of customers, the stage with the greatest divergence between the two systems (Table 2). Thus, by analysing the characteristics of each stage of consumption, the inequalities between the types of establishment are observed (Table 1).

Table 1: Characteristics of each establishment, by consumption stage

	Establishment	**Transport of workers**	**Transport of customers**
S_{rp}	Greater number of high power equipment installed (air conditioning, refrigeration)	Higher average distance (5 km) Motorisation: 79% Higher economic efficiency (€/m^2) and lower ratio of workers per m^2, which reduces unitary consumption (kwh/€)	Supramunicipal influence Higher establishment-home distance (7.3 km) Motorisation: 100% Lower use of public transport (1%)
S_m	Lower number of high power equipment installed	Lower average distance (3,4 km) Motorisation: 42% Higher cost of basket, which leads to higher total consumption (kwh/basket)	Municipal influence Lower average distance (0.8 km) Motorisation: 10% Greater use of public transport (8%)

3.2. Packaging waste vector

The generation of waste is also higher in a retail park (252.93 g) than in a municipal market (102,08 g), though the distribution between primary and secondary packaging and the materials used for the same present different characteristics in each establishment (Table 2).

First, the need in a retail park for products to be positioned in such a way that they are easily and rapidly acquired by their customers, means products are overpackaged and primary packaging is more relevant (92.92%). In turn, secondary packaging carries more relative weight at a municipal market, where it represents 25% of the weight as a consequence of the lower optimisation of plastic bags, as one is given per stall.

Second, the materials used in the manufacture of trays (PS, PP, HDPE), multilayer packaging (PET) and casing for other packaging (cardboard) is not generated or is generated in much smaller quantities at a municipal market.

Table 2: Inventory results for energy and packaging vector.

	Energy consumption (kWh/basket)				**Waste generation (g/basket)**		
	Facility	Worker transportation	Customer transportation	***TOTAL***	Primary packaging	Secondary packaging	***TOTAL***
S_{rp}	1.68	0.18	9.23	***11.1***	235.03	17.9	***252.93***
S_m	0.28	0.23	0.058	***0.57***	76.54	25.54	***102.08***
S_{pc}/S_m Ratio	6	0.8	160	***19.5***	3.1	0.7	***2.5***

3.3. Environmental impact

Following the pattern of energy consumption: the impact associated to this vector is higher for an establishment in a retail park, though lower for the transport of workers; and the impact associated to the transport of customers is more divergent, being between 75 and 233 higher in a retail park, depending on the category analysed (Table 2).

The impact associated to the generation of waste is lower for a municipal market, which represents between 22 and 48% at a retail park, depending on the category of impact. This is because, firstly, the generation of waste (in weight) at a retail park is 2.5 times greater than that of a municipal market; and secondly, materials with a greater impact per kg (PS, PET and cardboard) are found in much higher quantities in a retail park.

Finally, the overall impact of the shopping basket is between 6 and 28 times greater in a retail park, depending on the category analysed.

Table 3: Environmental impact of one standard shopping basket, by category of impact.

	ADP	**AP**	**EP**	**GWP**	**ODP**	**HTP**
	(kg Sb eq)	(kg SO_2 eq)	(kg PO_4^{3-} eq)	(kg CO_2 eq)	(kg CFC-11 eq)	(kg 1,4-DB eq)
Retail park (S_{rp})						
Energy	2.05E-02	1.34E-02	1.26E-03	3.07E+00	3.65E-07	7.39E-01
Packaging waste	8.92E-03	2.37E-03	3.21E-04	7.27E-01	1.14E-08	1.14E-01
Total	**2.94E-02**	**1.58E-02**	**1.58E-03**	**3.80E+00**	**3.76E-07**	**8.53E-01**
Municipal market (S_m)						
Energy	1.73E-03	1.91E-03	1.38E-04	2.46E-01	2.02E-08	6.51E-02
Packaging waste	2.50E-03	7.43E-04	9.25E-05	2.20E-01	5.29E-09	2.80E-02
Total	**4.23E-03**	**2.53E-03**	**2.08E-04**	**4.46E-01**	**2.08E-08**	**8.73E-02**
S_{pc}/S_m Ratio	**7.32**	**6.23**	**7.63**	**8.78**	**18.13**	**9.76**

Source: Authors from SimaPro V.7.1. and CML 2000 Methodology

4. Conclusions and proposals for improvement

4.1. Comparison of facilities

The environmental comparison determines that a municipal market is much the more sustainable option of the two types of food establishment we analysed, as the impact associated to a standard shopping basket is, on average, 10 times higher in a retail park than in a municipal market. In the food trade sector, measures to reduce environmental impact need to focus on the energy vector, which is highly represented in the two facilities we analysed.

4.2. Retail park

The transport of customers represents 83.2% of energy consumption and is what produces the greatest difference in this vector for the two systems of analysis. In this sense, it is proposed that the managers of such establishments should produce sustainable mobility policies for their customers, in order for the modality of motorised customers to be more similar to that observed for a municipal market (80% in public transport and 20% in a private vehicle), representing an approximate reduction of 30% of the impact associated to.

Current policies for reducing the amount of waste focused on secondary waste, such as the elimination of plastic bags (LDPE), have little repercussion as the relative weight in the total amount of packaging is only 7%. In this sense, policies in the field of waste have to be more focused on reducing primary packaging and the reduction of certain materials, like PET.

4.3. Municipal market

In the energy consumption of a purchase made at a municipal market, the greatest impacts stem from the establishment itself (49.5%) and the transport of workers (40.4%). Therefore, improvement activities have to be focused on the energy efficiency of the establishment itself, and on amortising the establishment's consumption by increasing occupancy of the commercial surface and promoting shared used by workers of private vehicles.

Meanwhile, policies for eliminating plastic bags as secondary packaging are of notable relevance in the waste vector. Nevertheless, the reduction or elimination of materials with high potential for impact on any of the categories analysed, such as polyester.

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A lunch plate model as a functional unit of food LCA and a basis for environmental communication

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ABSTRACT

The LCAs of varied standardized homemade and ready-meal lunches are described. The lunch plate model is used as a functional unit of LCA because environmental communication to consumers was emphasised and nutritional quality was stressed. The servings were based on omnivorous, vegetarian and vegan diet. Lunches represent 2-12% of climate impact for daily consumption of a Finnish consumer, and respectively 7-47% of eutrophication potential. Climate impact for homemade portions ranges between 650g and 3.81kg of CO_2 equivalent, and for the eutrophication potential between 0.7g and 4.6g PO_4 equivalent. Climate impact of a ready-meal portions ranges between 1.75kg and 2.35kg of CO_2 equivalent, and for eutrophication potential between 1.19g and 2.11g PO_4 equivalent. In most cases the main dish caused the greatest share of environmental impacts. However, the climate impact of salad can form even one third of the total. Difference between homemade and ready-meals was caused by differences in ingredients.

Keywords: food, diet, carbon footprint, environmental impacts, life cycle assessment

1. Introduction

The integrated product policy (IPP) has been a mainstream environmental policy in the EU during the past decade. It addresses the whole life-cycle of a product and a range of environmental impacts. Despite the fact that it has approached environmental impacts of products mainly from the production point of view, it also stresses information needs of consumers concerning environmental impacts of a product. It highlights responsible consumption.

In order to make responsible choices, consumers need reliable information. In order to be successful, environmental communication must, in turn, relate to everyday life, and the skills and practices of consumers. The messages should speak of issues and practices familiar to consumers. When it comes to food, various preferences and situational factors affect food choices, which make environmental communication challenging. It is impossible to take into account all the contributing factors, but it is important to understand the range in personal preferences. One of the obvious features of eating is that diet consists of several foods, and different foods make their own specific contributions to nutrition. Consumers do not choose between, for example, carrot and pork, but rather between entire dishes. What we eat is largely culturally determined and in order to understand the possibilities for changing the environmental impacts of food, we must assess the food combinations that people actually consume.

The aim of this study was to create a model for assessing environmental impacts of food choices in a suitable way to represent a basis for environmental communication to consumers. To focus the work, young people of 13-16 years were identified as the principal target group for communication.

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2. Methods

2.1. The lunch plate model as a functional unit

LCAs were performed on 30 different lunches. The investigated lunches followed the so-called plate model, which was chosen because we sought a model based on a balanced and healthy diet as we wanted to highlight the nutritional function of food because our target group was young people who perhaps exercise strong biases and might decide to avoid some foods despite their potential nutritional value. The plate model is commonly used for communicating to consumers how to make healthy food choices, and is therefore familiar to most Finnish consumers. A balanced meal according to the plate model is one quarter starch, i.e. potatoes, rice or pasta, one quarter meat, fish, poultry or pulses, and half vegetables. In addition, a meal should include bread with vegetable fat spread and skimmed milk or water.

In addition, two other criteria were used to ensure the nutritional quality of portions: 1) equal amounts of energy were made available, i.e. recommended for the target group (740 kilocalories), and 2) shares of energy from proteins, fats and carbohydrates were matched to the recommendations for the target group (The National Nutritional Council, 2005). To enhance the usability of the model, we ensured that 1) the servings were familiar to the target group and 2) similar servings could be eaten as a homemade meal or a ready-meal dish. Homemade foods were based on common recipes, and ready-meal foods were based on actual products of one producer.

The servings in Table 1 were based on 1) omnivorous, 2) vegetarian and 3) vegan diets as it is well known that significant differences exist in the environmental impacts of the main protein sources. Starch was represented by potato, pasta, rice or barley. The salad ingredients varied from outdoor-grown to greenhouse-grown, and the complementary bread was either dark rye bread or light whole-wheat bread. The amount of bread varied from portion to portion. The amount of vegetable spread (70% fat) on the bread was fixed at 10% of the quantity of bread. The drink comprised 2 decilitres of skimmed milk, or water with vegetarian dishes.

Table 1: 14 homemade lunches and 7 ready-meal lunches considered in the study.

	Homemade servings	**Ready-meal servings**
Macaroni casseroles:	♦ minced meat-macaroni casserole ♦ chicken pasta casserole	♦ minced meat-macaroni casserole ♦ chicken-pasta casserole
Potato based casseroles:	♦ ham casserole ♦ chicken casserole ♦ rainbow trout casserole ♦ vegetable casserole (lacto-vegetarian)	♦ ham casserole ♦ rainbow trout casserole ♦ vegetable casserole (lacto-vegetarian)
Chicken sauces:	♦ chicken sauce with wholemeal rice and ♦ chicken sauce with wholemeal pasta	♦ chicken in cream sauce with rice
Sausage meals:	♦ frankfurter and mashed potatoes	
Porridge meals:	♦ barley porridge with berry fool (lacto-vegetarian)	♦ barley porridge with berry fool
Vegetable patty meals:	♦ beetroot patty with barley (lacto-vegetarian) ♦ soy bean patty with mashed potatoes (vegan) ♦ soy bean patty with mashed potatoes (lacto-vegetarian) ♦ broad bean patty with mashed potatoes (vegan)	

In order to ensure research relevance, we 1) selected diverse foods with wide-ranging environmental impacts on global warming potential and eutrophication, and 2) tried to ensure that relevant information on environmental impacts using the LCA approach was achievable.

2.2. System Boundaries

All main phases and emission sources from cradle to grave are included in life cycle systems of lunches. Inputs of agricultural primary production, raw material production in agriculture, food processing industry, distribution, packaging and consumption are included. Within agricultural production, use of inputs (seed, fertilizer, manure, feed, energy) and machine work are included. Some minor sources of emissions are excluded, such as waste treatment. Processing and use of by-products in other production systems, and transportation are also excluded. System schemes of ready-meal lunches are illustrated in Figure 1. A system scheme of homemade lunches is largely similar.

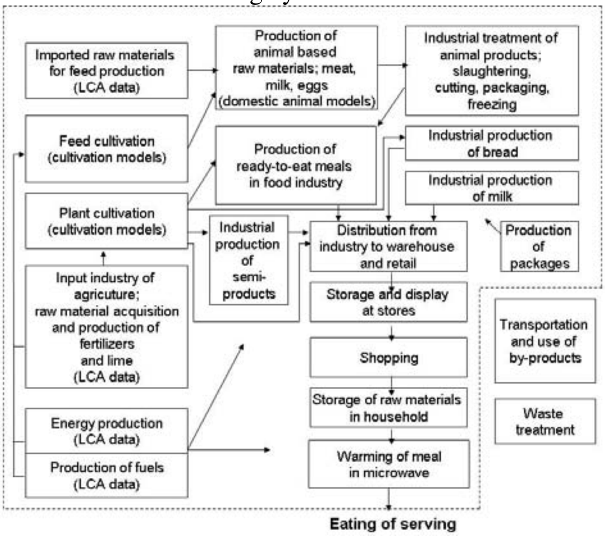

Figure 1: System schemes for ready-meal lunches. The system scheme for homemade lunches differs from this only in industrial and consumer phases, where different processes are used.

2.3. Life Cycle Inventory and Impact Assessment

The life-cycle models used for agricultural production corresponded to average Finnish production, with the exception of imported products and raw materials. For them LCA-based data from EcoInvent database were used. Finnish production of 20 plant products and 6 domestic animal products was modelled based mainly on primary data collected during this study. For the chicken, data from the previous study were used (Usva *et al.*, 2009).

Life cycle data on fertilizers and lime were from the chain actors, composition of industrial feed was from the major producers, and data on domestic raw materials for feed were from models used in this study. Activity data on agricultural production were from the national agricultural input-output database, national statistics, the literature, and personal communications. Activity data on the food processing and retail industries were collected from five Finnish companies. Data for the consumer phase were taken from the literature (Kauppinen *et al.*, 2009). The energy profile used for electricity and district heat was according average Finnish grid data with the exception of greenhouse production where sector-specific statistics were used.

Estimation of N_2O and CO_2 emissions from the field for models of climate impact were based on IPCC (2006). NH_3 emissions from fertilizer were estimated based on models from the EEA (European Environment Agency, 2006) and from manure, based on Döhler *et al.*

(2002). The emission model for nitrogen and phosphorus leaching is based on Grönroos (2003), but is further developed based on empirical Finnish leaching measurements made at MTT and the Finnish Environmental Institute. Saarinen *et al.* (2010) describe all the methods in detail. In the impact assessment, characterisation factors of climate impact were based on IPCC (2006) and site-dependent factors for eutrophication on Seppälä *et al.* (2004).

3. Results

Lunches represent 2-12% of climate impact for daily consumption of a Finnish consumer, and respectively 7-47% of eutrophication potential (Figure 2). This was assessed using the benchmark approach that describes the total environmental impacts of an average Finnish consumer (Nissinen *et al.*, 2006).

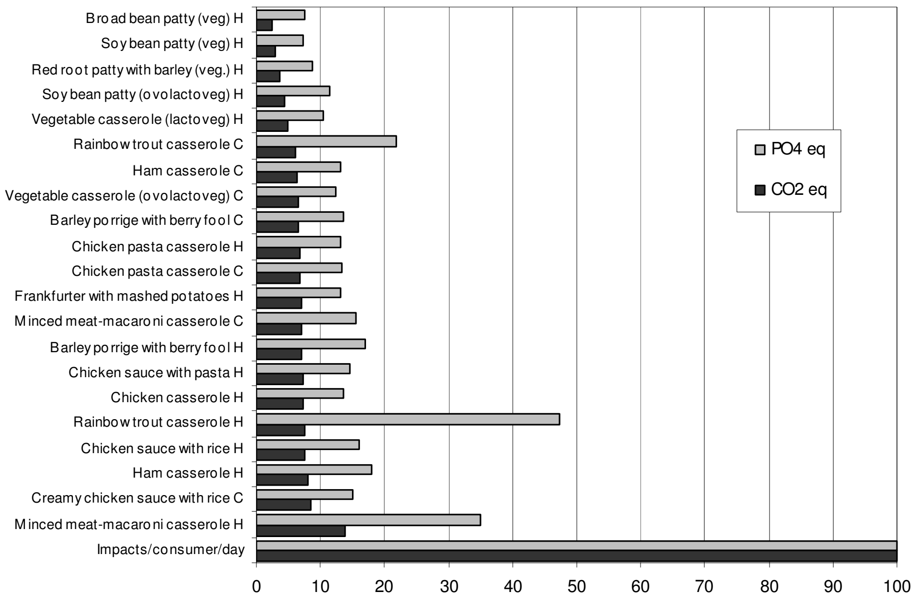

Figure 2: Climate impact and eutrophication potential of lunches in relation to average consumer daily impacts. H - homemade portion, and C - ready-meal meals.

Climate impact of a single homemade portion ranges between 650g and 3.81kg of CO_2 equivalent (Figure 3). For the eutrophication potential, the range is between 0.7g and 4.6g PO_4 equivalent. Animal-based meals exert a two- to threefold climate impact and a four- to five-fold eutrophication impact, compared with vegetarian dishes. However, internal differences between different meat and vegetable meals were also recorded. In most cases the main dish has the greatest share of environmental impacts. For some meals the share of the impact of salad can be as high as one third of the total. Salads were based on either outdoor or greenhouse-grown vegetables. The carbon footprint of the salad portion (150g) from greenhouse vegetables is over 600g CO_2 equivalent, and for outdoor products it varies between 130g and 370g CO_2 equivalent. Impacts on climate change of greenhouse vegetables are high in both absolute values and proportional to other components of lunch portions.

The relatively higher impact of rice in comparison with that of pasta is not unequivocal when the total impact of the meal is taken into account. Potato is, however, a clear winner in comparison with both rice and pasta, as long as no milk products are used for gratinating.

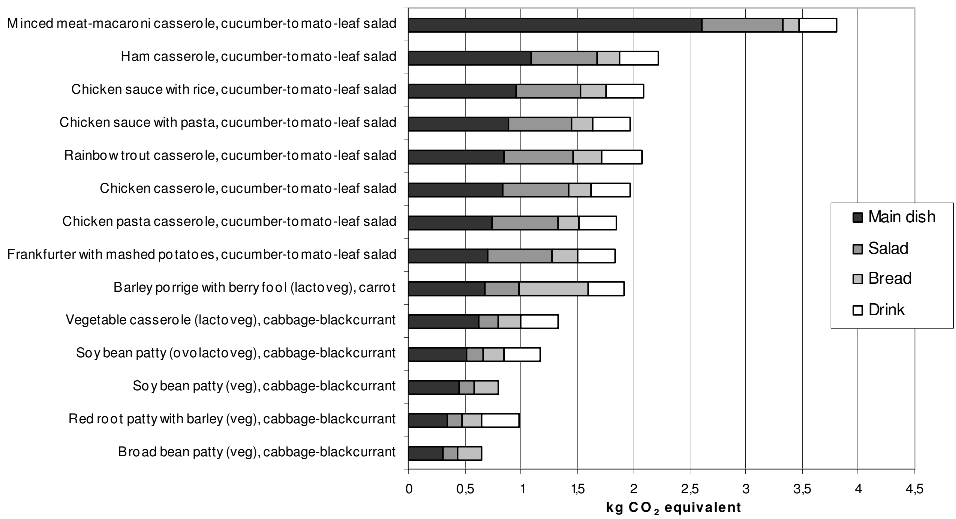

Figure 3: Climate impact of single homemade lunch portions.

Climate impact of a single ready-meal portion ranges between 1.75kg and 2.35kg of CO_2 equivalent. For eutrophication the potential range is between 1.19g and 2.11g PO_4 equivalent (Figure 4). Impacts of ready-meal lunches represent an average burden in relation to the total lunch repertoire. Comparing such portions, ready-meal lunches represent less of a burden than home-cooked ones. However, the differences between them are mainly due to different types of raw materials used, not e.g. energy efficiency of production chains.

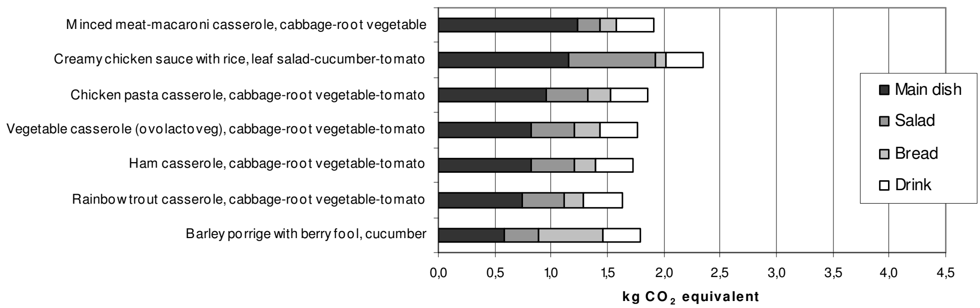

Figure 4: Climate impact of single ready-meal (convenience food) lunch portions.

4. Discussion

The lunch plate approach provides a suitable framework for consumers to consider environmental impacts of their food choices. It can well be used as a tool for environmental communication, providing a broader view of food choices than, for example, the carbon footprint of a single food product (e.g. a ready-meal product or an ingredient of dish). Climate impacts of beef can be up to 20 times higher than for a single plant-based food, but this study shows that differences between portions are much smaller than between extreme single foods, but still are significant between vegetarian and mixed diets. However, it remains unknown how total environmental impacts might change if the diet of Finnish people drastically changed to become vegetarian. Animal production also has environmental impacts other than those investigated in this study, and some impacts of animal production are positive, such as those on biodiversity.

The study indicates that the method of cooking and the anticipated benefits of industrial preparation of food are not as great as expected from the climate change point of view. The results highlight questions about small-scale production and local production-consumption systems, which would be interesting lines of investigation meriting further study.

Large amount of data were used in the life cycle inventory. Data were mainly based on primary data sources, and it represents the average Finnish production. The results are likely to be quite robust in that level. However, method is not sensitive to show varieties within different types of production chains.

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Relative GHG footprint of two healthy Nordic diets

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ABSTRACT

Using LCA we analyzed the GHG footprint of two healthy Nordic diets: One based on the Nordic Nutritional Recommendations (NNR) and the other on preliminary specifications for a New Nordic Diet (NND) as part of the OPUS project. Both diets were analyzed with the average Danish diet (ADD) as reference, and all diets were adjusted to similar energy and protein contents. The healthy diets were constructed by modifying ADD in three ways. By modifying the relative content of foods and beverages NNR emitted 8 % less GHGs than ADD, and NND 7 % less. By including transport associated with import, NND, which consisted of local produce only, emitted a further 5 % less GHGs than ADD, totaling a 12 % reduction. By including an organic share of 80 % in NND and the actual shares in ADD and NNR, NND emitted more GHGs, now only 5 % less than ADD.

Keywords: GHG (greenhouse gases), GWP (global warming potential), NND (New Nordic Diet), NNR (Nordic Nutritional Recommendations), OPUS

1. Introduction

This study is part of the OPUS project: '*Optimal well-being, development and health for Danish children through a healthy New Nordic Diet* '. The aim of OPUS is to introduce a science-based New Nordic Diet (NND) to the Nordic public through a large number of recipes developed by the some of the foremost Nordic chefs. NND aims at being simultaneously palatable, healthy and environmentally sustainable. NND will be tested in two large-scale intervention studies with multiple response analyses of several hundred adults and children.

In this study we test the GWP of two healthy diets relative to the average Danish diet (ADD) using their GHG emissions calculated by Life Cycle Analyses; NNR defined by the Nordic Nutrition Recommendations (Norden, 2004), and NND defined by preliminary recommendations in the OPUS project. Values for GHG emissions caused by organic and/or conventional foods and beverages were taken from the LCA-Food database (2004) using Stepwise method in SimaPro®, Halberg et al. (2006), Williams et al. (2006), Audsley (2009), Halberg et al. (2010) and by consensus among the authors based on more recent sources.

GHGs are only one of several environmental indices used in evaluating environmental effects of goods and services. We are well aware that it does not give a complete picture of environmental responses to food choices, but data for GHG are presently the most available environmental indicator. More environmental indices will be applied in future studies.

2. Methods and materials

The composition of ADD and NNR were described by the Danish National Food Institute and 2.-0 LCA consultants based on data from national questionnaires on food intake and data for food production and import from Statistics Denmark (Saxe et al, 2006). The environ-

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mental effects of foods and beverages are a result of what is produced, not of what is consumed. The NND is defined by three core elements: (a) changes in diet composition, (b) local products preferred to imported products, and (c) organic products preferred to conventional.

Table 1. Diet composition and emission of greenhouse gases. The first three columns give the weight of the main foods and beverages in the three diets of this study; ADD, the Average Danish Diet; NNR, A diet according to the Nordic Nutritional Recommendations; and NND, The New Nordic Diet. The following 3 sets of 3 columns give the potential GHG emissions compared of the three diets. NND contains only Danish produce and it is 80 % organic by weight.

Products	Diet composition			Emission of greenhouse Gases, GHG, kg/person/year								
	kg/person/year			Composition implemented			Local purchase implemented			Organics implemented		
	ADD	NNR	NND	ADD	NNR	NND	ADD	NNR	NND	ADD	NNR	NND
Beer, wine, alcohol	114.5	45.9	57.2	154.2	62.0	52.8	176.7	71.1	52.8	176.7	71.1	52.3
Berries	3.5	6.4	65.1	2.4	4.4	44.6	2.8	5.3	44.6	2.8	5.3	44.6
Butter	2.6	0.5	1.3	16.7	3.1	8.3	16.9	3.2	8.3	16.6	3.1	7.5
Cabbage	6.1	11.6	18.3	1.4	2.6	4.1	2.5	4.7	4.1	2.5	4.7	4.1
Candy	20.3	11.1	10.1	123.6	67.8	61.8	141.8	87.8	61.8	141.8	87.8	61.8
Cheese	13.4	15.2	21.9	154.0	174.0	250.9	154.5	174.4	250.9	154.4	174.3	248.4
Coffee+tea+cocoa: dry	15.7	8	7.9	118.8	60.1	6.8	118.8	60.1	6.8	118.8	60.1	6.8
Convenience	5.2	4.6	2.6	4.0	3.5	2.0	4.6	4.0	2.0	4.6	4.0	2.0
Dairy products	138.3	166.8	197.5	166.5	205.8	237.8	167.0	205.8	237.8	161.7	198.7	214.0
Eggs	8	19.8	23.8	16.0	39.5	47.4	16.1	39.8	47.4	17.3	42.7	60.1
Fruit. excl. berries	85.6	149.7	248.8	46.0	81.5	82.8	68.9	122.1	82.8	69.6	123.3	116.9
Herbs	1.8	1.7	5.2	1.6	1.5	14.1	1.9	1.9	14.1	1.9	1.9	14.1
Juice	45.5	24.9	22.8	45.5	24.9	22.8	50.7	27.7	22.8	51.7	28.2	27.7
Legumes	3.6	5.5	15.2	1.7	2.5	7.5	2.3	3.5	7.5	2.3	3.5	7.5
Marmalades	3.8	6.1	0.1	2.0	3.0	0.1	3.5	5.4	0.1	3.4	5.4	0.1
Meat, industrial	74.9	61.6	52	738.7	562.6	509.9	742.6	565.6	509.4	742.8	565.9	546.5
Meat, game	0	0	1.5	0.0	0.0	4.5	0.0	0.0	4.5	0.0	0.0	4.5
Mushrooms +lettuce	7.8	12	6	8.8	13.6	6.9	10.2	15.7	6.9	10.2	15.7	6.9
Mushrooms. wild	0	0	1.8	0.0	0.0	1.8	0.0	0.0	1.8	0.0	0.0	1.8
Nuts	1.6	1.4	11	0.8	0.7	4.7	2.0	1.8	4.7	2.0	1.8	4.7
Oils excl. rape	11.7	16.4	0	29.1	52.6	0.0	29.4	55.7	0.0	29.4	55.6	0.0
Oils of rape	0	0	11.7	0.1	0.0	41.4	0.1	0.0	41.4	0.1	0.0	35.2
Pasta, industrial	6.2	5.9	0	5.6	5.3	0.0	7.1	7.2	0.0	6.8	7.0	0.0
Potatoes	58	94.3	87	12.3	19.8	18.5	15.6	24.9	18.5	15.5	24.7	17.3
Roots, excl. potatoes	19.7	31.1	98.6	3.7	5.8	18.3	7.3	11.5	18.3	7.6	11.8	22.9
Rice	3	4.7	0	10.4	16.5	0.0	11.8	18.7	0.0	11.8	18.7	0.0
Seafood and fish	11.2	21.2	25.1	35.6	67.6	81.7	38.1	72.3	81.7	38.1	72.3	81.7
Softdrinks	118.6	30.9	0	16.6	4.3	0.0	19.3	5.3	0.0	19.3	5.3	0.0
Sugar	4.9	3.4	2.5	4.8	3.3	2.4	4.8	3.3	2.4	4.8	3.3	2.4
Vegetables, others	45.5	61.8	61.5	135.7	193.8	183.7	142.9	202.5	183.7	148.1	209.1	236.8
Wheat, proc. products	39	35.4	0	33.0	29.3	0.0	33.6	29.7	0.0	33.3	29.7	0.0
Whole grain products	39.2	66.3	84	30.5	50.7	65.3	35.3	61.6	65.3	34.9	61.3	60.4
Other products	1.5	0.1	3.3	1.8	0.5	3.4	1.8	0.5	3.4	1.8	0.5	3.4
Sum kg/person/year	911	924	1144	1922	1763	1786	2031	1893	1786	2033	1897	1892
Energy, MJ/person/day	13.21	13.25	13.18	-	-	-	-	-	-	-	-	-
Protein g/person/day	137.2	137.0	137.5									

The preliminary specifications for NND changes the contents of food and beverage relative to ADD as follows: 1.5X ADD fruit, 18.8X ADD berries, 3X ADD cabbage, 5X ADD roots, 1.5X ADD potatoes, 4.3X ADD legumes, 1.4X ADD other vegetables, 2.1X ADD whole grain products, 7X ADD nuts, 2.3X ADD seafood, 0.7X ADD meet, 1.4X ADD dairy products, 0.7X ADD cheese, 1.5X ADD eggs, 0.5X ADD beer, butter, candy, cake, convenience, ice cream, sugar; No rice, industrial pasta, wheat bread, chocolate, tea, coffee and cocoa. Healthy pasta, marmalade, and juice are produced by local suppliers based on the extra amount of fruit and vegetables included in NND. Wine and alcohol is substituted by beer.

The DANKOST3000® software was used to calculate the overall energy and protein content in the three diets. With the above specifications for NNR and NND they were a little short in energy and protein relative to ADD. By adding 6 kg of both cheese and eggs per year to NNR and 12 kg of both cheese and eggs and 120 kg apples (for 0.25 l juice a day) to NND, both of the healthy diets had energy and protein contents similar to ADD (Table 1, Fig. 1). We find this to be a reasonable foundation for comparison of diets: simultaneously satisfying hunger and protein demand. Protein is particularly important for elderly people.

3. Results

The total weight of NNR and NND were respectively 1 % and 26 % larger than ADD (Fig. 1). Not counting drinking water, the main contributors by weight are dairy products, beverages, fruit, meat, potatoes, and vegetables. The larger weight of NDD was mainly due to increased contents of fruit, roots and legumes with their high content of water and fiber.

The indicated food and beverage categories are used in the OPUS design, but in our calculations we have used approximately 350 individual foods and beverages.

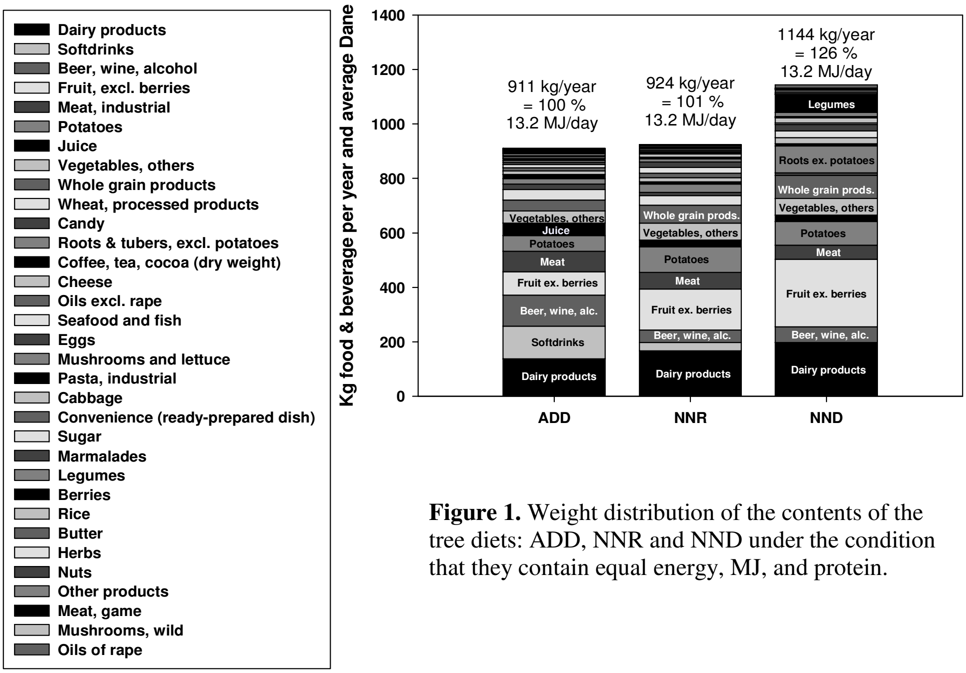
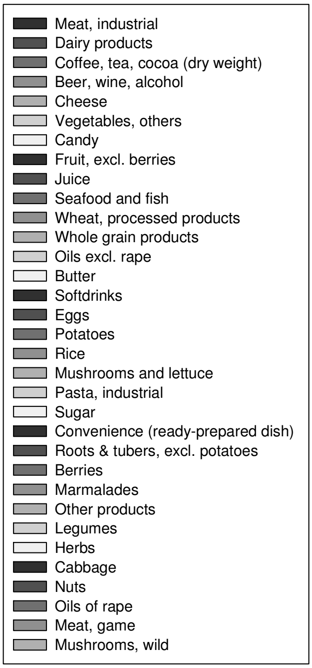


Figure 1. Weight distribution of the contents of the tree diets: ADD, NNR and NND under the condition that they contain equal energy, MJ, and protein.

3.1. Contribution to GHG-emissions by changes in diet compositions

The first level of calculations of effects by diet choices on GWP include changes in content of different food and beverage categories consumed in NNR and NND relative to ADD (Table 1, Fig. 2). At this stage we neither include emissions caused by transport associated with import, nor do we include effects of organic vs. conventional products. Under these conditions, the NNR diet is 8 % better for the environment – measured as GHG emissions – and the NND is only 7 % better (Fig. 2).



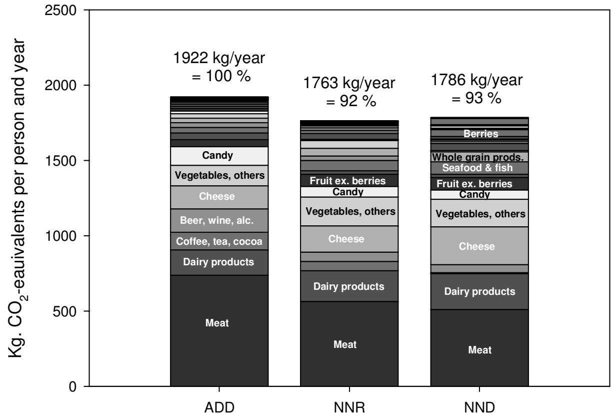


Figure 2. Potential GHG emissions caused by choosing any of the three diets, when they are distinguished by different relative content of food and beverages.

3.2. Contribution by including local produce

The second level of calculations of effects on GWP by diet choices includes means of transport (truck, ship, plane), transport distance (http://www.viamichelin.com), and cooling/ freezing en route simulated by data from Ecoinvent for a small diesel generator. For ADD and NNR we used the actual ratio of imported foods, while for NND there were no imports. It is assumed that production efficiency is similar in Denmark and abroad. The benefits of NND measured as GHG emissions are improved from 7 % to 12 % relative to ADD (Fig. 3).

3.3. Contribution by including organic products

At the third stage of calculations we added/subtracted GHG emissions associated with substituting conventional products with organic products at 2009 ratios for ADD and NNR to an overall ratio of 6.6 % organics. For the NND diet we included all the organics we had data for, to an overall ratio of 80 % organics. 23 organic products were included in the calculations, seven ‘negative’ (apples, beef, carrots, chicken, eggs, non-alcoholic beverages, tomatoes) *increased* GHG emissions, and 15 ‘positive’ (beer, butter, cheese, coffee, lamb, milk, pasta, rape oil, pork, potato, rolled oats, rye bread, wheat flour and bread, and yoghurt) *decreased* GHG emissions. For NND 382 kg/person/year of ‘negative’ organics increased GHG emissions by 159 kg/person/year, while 588 kg decreased GHGs by a total of 53 kg GHGs. Thus, the net effect by including organics in NDD was negative by 106 kg GHGs person and year (Fig. 3 and Fig. 4).

However, other effects of organics are positive, e.g. protection of soil structure, omission of pesticides, and better animal welfare. This support inclusion of organics in future diets.

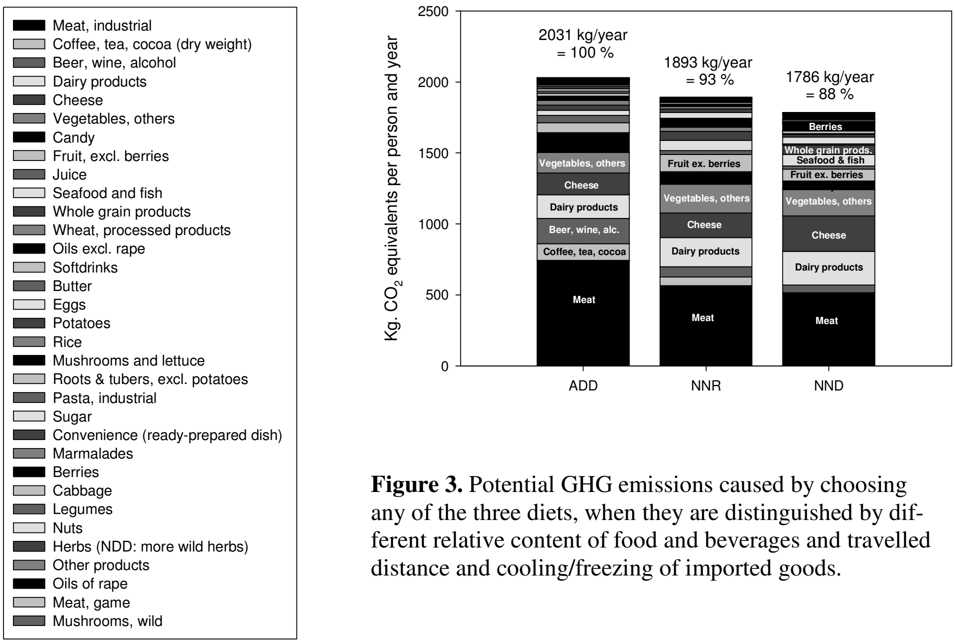


Figure 3. Potential GHG emissions caused by choosing any of the three diets, when they are distinguished by different relative content of food and beverages and travelled distance and cooling/freezing of imported goods.

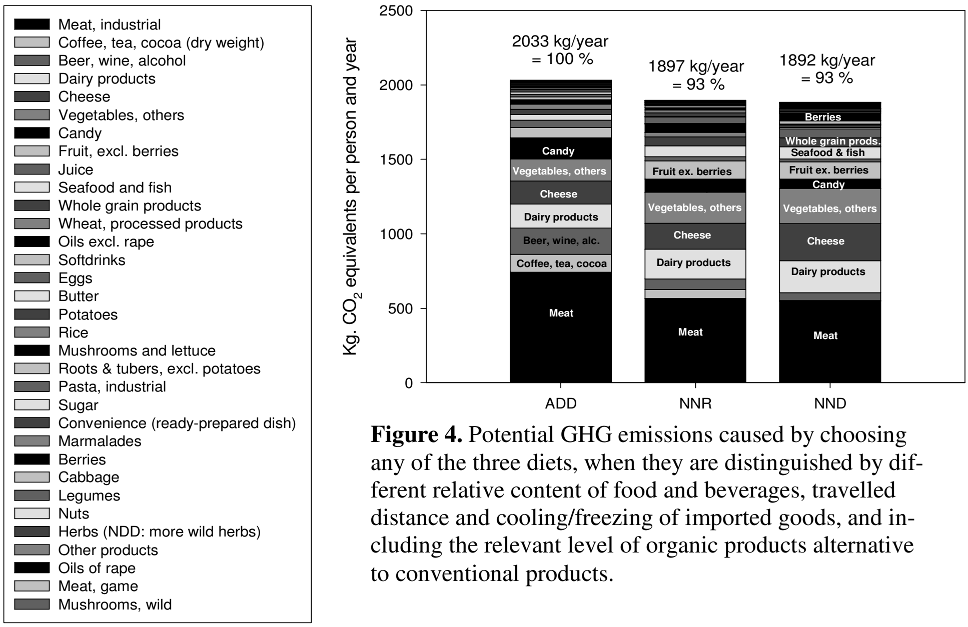


Figure 4. Potential GHG emissions caused by choosing any of the three diets, when they are distinguished by different relative content of food and beverages, travelled distance and cooling/freezing of imported goods, and including the relevant level of organic products alternative to conventional products.

4. Discussion

We have used the best available data for the potential GHG emissions of all foods. This means that the Danish LCA-Food database was updated for items like dairy products and more. Uncertainties include aggregation uncertainty, geographical uncertainty and emission uncertainty. We have estimated the coefficients of variation for emissions, and for most food categories these were smaller than the differences between the emissions of the total diets. This gives us confidence that the observed differences between the diets are significant. In the final analysis, choosing either NNR or NND are significantly better for the GWP than choosing ADD (Fig. 4). The alternative diets mainly gain their advantage over ADD for two reasons: (1) the 30 % decrease in meat, and (2) the 50 % decrease in beer, sweets and candy. Furthermore, to make NND fully Nordic, imported fruits and nuts were substituted with Nordic fruits and nuts; wine and alcohol were substituted by beer; tea, coffee and cocoa by herb tea; and chocolate by ice cream. All these substitutions improved NND's GWP. Excluding imports in NND was as beneficial to GWP as including 80 % organics was harmful.

To construct climate-friendly diets reductions of wine, beer, coffee, sweets and candy was as efficient as reductions in meet. A study undertaken after the submission of this paper showed that substituting beef with more pork and chicken is an alternative way of reducing climate effects, which is potentially as efficient as choosing a healthy, meatless diet. But it is uncertain which strategy is the easiest to put into practice.

The GHG savings by diet choice may seem small. But the potential for reduction in GWP by switching from ADD to NNR (136 kg GHG saving per year and person) or NND (141 kg GHG) are comparable to other realistic means of environmental protection available to individual citizens, e.g. a 10 % savings on heating of individual homes (130 kg GHG saving). In this perspective the environmental protection by choosing NNR or NND rather than ADD is quite significant. Additional benefits of the alternative diets are improved health, and possibly a lower overall price (Saxe et al., 2006) – depending on the surcharge for organics.

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Environmental impact of canteen meals: comparison of vegetarian and meat based recipes

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ABSTRACT

It is generally known that agricultural production of meat is one of the main contributors to the environmental impacts of food consumption. However, the assessment of the actual potential to reduce the environmental impact by choosing a vegetarian diet is complicated because meat cannot be directly replaced with vegetables or other products. Thus, in LCA studies it is difficult to compare the impacts of a certain amount of meat directly with another product. We compared 10 different choices of canteen meals in order to overcome this obstacle. Therefore, public canteens in the city of Zurich provided recipes of typical meals with and without meat. One typical portion of such a lunch was chosen as the functional unit for comparison. The comparison shows clear benefits from choosing a vegetarian meal. In average, the global warming potential of meat meals was 3 kg CO_2-eq compared to 0.9 kg CO_2-eq for the vegetarian choice. Also other environmental impacts of vegetarian meals are considerable lower. The results allow us to draw conclusions on the influence of different parameters on the overall environmental impact of canteen meals. For instance, it facilitates the estimation of the influence of the vegetable provenance on the LCA of a meal. The presentation will describe the approach and present the results from this comparison. The results have been used by the WWF Switzerland in order to promote a vegetarian day in canteens[1].

Keywords: food, environmental impact, canteen meals, vegetarian, meat

1. Introduction

Food consumption contributes considerable amounts to the total global greenhouse gas emissions. The main part of the environmental impact arises from the agricultural production of meat. A vegetarian diet is therefore seen as an instrument to reduce the environmental impact and greenhouse gas emissions from food consumption. The comparison of meat products with vegetarian alternatives however is complicated because vegetable or other products cannot always one-to-one substitute meat.

In order to overcome this obstacle, we assessed the environmental impact of 10 different choices of meat based and vegetarian canteen meals. The meals represent both composed meals with main and side dishes as well as and one-pot dishes. Canteen kitchens of hospitals, retirement homes and other public institutions of the city of Zurich, Switzerland, provided the recipes for these meals.

2. Life cycle inventory analysis

The life cycle inventories of the five meat based meals and five vegetarian meals were chosen from the list of different canteen meals. The functional unit is one serving of the main dish with sides, which allows for a comparison of composed dishes with stews and other one-pot dishes. The composition of the meals is shown in table 1.

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[1] http://www.wwf.ch/de/tun/tipps_fur_den_alltag/essend/aktuell/

Table 1: Meat and vegetarian meals investigated in the study

Meat meals	**Vegetarian meals**
Chop of pork with roesti and carrots	Spaetzle with vegetables
Braised meat beef with french fries	Curry with vegetables and rice
Lamb stew with french fries vegetables	Lasagne with vegetables
Sliced veal in cream with roesti and carrots	Sliced tofu in cream with roesti and carrots
Chicken drumstick, fried with French fries and courgette	Risotto

The amounts of ingredients are taken from the recipes. For a minority of ingredients the LCI data had to be estimated using similar ingredients (Jungbluth *et al.* 2010).

The electricity input for cooling, food storage and material use for kitchen equipment is not accounted for in this study. A rough estimation of the electricity consumption for the meal preparation however is included in the study. The electricty consumption is derived from the environmental report of SV service, a Swiss canteen meal provider (SV (Schweiz) AG 2008). We attributed the same values to all main and side dishes. Meals with a main and a side dish therefore obtain an increased value of electricity demand in contrast to a one-pot dish.

3. Impact Assessment

The impact assessment has been carried out for greenhouse gas emissions (Solomon *et al.* 2007) and for environmental impacts based on the ecological scarcity method 2006 (Frischknecht *et al.* 2009).

Meat based meals cause an average global warming potential of 3 kg CO_2-equivalents per serving, whereas the supply of a vegetarian meals emits 0.9 kg CO_2-equivalents (see Figure 1). The difference mainly arises from the high environmental impact due to meat production (see Figure 2). Only a small amount of greenhouse gas emissions can be attributed to the side dishes. On the other hand, the evaluation of the global warming potential of the individual meat based meals reveals a high variance of greenhouse gas emissions from meat production. Meals based on beef or veal cause relatively high emissions in comparison to the use of pork or poultry. Consequently, beef or veal meals reach a global warming potential of more than 4 kg CO_2-equivalents. Meals containing poultry or pork range from 1.5 to 2 kg CO_2-equivalents.

Similarly, the vegetarian meals show some differences within their category. Risotto or lasagne cause less than 1 kg of greenhouse gas emissions. Spaetzle and the vegetarian alternative of veal in cream, tofu in cream, range between 1 and 1.5 CO_2-equivalents.

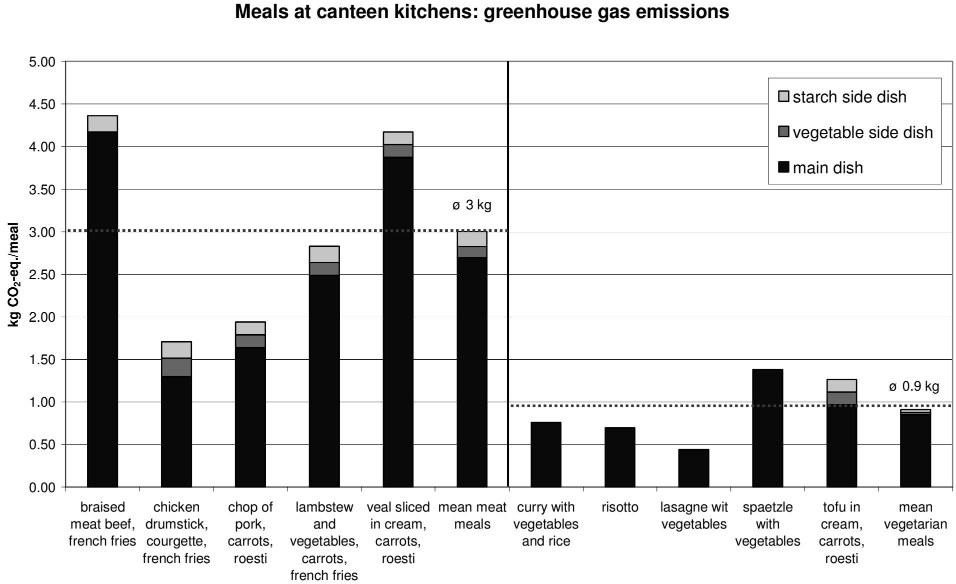

Figure 1: Global warming potential of different meals

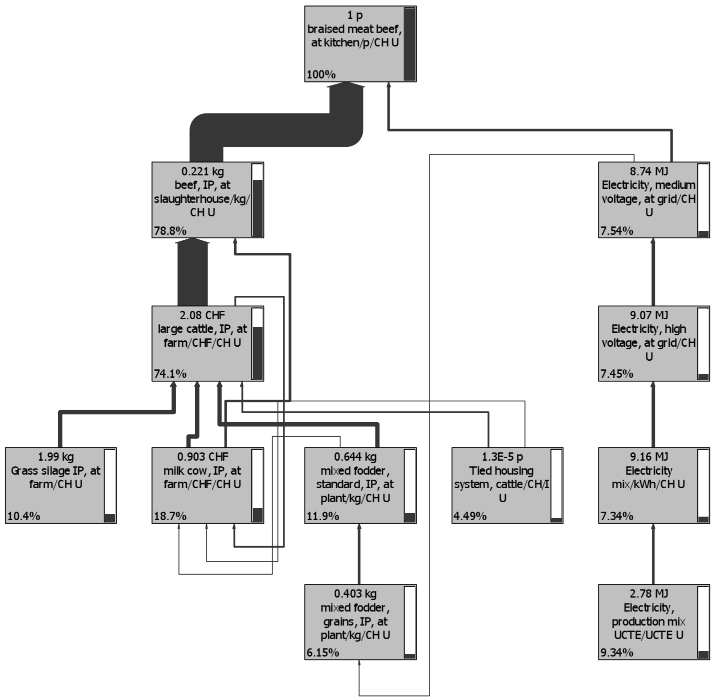

Figure 2: Major life cycle of the provision of a meat based meal (braised meat beef) and LCIA with the global warming potential (GWP 100a).

The impact assessment according to the ecological scarcity 2006 method (Frischknecht *et al.* 2009) shows similar patterns (Figure 3). The meat-based meals have an average environmental impact of 6622 Ecopoints per meal and the vegetarian meals account for 2085 Ecopoints. The environmental impact of the side dishes becomes more important, because of the higher weightning of vegetable production.

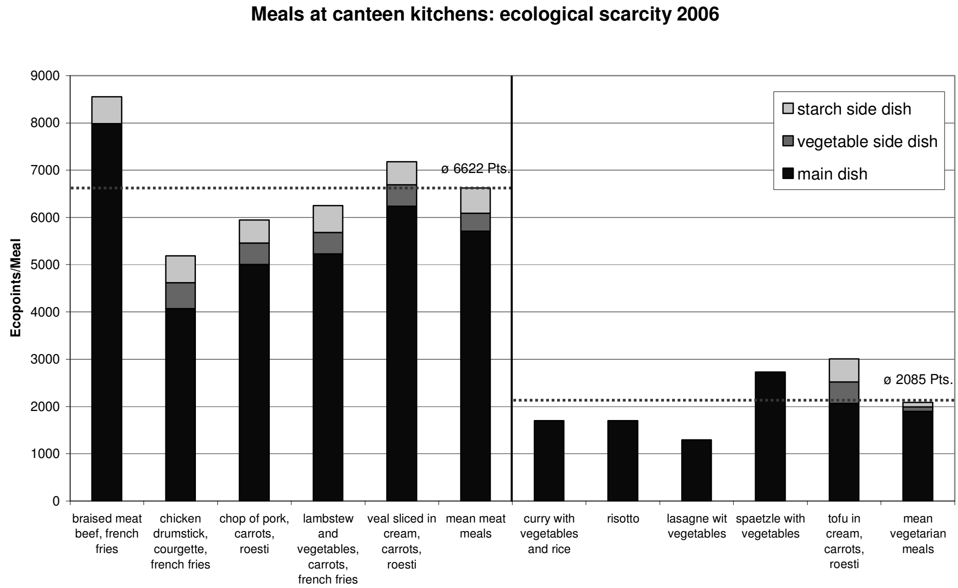

Figure 3: Total environmental impacts of meals evaluated with the ecological scarcity method 2006

4. Conclusions

The average global warming potential and the environmental impact of meat based meals are considerable higher than for vegetarian meals. The meat-based meals cause 2 kg greenhouse gas emissions or 4000 Ecopoints more compared to an average vegetarian meal. Consequently, a vegetarian diet makes a significant contribution to the reduction of the global warming potential due to food consumption.

Although the results show major differences between the meat based and the vegetarian meals, the expression of a relative difference has to be handled carefully. The LCI for instance excludes the electricity demand for food storage and consideres only rough assumptions for the energy demand for the meal preparation. Considering these additional energy demands the overall environmental impact of canteen meals will be higher. The absolute difference between the meals however should remain unchanging.

As is a high variance within the meat or vegetarian meals, the difference between two individual meals can be smaller or higher than the difference resulting from the average values.

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A scoping study towards an LCA for Quorn^{TM} mince

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ABSTRACT

There is growing evidence of the need to reduce our consumption of meat and its impact on health and the environment. Quorn is the world's leading meat free brand and is based on a unique fungi protein called mycoprotein. Diets rich in mycoprotein have been reported to offer a beneficial effect on health, particularly in tackling obesity. Research into scoping the lifecycle analysis (LCA) for Quorn mince has been carried out in order to begin to understand the environmental impact. Issues encountered with carrying out the LCA are discussed and conclusions presented to show that whilst more work is needed, Quorn mince may have half the embedded carbon when compared with beef. The acknowledged health benefits of mycoprotein combined with lower levels of embedded carbon compared with meat suggest a valuable role for Quorn with consumers who wish to reduce meat consumption without sacrificing the recipes and textures they enjoy

Keywords: Quorn, Mycoprotein, Lifecycle analysis, Sustainability

1. Introduction

The challenges we face in delivering a sustainable lifestyle to a world population predicted to grow to nine billion by 2050 are enormous. Central to this issue is future food security, the sustainable diet and a reduction in the consumption of animal fats and protein within developed economies (Friel, 2009).

Quorn is the world's leading meat free brand with products sold in ten countries worldwide including the UK, USA and Australia. All Quorn foods contain mycoprotein. Mycoprotein is a member of the ascomycota family of fungi - *Fusarium venenatum* PTA 2684 (Yoder and Christianson,1998) - as are morels or truffles, and was discovered in the 1960's after a search for a new micro-organism that could convert starch into high quality protein (Angold, 1989).

Quorn foods are popular with both vegetarians and meat reducers alike, and offer benefits of lower fat content when compared with the meat equivalent. Studies have also shown that consumption of foods rich in mycoprotein can help maintain healthy cholesterol and promote satiety (Denny, 2008), the latter an important feature in today's obesogenic food environment, however the level of embedded carbon in Quorn foods is not known.

The purpose of this study was therefore to begin to develop this understanding by scoping a lifecycle analysis (LCA) for the production of Quorn mince relative to beef.

2. Objectives and methods

This paper describes the findings of a scoping study aimed at developing an analysis of the greenhouse gas (GHG) emissions expressed as CO_2 equivalents (CO_{2e}) for production of mycoprotein and its subsequent conversion to Quorn foods, as compared with the equivalent process for animal protein. Quorn mince was chosen as the best selling of the range of Quorn foods.

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The objectives for this study were thus to:

1. Develop detailed process maps for meat, mycoprotein and Quorn mince production.
2. Provide an analysis of each process in terms of environment impact;
3. Identify available data for each stage of the process and assumptions that would be required in a full quantitative analysis.

From the limited available data in literature on the processing of meat products and primary data associated with the production of Quorn mince, this study set out to establish a framework for comparing the environmental impact of mycoprotein, Quorn mince and beef. At the outset it was recognised that this initial analysis would provide rough estimates with data still to be considered and added to the process calculations, and the analysis employed would be carried out to identify a suitable structure that could be used to obtain a more accurate estimate of the comparison requested.

The PAS 2050 approach (BSI 2008) was used as a basis for developing the LCA for Quorn mince production. From the data collected, process maps were 'drawn' of both the mycoprotein and Quorn mince production . These process maps illustrate the processes involved, the pieces of equipment used, and the various inputs and outputs required in the production of the mycoprotein, and then in the formation of the Quorn mince and final storage prior to dispatch to the customer. GHG conversion factors used within the analysis of data were those published by Defra (2009).

For comparison, the key steps, inputs and outputs for the production of beef were identified, mainly from the work of Williams et al. (2006). The agreed end point was identified as the factory gate.

A selection of primary data for mycoprotein and Quorn mince production were obtained from factory records. This consisted mainly of utilities consumption data and quantities of raw materials required. Where necessary, secondary data were obtained regarding glucose (Galitsky et al. 2003), ammonia (Rafiqul et al. 2002), albumen (Defra 2007) and sodium hydroxide (Kiros and Bursell 2008) production. Beef production figures used in the model are based on UK profiles for commodity production, and the calculations do not include the production of feed that originates from overseas (such as soya bean production in South America and maize grain production in the USA

3. Results and discussion

Whilst there is extensive debate about how best to manage food production in a more sustainable manner (McMichael et al. 2007) it is not the purpose of this study to engage in that debate. Rather it is to draw upon existing research into the environmental impacts of meat production in order to provide a clear comparative structure for evaluating the life cycle impacts of mycoprotein and Quorn foods.

Figure 1 depicts the LCA process diagram derived for Quorn mince production with Figure 2 for beef derived from the Williams model (Williams, 2006). Having defined the detailed process diagrams it was then possible to carry out a detailed analysis of the raw materials and process steps, using primary data where possible, in order to provide an accurate starting point for the LCA of Quorn mince and beef production. These findings are summarised in Table 1. Secondary data has been included in the analysis. This has been derived from various sources of published literature that will be less accurate for the specific processes being investigated in this study.

Figure 1. Expanded LCA for Quorn Mince

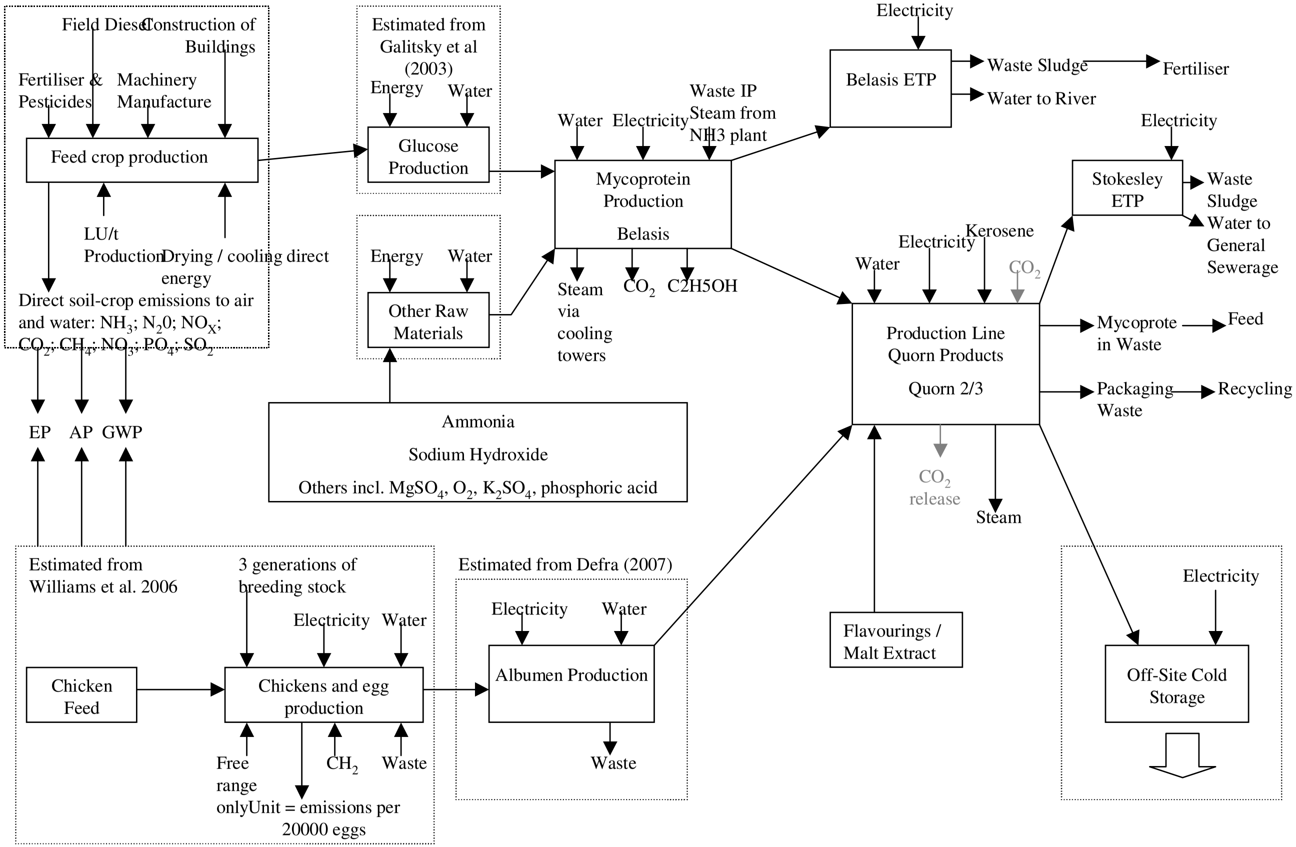

Figure 2. LCA for UK Beef Production (derived from Williams et al. 2006)

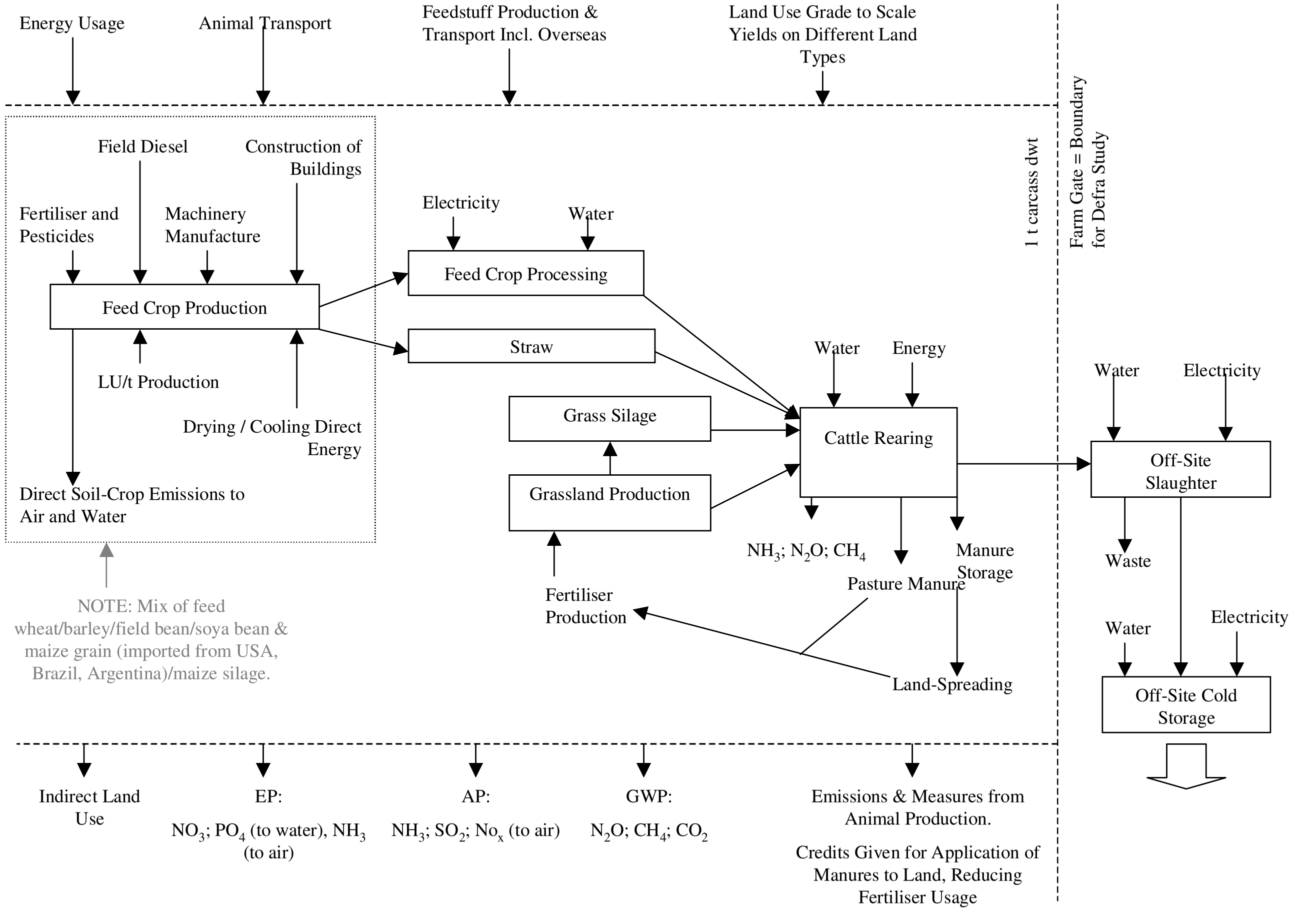

Table 1 Summary of the analysis of mycoprotein and Quorn mince production compared with beef, derived from detailed analysis of raw materials and processing to finished product.

		Beef	Slaughter	1 te Beef	Mycoprotein production	Quorn min-ce production	1 toe Quorn mince
Per te	unit						
Energy	MJ	26886	1764	28650	35549	15065	50614
Water	m^3	4316	4.9	4321	182	2703	2885
CO_2	kg	2918	266	3184	2626	1959	4585
CH_4	kg	291	0.01	296.5	0.21	5.24	5.46
N_2O	kg	9.25	0.01	9.26	1.03	3.63	4.66
NH_3	kg	78		78.	0.83	29.33	30.16
PO_4	kg	0.79		0.79	12.65	0.63	13.28
NO_3	kg	141		141	4.3	20.1	24.4
kg CO_{2e}	GWP	13989	268	14257	3111	3729	6840
kg PO_{4e}	EP	121		121	3	30	33
kg SO_{2e}	AP	296		296	3	102	105

Note: slaughter data www.danishmeat.eu/DMRI/Knowledge_abo/External_envi.aspx

Table 1 suggest that tonnes of CO_2 equivalents released per tonne of product (ending at the storage of the products prior to distribution and consumption) are: 14.3t CO_{2e} per tonne of beef; 6.8t CO_{2e} per tonne of Quorn mince. This can reduced to 5.6t CO_{2e} if steam production is not included as the steam used is a waste product from a separate manufacturing process. For Quorn mince, the production of mycoprotein contributes 3.1t CO_{2e} and the rest is generated from the processing of the mycoprotein into Quorn mince. It should be noted that the data for beef relates to whole carcass. Cutting yield to convert to beef mince has not been consisdered but typically runs at 40 – 50%. Factoring this into the analysis will have a significant impact on the comparison. The study of Quorn mince also suggested a significant contribution to levels of CO_{2e} from the glucose used in fermentation and the egg white used in further processing (Figure 1). Further research will focus on ways to confirm this observation, and will start with development of primary data for these raw materials rather than the secondary data used here.

These initial estimations suggest that despite a higher energy use, significantly lower levels of other potent GHG such as CH_4 and N_2O in the Quorn LCA results in a significantly lower level of CO_{2e} than for the production of beef whole carcass. However, it should be noted that these are minimum estimates for the Quorn products. With more detailed and accurate information from suppliers it will be possible to make a more comprehensive assessment of the contribution of Quorn products to the release of CO_2e. Once validated and analysed in greater detail, this would provide the starting point for completing a carbon footprint based on PAS 2050 (BSI 2008) designed to assess the product life cycle and greenhouse gas emissions, land and water use.

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Analysis of the climate intensive processes in the supply chain of fresh milk – process step dairy plant and consumption

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ABSTRACT

The aim of the study project is to investigate the whole supply chain of fresh milk with qualitative data inquiry. The first results refer to one German dairy plant. The main energy intensive processes are heat treatment and cool storage, the impact of transport to the dairy plant is rather low. Regarding energy specific CO_2 emissions for Germany almost 50 % of the total CO_2-emission from the dairy plant has to be assigned to the cool storage. Taking further steps into account, it is notable that consumer activities are relevant. Estimating the energy turnover from cool storage in private households we find 11 kJ per litre milk and day even with a refrigerator of the category A++, which is much more efficient than the German average refrigerator. If the milk is stored for an average of 4 days there is a CO_2 emission of 7 g per litre stored milk.

Keywords: dairy plant; consumer; energy turnover; CO_2-emission

1. Introduction

Goal of the study project is to investigate the whole supply chain of drinking milk in Germany with qualitative data inquiry from farm to consumer.

The production of drinking milk in Germany amounts to 5,132,400 t in the year 2008 (BMELV, 2009). On the German market 3 different types of drinking milk are relevant: UHT milk, pasteurised milk and ESL-milk. ESL milk means pasteurised milk with a second heating process and/or microfiltration for an extended shelf life between 18 and 30 days (Kaufmann, 2009). ESL- and pasteurised milk are summarised as fresh milk.

All types of drinking milk are available with at least 3.5 % fat and with 1.5 to 1.8 % fat. Skimmed milk with a maximum fat content of 0.5 % is out of relevance, only 3 % of the produced drinking milk in Germany is skimmed milk. 43 % of the produced drinking milk refers to whole cream milk and 54 % to semi skimmed milk. Around 70 % of drinking milk shares to UHT milk and ~ 30 % to fresh milk (BMELV, 2009).

The first results of the study project which are presented in this paper refer to a German dairy plant producing ESL milk with an annual raw milk processing of approximately 300,000,000 l raw milk. ESL milk's share is nearly 30 %. Data assess for the use phase, the energy demand for cool storage of fresh milk at consumers' refrigerator is quantified to relate the impact of the different phases.

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1.1. Functional unit and system boundaries

The functional unit was set to 1 litre provided drinking milk. Two types of fresh milk are included, semi skimmed milk (1.5 % fat) and whole cream milk (3.5 % fat) with the average specific weight of 1.029 kg/l. The reference year is 2008. The collected data imply one dairy plant with all steps in processing ESL-milk as well as the transport from farm to dairy by external conveyance. The supply transport of packaging and further equipment and input like detergence are not included. The part of distribution to retail and purchase of the consumers will be investigated in further research. For the use phase the energy demand to run a refrigerator for cooling fresh milk is calculated, without the production of the unit.

1.2. Allocation

In the dairy the process steps for treating ESL-milk are assessed in dissociation of other milk products. The storage of the packaged milk occurs in a stock with other milk products. For this process step energy requirement is allocated on the basis of the product mass. Consumers' refrigerator is assumed with a fill rate of 50 %. This implies that a volume of around 75 litres is used for different products. Resting time of the fresh milk in the refrigerator is estimated at 4 days.

2. Material and methods

Data collection has been realized with personal survey and process analysis. All process steps in the dairy are investigated and their energy demand is charged. Data for transport to dairy plant is investigated with questionnaire. The conveyances are asked about their fuel consumptions and the total mass of milk transported throughout the year 2008.

The information about refrigerators' energy demand and their volumes are taken from several producers' specifications.

3. Results

Main results of delivered energy consumption are summarised in Table 1. The largest part of the total consumption of energy at the dairy are heat treatment and cool storage, although heating processes are optimised by using heat recovery. Milk transportation from farm to dairy is managed by conveyances. The questionnaires for gathering these data have been returned from 50 % of the conveyances and are evaluated. The obtained data represents 40 % of the total amount of raw milk delivery. The energy demand for transportation is rather low compared to heating and cooling processes.

Table 1: Delivered energy for milk processing referring to 1 l of fresh milk

Transportation from primary production to dairy plant (standard deviation)	0.1 (± 0.04) MJ/l

Pasteurisation and heat treatment	0.53 MJ/l
Packaging	0.02 MJ/l
Cool storage	0.29 MJ/l
Dairy plant in total	**0.88 MJ/l**

In consideration of different primary energy sources the CO_2-emissions are ~ 100 g CO_2/l fresh milk in total, within 7 g CO_2/l for transportation, as shown in Table 2. Regarding the hot spots for CO_2 emission and for energy use the distribution is displaced. Depending on the mix of primary energy sources for power generation and the respective efficiency factor, almost 50 % of the total CO_2-emission from the dairy plant has to be assigned to the cool storage. While cooling is managed with electric energy, heating processes are mainly managed with gas.

Table 2: CO_2 emission from energy consumption referring to the disposal of 1 l of fresh milk

Transportation from primary production to dairy plant (standard deviation)	7 (± 3) g CO_2/l
Pasteurisation and heat treatment	38 g CO_2/l
Packaging	3 g CO_2/l
Cool storage	46 g CO_2/l
Dairy plant in total	**94 g CO_2/l**

Taking further steps into account, it is notable that consumer activities are relevant. By estimation of the energy turnover from cool storage in private households we find 11 kJ per litre milk and day even with a refrigerator of the category A++ (EC 2003/66). With a refrigerator of the category A+ there is an energy turnover of 16 kJ per litre and day. If the milk is stored for an average of 4 days there is a turnover of 44 kJ and 64 kJ for the categories A+ and A++ respectively. The emission of CO_2 amounts 7 g and 9 g respectively. These data implicate that the refrigerator usually isn't filled up completely.

4. Discussion and Conclusions

The results of CO_2 emission are determined to the German energy mix, with 159 g CO_2/MJ (UBA, 2010). An imprecision of 5 to 10 % is expected for the data of the dairy because of assessments.

Further investigations are necessary to value the dairy processes and to close the supply chain. For the present there is the high relevance of cooling at all levels in the supply chain. Regarding the estimations of Matthes *et al.* (2008) an average refrigerator in Germany consumes 220 kWh in the year 2010. This implicates an energy demand of 29 kJ per litre milk and day or a CO_2-emission of 19 g per litre milk for a storage period of 4 days under the above mentioned conditions. This value is considerable higher than the one represented in chapter 3, because the market penetration with high efficient refrigerators (A+, A++) is not fulfilled yet. The data reflects that cooling at the use phase corresponds to 20 % of the CO_2-emission emitted during milk processing. The assumed conditions at consumer stage (50 % filling rate and 4 days of storage) are not yet verified. Regarding the shelf life of 3 days after opening the package, and considering the cool storage after purchase, it seems to be a realistic value.

5. Recommendation and perspective

The investigation of one dairy plant reveal, that cooling processes especially electrical based cooling systems are very energy intensive and cause the main CO_2-emission during milk processing. Mitigation could be reached by technical improvements, for example optimising the control of air at the gate between warm and cold areas. For verifying the outstanding weight of cooling processes further plants have to be investigated.

Consumers should be motivated to buy a high efficient refrigerator, if they need a new one. Units which are only used once in a while should be turned off in times of non-use.

To complete the supply chain the parts of primary production, distribution to retail and consumer purchase on the entire emission of CO_2-equivalents have to be included. Further investigation will also compare different dairies regarding their size. It is supposed that a minimum size of the production unit is necessary for producing efficiently (ecology of scale; Schlich, 2005). Hot spots in energy demand and GHG-emissions should be identified to conclude possible improvements in the supply chain.

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Moving towards a Zero km distribution model to reduce environmental impact and preserve food quality and safeness

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ABSTRACT

The LCA model is normally used to analyse environmental impact on many different situation; food transportation is one of those situation actually strongly related to environmental impact in fact, today, all that is served on our tables walks for not less than 1900 km. In order to analyse new chances on reducing distances between producers and consumers, to reduce environmental impact and finally achieve best practices on using the LCA instrument along the food chain, the actual work will study if and what could be possible to change to organize a “ZERO KM” distribution model. Using a shorter distribution chain in fact, we could provide best food, with best prices, protecting its safeness because of its national or even regional belonging and, last but not least this could even be an important instrument to protect the “Made in Italy production” by being counterfeited.

Keywords: LCA, Distribution, Environmental impact, life cycle, chain.

1. Introduction

Introducing In considering environmental impact issues related to the food product distribution chain, we believe it useful to introduce some aspects of the implementation of the supply chain. It should first be clarified that there are substantial differences relating to the origin of food products within and outside the European Union. Indeed, today we know that goods moving within the EU must bear those necessary guarantees of quality and consumer protection sustained by all goods crossing the borders or entering in the markets of Member States (the safety of food products is now guaranteed in the EU by the entry into force of REG. EC No. 178/2002).

However, food product supplies have similar distribution characteristics whether coming from within or outside the EU. Traceability of production becomes indispensable to monitor the safety and quality of processes, especially in food products. Each product’s life cycle assessment is based on the "cradle to grave" principle: starting out from the raw materials, through the creation of the product to tracking all components back to the product’s origin. Thus, considering all the interrelated stages of the "from farm to table” life cycle approach may well serve as the contextualization of the principles of LCA in the traceability chain, emphasizing the close and direct link between consumers and producers (Cifarelli, A., Greco, P. D. /2009).

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The Life Cycle Analysis of the food chain, therefore, aims to obtain a quantitative assessment of environmental benefits and energy consumption, with an implementation that impacts on the length of the distribution chain. In fact, this allows quantifying the environmental impacts of complex industrial sectors by following a rigorous scientific approach, taking into account the environmental impact and energy consumption related to raw materials and industrial by-products, consistently comparing alternative industrial systems.

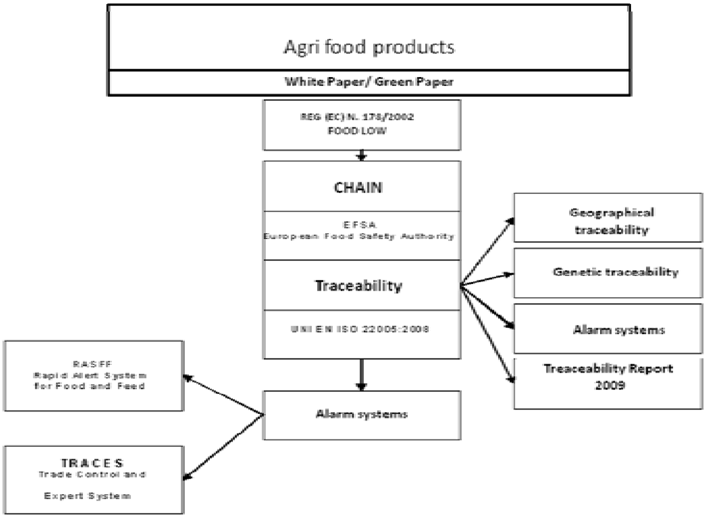

Figure 1: Implementing REG. EC No. 178/2002.

In addition, it also provides an opportunity to assist land management organizations in planning and developing guidelines for the environmentally sustainable development of the districts involved. This makes it possible to account for the entire consumption of raw materials and energy sources and all emissions into air, water and soil in the chain through all stages of the life cycle, from raw material extraction to final waste disposal. This work is unable to provide a definitive assessment on the application of the principles in the food industry from it origins from a scientific activity that relates to regional realities, but still acting to the end of 2010.

2. The chain

For a correct understanding of an LCA related to the food product sector, it is perhaps necessary to start from the definition of the so-called "boundaries". It is through the supply chain that the boundaries are delineated within which to gather information, monitor and verify activities and possible actions for the health protection of consumers in relation to food products: the precise identification of all the steps that contribute to the formation (supply and production) and marketing of a product thus becomes crucial (Greco P. D. /2008).

Tracking and traceability in an LCA analysis helps solve the problem of allocation and imputability of emissions. In fact, the chain represents the structure to indicate and identify all those (companies) that contribute to the finished product up to its release to market through a linear representation of the route followed by the main raw materials to become the finished product. In different production methods, the size of the chain may differ depending on the number of individuals engaged in the completion of the production process, particularly in relation to the product changing place or time to make it available to the consumer.

The length of the route and therefore the number of steps through the various points of the product's production and processing is used to indicate the structure of the industry according to a statement that can vary from a simple "short chain" to a much more complex and structured "long chain". A limited number of processing steps commonly identifies a short chain with stages that, in the case of food products, easily identify the upstream producers and consumers along the chain itself. This type of chain, especially recently, is rediscovering its potential related to its small size and therefore the proximity of the producer to the consumer, enabling responding more effectively to the increasing demand for the reduction of product costs (in practice, the fewer the steps, the greater the ability to keep sales costs low).

The short chain is thus finding application in all those situations where it is useful to bring the consumer closer to the firm to ensure a greater flow of information or an enhanced perception of given guarantees (as an example: the different experiences of biological production types where the proximity of the producer and the information represent the springboard for these kinds of products). A long chain is instead defined by a production process constituted by a significant number of steps, which render the visibility of all stakeholders in the production of the product more difficult.

The length of the chain is closely related to the number of people who are part of the production process: this is true when this concept is applied to the growing availability of products that, due to their different characteristics (growing complexity in product processing), require more and more steps. In essence, the growing demand for products with increasingly complexity induces the production fulfillment paths to be lengthened in which today we can even identify individual microfilaments (chain structures located in the same sectors) that contribute to the production or processing of the product.

In fact the chain represents the structure to indicate and identify all those (companies) that contribute to the finished product until its release to market through a linear representation of the route followed by the main raw material to become product finished. Due to theDifferent modes of production, the size of the chain may differ depending on the number of individuals engaged in the completion of the production process, particularly in relation to the product changing of place or time it get to be available for the consumer.

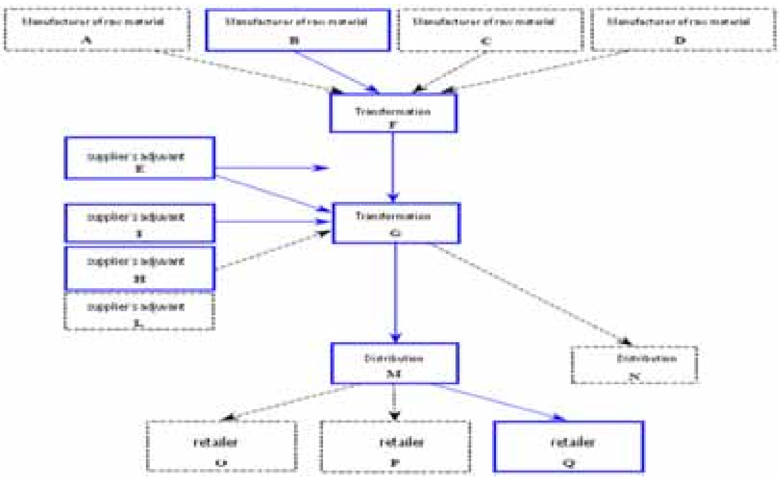

Figure 2: Long Chain Model.

3. Traceability

Traceability in the food products sector is the ability to trace information in all stages of the food chain, tracking and following the path from “farm to table" i.e., to documenting the history of a food product through all its production, processing and distribution stages. In light of this, it is clear that a traceability system can not be applied without a clear concept of the supply chain; tracing the upstream to downstream path of a product means being able to clearly identify not only all the steps of the production cycle, but also all the subjects and geographical locations that are an integral part of this process.

Being able to correctly "track" a product, means realizing the possibility to move backwards along the same path (the concept of traceability), making it possible to act promptly in case of danger to human health. Backward tracking along the chain enables ensuring the immediate withdrawal from the market of potentially unsafe products to human and animal health (to do this it becomes necessary to create conditions that allow tracing back along the production pathway to precisely identify the exact point of action), (Rossi, A. /2003).

4. The Long Chain

From the foregoing, it is clear that the input and output variables are the fundamental elements on which to apply the principles of optimization that can change the implementation of the food chain. As shown in the figure below it is precisely on these variables that the effectiveness of the principles of LCA can improve distribution performance (Rossi, G. /2004).

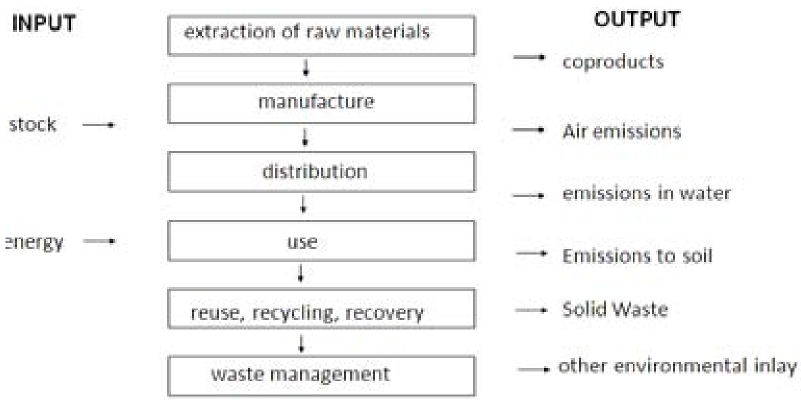

Figure 3: Characteristic aspects of the model of long chain.

5. Advantages related to a Short chain application

The privilege of purchasing and consuming local products creates added value for the area where the production takes place and, when focusing on the environment, encourages biodiversity. A second advantage of production according to the short chain logic derives from the shorter path that goods travel towards the distribution location, allowing a reduction of air emissions resulting from fuel consumption and thereby reducing the pollutants that the classical long chain leads to.

The short chain is thus able to preserve the biodiversity of goods and preserve the natural features of the resources. Small producers, by establishing a corresponding relationship between supply and demand, can thus offer a service that ensures continuity. By planning production and delivery, as well as reducing waste (especially special waste) and benefiting from the seasonality of products, land use in agricultural production can be reduced. The short chain, from the perspective of organic agriculture, is not only a choice but also a rural development production model that aims to protect and enhance, without the use of synthetic chemical pesticides and fertilizers, environmentally friendly techniques, protecting the environment and natural resources, identifying itself with the principle of sustainability. Chemical substances and synthesis techniques are excluded from the entire production cycle, favoring all those natural techniques that are in harmony with the life cycles of plants and animals. Another important feature in this context is packaging methods. Consumers and producers must pay greater attention to how products are packaged: using less plastic, generally reducing packaging or even eliminated it where unnecessary. This is possible in the short chain, packaging is much more complex and expensive, especially in environmental terms, the longer the chain and the more complex the packaging life cycle. One way of virtuously reducing packaging is obtained when organized producers are able to provide self-service distributors for certain products (e.g. milk, but also fruit). In the simplest form of short chain opens the manufacturer, usually in the same company production area to sell their products, (Niels Halberg /2003).

6. Conclusions

The implementation of short chain could offer benefits in terms of environmental savings, protection of biodiversity and characterization of regional products. Without beeing regarded as the only solution to the issue addressed, furthermore it may also help for a more simple and effective application of the principles of tracking and tracing, ensuring better protection for consumers' health.

Beginning with this work, we intend to take the cue for a more detailed analytical work, which should lead to consistently identify opportunities to apply the principles of LCA to the production chain and distribution; the analysis will have to consider all those different contextualisation in which the benefits of short chain set could be attributed, in specific cases, to those chains with more complex features.

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Environmental analysis of construction and management of urban park by means of LCA

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ABSTRACT
The construction and management of urban green areas can be linked into the more general problem of studying the ecology of cities and the introduction in the management of bio-technological practices. The sustainable construction of a park should be designed to make it self-sufficient and less costly, in its design must take into account the concept of renewability. This paper aims to analyze, using the LCA methodology, design and management of a public green areas of the Apulia Region (Italy). The results showed that the construction of the park has more impact than its management although it is considered a time of useful life of the park of 40 years. Regarding the management of the park, the largest impacts are caused by the use of fertilizers and electricity, regarding the construction of the park, the largest impacts are caused by the construction of fences (steel and concrete)

Keywords: Urban Park, Plants maintenance, LCA, Sustainable design of green areas.

1. Green parks in urban areas

The green areas of cities, defined as areas with natural or artificial vegetation, became a collective value, evolving with the human civilization. The purposes for which the parks were built in the city have changed over the centuries, and have become by purely aesthetic and recreational to functional. Green urban areas serves multiple functions: Plants in urban areas reduces the effects of degradation and the impacts generated by buildings and human activities; in some urban areas, especially near hospitals, the presence of green areas contribute to creating an environment that can promote recovery of patients; the green area provides an important protective effect on land in sensitive or degraded areas; parks, gardens, tree-lined avenues and squares, perform an important social and recreational needs and provides a vital service to society; the presence of green areas has great importance from the cultural point of view, both because it promotes the people knowledge of Botany and natural science, both for the educational function (educational green areas) for new generations; the presence of green areas greatly improves the urban landscape because it breaks the monotony of city blocks. For this purpose it is important to promote the integration of architectural elements and plants in the design of cities. The location of a park is often forced, so it is very important to the suitability of sites for the cultivation of plants. The choice of plant species is fundamental to building green areas because they affect the aesthetics, functionality and management of a park. In Mediterranean environments is preferable to plant native species, which needs less maintenance and watered. In addition to these you can also choose some non-native plants to meet aesthetic requirements. In order to obtain a visual effect more varied, it is customary to mix plants with lit flowers with evergreen Mediterranean with small flowers plants. It 'necessary also to alternate deciduous and evergreen plants and adequately take account of colors and times of blooms. A park in

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every season must submit leaves and flowers of different colors and shape. For the introduction of non-native plants, is helpful to assess the nutritional and maintenance needs, in order to ease the burden on park management. The choice of plants is also very important for phytosanitary purposes. The native plants in fact are usually less susceptible to diseases and therefore require fewer treatments than imported species. The use of pesticides in addition to increasing pollution in urban areas, can be harmful to the users of the area. If the plants are resistant and suitable to the climate conditions, there will be less use of chemical defense. Is also important to consider the accretions of trees and shrubs, preferring species with rapid growth. For proper design of green areas is also important the choice of furniture, both for materials and for both functionality and safety. When we analyze the parks of Apulia Region municipalities, there is a sufficient total allocation of green areas, although this is not always well appreciated by the construction and management practices. Often in some neighborhoods, individuals contribute to increasing the presence of green areas especially when building typologies allow this. Green areas in Apulian cities are represented by specific typologies. In the case of small towns there is a public garden usually, located near the historical and cultural center of the city, and small green service areas close to schools and public offices. There may be other parks in the suburbs. In larger towns you can normally find one or more parks, of varying extent, in semi-central areas, and a series of neighborhood gardens, in addition to the green on the roads and services (hospitals, cemeteries, government offices, etc.).

2. The Urban Park productive cycle

In order to acquire detailed information about the urban parks or city gardens realization and management, the productive cycle (Figure 1) of typical Apulian green area, which placed in Noci (BA) with a surface of 5,280 m^2, has been examined.

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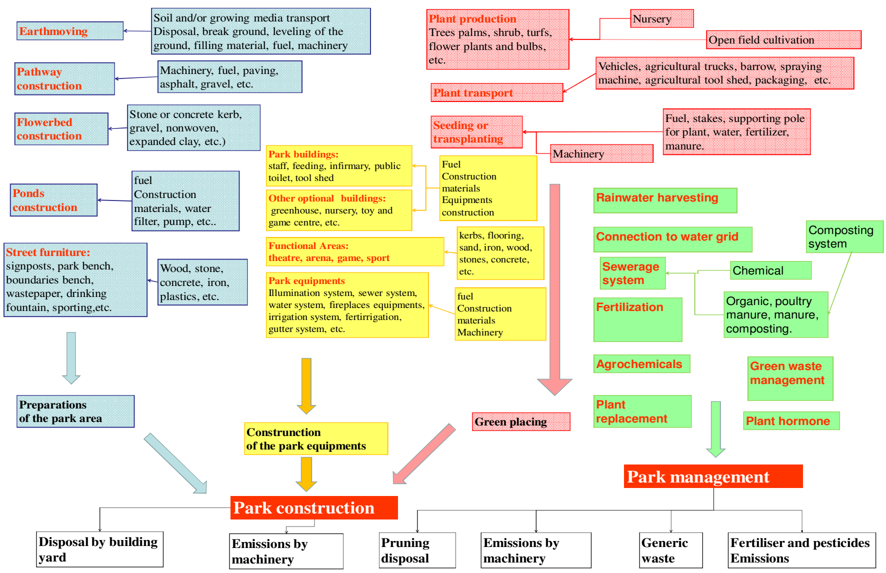

Figure 1: Productive cycle of an urban park

The construction of a city park is due to the implementation of the excavation works and carry-over of soil, construction of facilities, the creation of paths and flower beds. These activities are normal processes used in building construction and their size can vary greatly depending on the choice of construction site and the kinds of soil. The urban parks can also be equipped with special equipment for recreation or sport and are always present furniture for outdoor areas such as benches, fountains, litter bins and play areas for children. Another important aspect is the placing of plants, as a part of it (trees) may already be on site and an others part (bush, or others plants) being produced in nurseries and then transported and planted. Regarding the management of urban parks, the use of resources and energy can vary greatly depending on the type of plants used and their adaptability to the climate zone in which stands the park. The use of plants typical of the climate zone causes plants to have healthier and more resistant to disease, less water demand and less use of pesticides. The agronomic management of plants appears to be important, as the use of chemical or organic fertilizers, disposal of pruning or use them for composting, changing highly energy requirements and outputs of the process. In particular, the pruning of the hedges are always achieved, while that of trees and ornamental plants is carried out according to aesthetic conception of the staff that manages the park. The management of farming operations can be performed by public agencies with the equipment of the park but it is often entrusted to private that use its equipment and facilities to carry out ordinary and extraordinary maintenance.

3. The LCA Methodology

The LCA study was carried out according to ISO 14040-44 standards (ISO, 2006). The analysis of the construction and management of a public park suggested the adoption of the following functional unit to which we refer the main flows of materials and energy: 10,000 m^2 of Park area. This area was defined in a conventional manner comparing to 10,000 m^2 areas with vegetation and paved areas. Vegetation in the park and is distinguished among conifers, broadleaf, hedges and shrub, and their quantity was compared to the surface defined. The boundaries of the system define the process units to be included in the LCA study. The boundaries adopted in this study include the following phases: Earthmoving, the construction of paths and flower beds, the furniture for outdoor areas such as benches, fountains etc., as suggested in many LCA analyses applied to agriculture cultivation (Audsley *et al.*, 1997; Cowell and Clift, 1997; Gaillard, 1996; Hauschild, 2000; Milà and Canals, 2003; Wegener Sleeswijk, *et al.,* 1996). The buildings were not counted because not present in the primary data collected. The maintenance of the park includes all agricultural activities for growing plants such as the use of fertilizers, pesticides, mulches, irrigation equipment, machines for pruning and grass cutting, with their energy consumption, and include materials such as support poles , anchor cables and screens for plants. Use and end of life phases are not included. To model the system and to evaluate the environmental impacts the GaBi 4 software was used. The selected method for the classification and characterization of the inputs and outputs of the inventory is the CML-2001 (Guinee *et al.,* 2001). Data on energy, water, materials consumption and on equipments were collected on-site and refer to the years 2009-2010; background data come from various sources (commercial databases, literature, products technical sheets etc.). The main geographical characteristics of the park analyzed are shown in Table 1. For the production of pesticides we used the procedures suggested in literature, which consider only the total manufacturing energy consumption for some active ingredients of the pesticides and model the missing active ingredients with the active ingredients of the same chemical family or having the same type of use (insecticides, fungicides etc.). Pesticide use has been referred to a dispersion model in the open field (Birkved and Hauschild, 2006) taking into account the physical properties of the active ingredients used in the Noci's park. In order to evaluate the macro-elements (N, P, K) dispersed into the environment during the use of fertilizers, a balance was calculated between the quantity applied, the amount evaporated into the air and the amount absorbed by the plants, finally giving a value to the residual amount percolating into the water shed and into the soil (Antòn, 2004; Bentrup *et al.,* 2000; Weidema and Mortensen, 2005). The plants grew in the park have been evaluated as an input provided by nurseries. The potted plants (hedges and ornamental plant) were considered as obtained from cuttings or seed (Russo and De Lucia Zeller, 2007). For trees (conifer and broadleaf) was considered their growth in open fields in the nursery for seven years.

Table 1: Park's description

Municipality data		Park data	
Surface (km^2)	148	**Surface (m^2)**	5280
Altitude (m)	420	**Year of construction**	1947
Residence population (ab.)	19564	**Management**	Municipal management
Population density (ab/km^2)	131	**Type of soil**	Clay
Mean temperature coldest month (°C)	6,5	**Type of plants**	Mediterranean
Mean temperature hottest month (°C)	17,0	**Surface flowerbeds (m^2)**	3600
Phytoclimatic area	Lauretum	**Number of trees**	177
		Numbers of shrubs	407

4. Results and discussion

Figure 2 shows how the construction of the park, considered with long useful life of 40 years, has greater impact than management. The ADP index depends primarily on the construction of fences and paths (Figure 3). The construction of fences is the major cause of impact for indices AP, GWP_{100}, ODP, together with plastic irrigation pipes, and POPC.

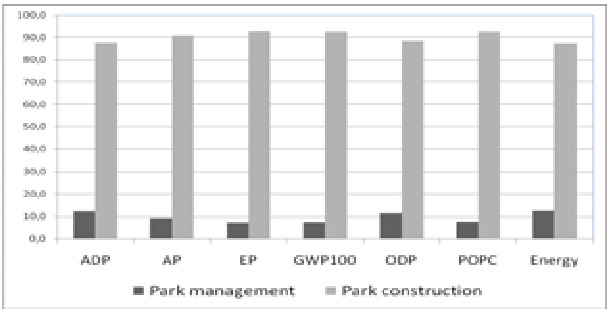

Figure 2: Comparison between management and construction of analyzed park.

The index EP is influenced by the use of fertilizers for the production of plant in the nurseries (Figure 3). The use of fertilizers, fuel and electricity are the major causes of impact on ADP index in management analysis (Figure 4). For the management of the park, for the indexes AP, GWP_{100}, ODP and POPC are the use of fertilizers and electricity consumption that cause the greatest impact.

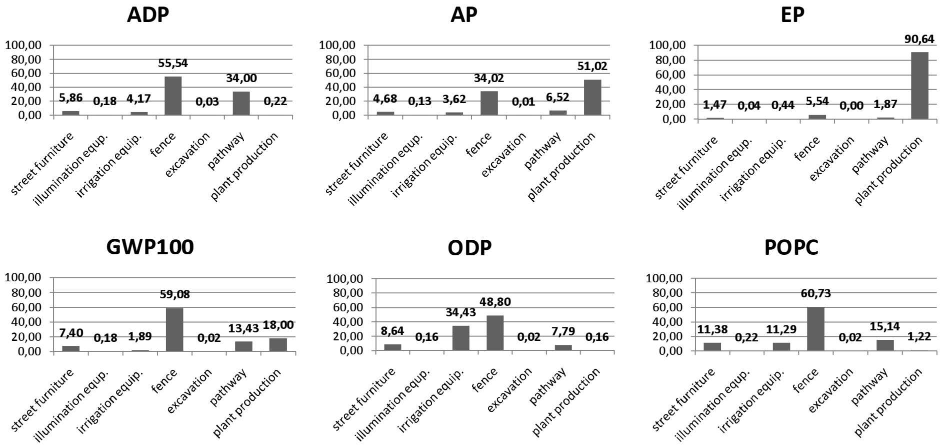

Figure 3: Impact indicators for the construction of the park.

The use of fertilizers, during routine maintenance activities, is the major causes of impact on EP index (Figure 4).

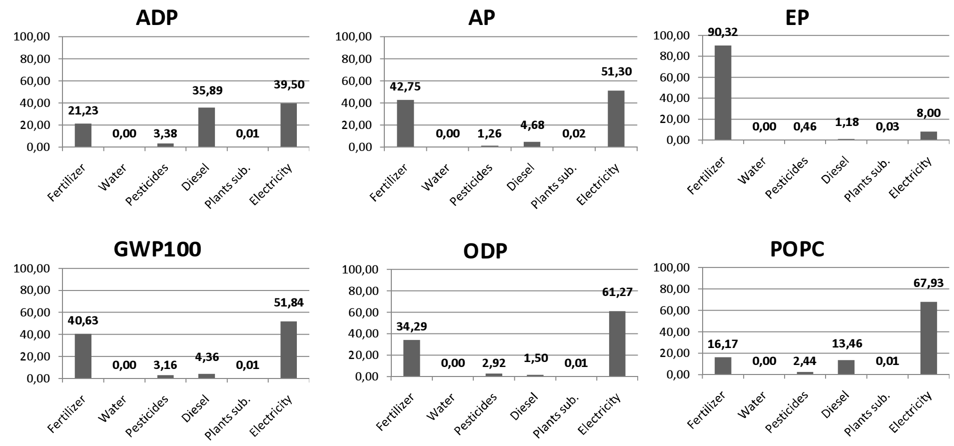

Figure 4: Impact indicators for the management of the park.

5. Conclusion

The carried out work is based on data for one city park only. Is still ongoing a data collection of other green Apulian areas that will allow more defined conclusions on the inputs of realised inventory. Will be possible realise also some comparisons between different construction methods and management practices. The fence of the park are made of concrete and steel, therefore the use of appropriate plant species for this purpose could reduce the impacts of their construction and fulfil the function of protecting the green areas.

Gravity irrigation systems, use of mulch in natural materials, selection of hardy plants that require few fertilizers and water, the distribution of pesticides by means of drip rather than spray, are solution that can improve the environmental load produced by park management. The practice of pruning composting can bring a double benefit. In fact it's possible reduce the amount of biomass for disposal and use of chemical fertilizers. The compost produced can replace, in part, chemical fertilizers with the advantage to improve soil quality.

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