National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

The *environmental sustainability* of the Dutch *diet*

Background report to 'What's on our plate? Safe, healthy and sustainable diets in the Netherlands.'

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Synopsis

The environmental sustainability of the Dutch diet
Background report to 'What is on our plate? Safe, healthy and sustainable diets in the Netherlands**.**

A sustainable food system is a system that provides sufficient food and nutrition for all people, considering current as well as future generations. Moreover, in a sustainable food system the ecological system is protected. The current global food system is not sustainable. Worldwide, food production and consumption are responsible for around 25% of the total emission of greenhouse gases and for 60% of the terrestrial loss of variation in plant and animal species (biodiversity).

In this report, the Dutch National Institute for Public Health and the Environment (RIVM) describes in what ways and to what extent the production of foods as consumed in the Netherlands has an impact on the environment. Meat and dairy (including cheese) contribute most environmental impact, followed by drinks. For many foods, the production phase (agricultural phase) causes the largest environmental burden. Production of meat and dairy requires a large area of land and high inputs of water. These foods also have the highest impact on acidification and eutrophication. The production of fruit requires a relatively high amount of water. Although the primary production phase is most important for the total environmental impact of most foods, the use of fossil fuels and raw materials for packaging, transport, conservation and preparation of food products are also relevant. This report provides an overview of the current knowledge on the environmental sustainability of foods and diets eaten in the Netherlands.

(Technological) innovation can help to reduce unwanted emissions and reduce the need for input of natural resources of all types of foods. Avoiding food waste and avoiding overconsumption of food and drinks induces a lower demand for food production and this will benefit the environment. The type of food and drinks chosen will affect environmental impacts of daily diets, like less meat consumption and more tap water instead of soft drinks and alcoholic drinks.

This report is one of four background reports that form the basis of a knowledge synthesis on healthy, safe and sustainable food. This knowledge synthesis is published on the 24th of January 2017.

Keywords: food, diet, ReCiPe, life cycle impact assessment, LCA, environmental impact, model

Publiekssamenvatting

De ecologische duurzaamheid van het Nederlandse voedingspatroon
Achtergrondrapport bij 'Wat ligt er op ons bord? Veilig, gezond en duurzaam eten in Nederland.'

De productie en consumptie van voedsel legt een grote druk op het milieu. Dit komt onder andere door intensief gebruik van landbouwgrond en door de uitstoot van broeikasgassen bij de productie van voedsel. Ons dagelijks eten heeft dus grote invloed op het milieu. Wereldwijd is de voedselproductie en -consumptie verantwoordelijk voor ongeveer 25 procent van de totale uitstoot van broeikasgassen. Daarnaast is deze voor 60 procent verantwoordelijk voor het verlies aan de variatie van gewassen en dieren (biodiversiteit).

Het RIVM heeft in dat verband beschreven hoe en in welke mate de productie voor de huidige Nederlandse voedselconsumptie een belasting voor het milieu vormt. Daaruit blijkt dat vlees, zuivel (inclusief kaas) en dranken het meest belastend zijn. Voor de meeste voedingsmiddelen zit dat vooral in de productiefase. Zo is veel land en water nodig om vlees- en zuivel te produceren. Ook zorgen deze producten voor de meeste verzuring/vermesting van de bodem en het oppervlaktewater. Voor de productie van fruit is relatief veel water nodig. Hoewel het primaire productieproces van de meeste voedingsmiddelen de grootste milieudruk veroorzaakt, is ook het gebruik van fossiele energie en grondstoffen voor het verpakken, transporteren, bewaren en bereiden van producten relevant; in welke mate verschilt per product. In dit rapport wordt de milieubelasting van ons voedingspatroon meer in detail beschreven.

De milieubelasting kan worden verminderd door (technologische) innovaties die per voedingsmiddel de uitstoot van ongewenste emissies verlagen en/of overmatig gebruik van natuurlijke hulpbronnen verkleinen. Minder voedsel verspillen en niet teveel eten en drinken zorgen ook voor minder milieubelasting. De consument kan daarnaast een bijdrage leveren met zijn keuze voor bepaalde voedingsmiddelen, zoals minder vaak vlees en vaker kraanwater in plaats van frisdrank en alcohol.

Dit rapport is een achtergrondstudie voor de rapportage 'Wat ligt er op ons bord? Gezond, veilig en duurzaam eten in Nederland' van het RIVM die op 24 januari 2017 is verschenen. Hierin worden de aspecten van gezond, veilig en ecologisch duurzaam voedsel geïntegreerd weergegeven.

Kernwoorden: voedingsmiddel, voedselconsumptie, levenscyclusanalyse, milieubelasting, Nederland, kennissynthese

Contents

Summary

The background report "The environmental sustainability of the Dutch diet" addresses various questions regarding the environmental sustainability of the Dutch food consumption pattern.

With our current way of life, total resource use is about 4 to 5 times higher than the suggested sustainable level; four of the nine planetary boundaries are now being transgressed as a result of human activity [1, 2]. Food production is a major determinant of environmental sustainability. Globally, food production and consumption are e.g. responsible for about 25% of total greenhouse gas (GHG) emissions. In addition, agricultural activities related to food production have caused over 60% of the loss of terrestrial biodiversity.

A food system includes production, processing and consumption aspects and the link between them. A sustainable food system refers to the ability to maintain the food and nutrition needs of current and future populations while protecting the ecological systems that provide food. There is a difference between the Dutch food system (including both production and consumption) and the Dutch food consumption or diet as such. In this synthesis, we start from the foods actually consumed in the Netherlands, including imported food (ingredients) from other countries (mainly wheat, (palm)oil and fruit).

The FAO defines sustainable diets (or in other words sustainable food consumption patterns) as 'diets protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources'. From this definition, it is clear that sustainability of food systems and/or sustainable diets imply a long-term perspective, and that many aspects related to food production and consumption have to be considered, such as environmental burden, social and economic dimensions, as well as animal and human health.

In order to monitor the environmental sustainability of our food consumption system, indicators are needed. The set of most suitable indicators /metrics is still under discussion. In this report, we focus especially on selected indicators for the use of resources as well as environmental impact caused by emissions. The environmental impact via greenhouse gas (GHG) emissions is evaluated the most extensively, for foods as well as diets. In addition, the indicators for land and water use, soil acidification and degradation, marine and fresh water eutrophication are discussed.

This report provides an overview of the current knowledge on the environmental sustainability of foods and diets eaten in the Netherlands.

The aim of this report is to describe:

- the environmental sustainability of different types of food (per kg of food)

- the environmental sustainability of the Dutch food consumption pattern
- policies and private initiatives that influence the environmental sustainability of food production and consumption
- management perspectives for more sustainable food consumption.

Environmental sustainability of foods and diets
For many food products, the production phase (agricultural phase) is the phase associated with the largest resource use and highest environmental impacts. The production phase usually requires a large area of land, and high inputs of water, energy and fertilizers (N, P and K), as well as large emissions into the environment, such as greenhouse gasses and pesticides. The type and intensity of the various environmental impacts differs between and within food groups. In general, it can be stated that of all food groups, meat and particularly beef, has the largest impact (per kg of food) on climate change, acidification, marine and fresh water eutrophication, and land use. The impact of meat is highest on these impact categories, followed by cheese, fish, and dairy (excluding cheese). For the impact category ‘water use’, the ranking of the assessed food groups is different: meat again has the highest environmental impact, but also certain types of fruit require relatively large quantities of water, mainly for irrigation. The impact of vegetables on water use is lower, but not negligible; it is more or less equal to that of dairy.

The environmental sustainability of (Dutch) daily diets is only assessed quantitatively for GHG emissions (in CO_2 equivalents) and land use, as there is yet a lack of quantitative data enabling assessment of the level of impact of the Dutch diet. Daily GHG emissions due to food consumption depend on age, gender, energy needs, and type of foods and drinks consumed. Therefore, considerable differences between individuals may exist. Meat and cheese consumption constitute 40% of the GHG emissions of daily Dutch diets. The contribution of drinks (including dairy drinks) to daily GHG emissions is approximately 20%. Both food consumed at dinner and food consumption in between meals (i.e. drinks and snacks such as cheese) cause the highest food-related GHG emissions.

Modelling studies show several options that can lead to a reduction of GHG emissions and land use, based on currently consumed diets. Reducing energy intake according to requirements reduces climate impact at a population level. Overconsumption drives unnecessary environmental impacts, and contributes to overweight and obesity. In addition, reduction of animal-based foods (especially red meat i.e. beef, lamb and pork) and/or replacement of these foods by lower impact plant-based foods, reduces GHG emission and land use. A complete avoidance of meat and dairy, however, might not be the most optimal solution either from an environmental point of view (land use and biodiversity aspects) or with regard to nutritional adequacy. Changing towards a healthier diets (complying with dietary guidelines) does not automatically result in a lower environmental impact. To reach this, additional actions are needed, such as further lowering meat consumption and/or choosing only those foods with a relatively low environmental impact from each food group.

Policies and private initiatives related to sustainability of foods and diets
This report describes the existing policies and private (sector) initiatives for a more sustainable food production and consumption in the Netherlands. The different policies, both at EU level and national levels, are described based on the supply chain of food products, i.e. from production, via processing and retailing, towards waste prevention and reduction. Numerous private sector, (semi)governmental or citizens' initiatives exist to move towards a more sustainable food consumption pattern. These initiatives mainly target reducing food waste. In the consumer phase, the annual amount of avoidable food waste is estimated at 47 kilos per person; this is mainly dairy, vegetables, fruit, potatoes, rice, pasta and bread. Furthermore, several initiatives promote the consumption of seasonal, organic and/or local food.

Management perspectives
Both nationally and internationally, the awareness of the importance of a sustainable food system is growing. To come to more sustainable food consumption patterns in the Netherlands, all actors throughout the life cycle of food products need to move in a more sustainable direction. In their food policies, governments at EU and national levels could focus more on protecting the ecological systems that produce food. (Technological) innovations could lead to a more sustainable food production, with less input of natural resources and less output of unwanted emissions. Innovation in the food sector such as within the green protein alliance could also support less animal-based and more plant-based foods. A government can stimulate sustainability with financial and fiscal measures, by sustainable public procurement, or by facilitating contacts between the actors throughout the supply chain. Another role off the government is to provide correct and transparent information/education on the (environmental) sustainability of foods, (food) consumptions patterns, and on directions towards a more sustainable consumption pattern.

Food producers can take responsibility by making their production processes more sustainable, e.g. by shifting towards the use of renewable energy sources and by changing their production methods, as well as by extending the types of foods presented to the consumer. In the food (processing) and retail industries, 'sustainable sourcing' of commodities and foods should be the standard, also with respect to social (fair trade) and animal welfare aspects. Furthermore, the information provided about foods can be made more transparent. Finally, consumers can adapt towards more (environmental) sustainable food purchase, preparation and consumption patterns, either by the amounts (avoiding overconsumption and overbuying) and type of foods (more plant-based) consumed, or by the way in which the foods are packaged, prepared (e.g. re-use of leftovers) and transported (e.g. by bike).

1 Introduction

1.1 Diets and environmental sustainability

With our current way of life, total resource use is about 4 to 5 times higher than the suggested sustainable level [1, 2]. Scientists agree that changes are immediately required in all fields [3]: the planetary boundaries for biosphere integrity (biodiversity loss and extinctions) and biogeochemical flows (phosphorus and nitrogen) have already been transgressed as a result of human activity [2; figure 1]. At the end of 2015, important international agendas were adopted -the Paris Climate Agreement to limit global warming to a 1.5°C to 2°C increase, and the United Nations Sustainable Development Goals [4]. Both agreements reflect the world's recognition that action needs to be taken by all nations in order to ensure a more stable and resilient earth system.

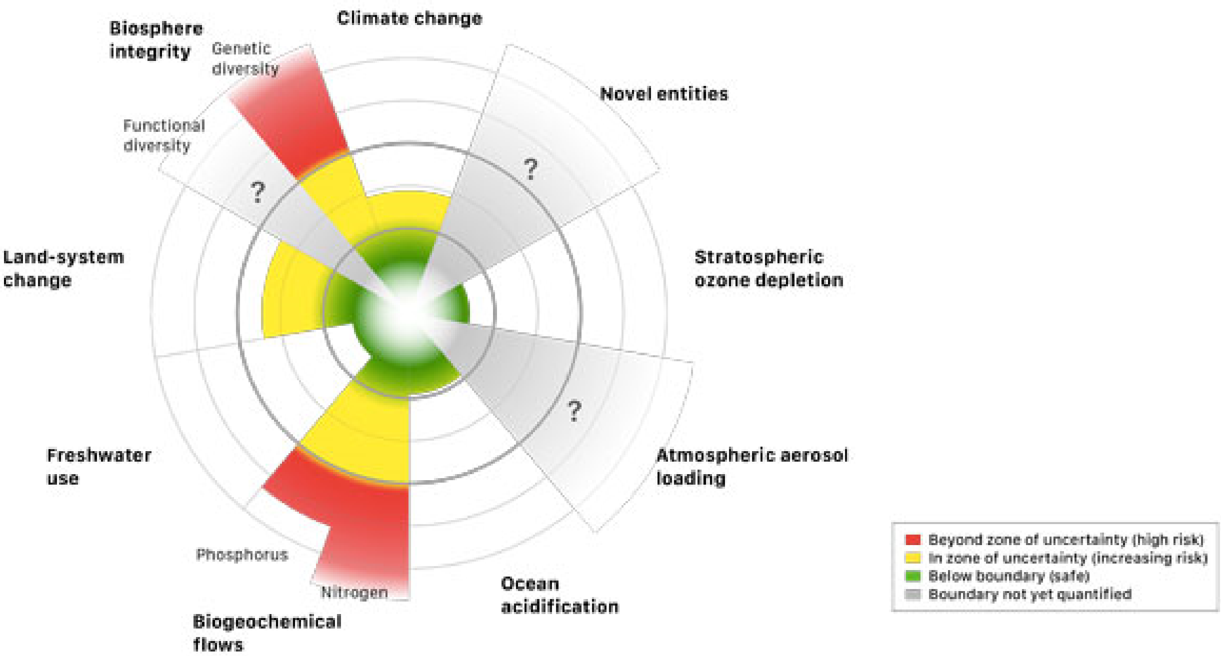

Figure 1.Estimates of how the different control variables for seven planetary boundaries have changed from 1950 to present. The green shaded polygon represents the safe operating space. From: Steffen, Richardson [2]. Reprinted with permission from AAAS.

Food production is a major determinant of environmental sustainability; energy and transport are other major determinants [5-7]. Agricultural food production has caused over 60% of the loss of terrestrial biodiversity [8]. This is mainly due to the conversion of natural habitats into land used for (intensive) agriculture, as agricultural land has a much lower biodiversity than natural land. Of the total nitrogen and phosphorus inputs via fertilizers, only 15-20% is actually present in the food that reaches the consumers' plates, implying large nutrient losses to the environment [9]. Phosphate and nitrogen losses and pesticide emissions reduce the biodiversity of fresh water and coastal seas [10].

In the Netherlands, loss of soil quality via acidification and loss of fresh and marine water quality via eutrophication is a serious problem [11]. Critical loads of nutrients, especially nitrogen, are constantly exceeded [11]. With respect to the use of fresh water for global food production, as much as 85% of fresh water use goes to agricultural irrigation, of which 15–35% is thought to be unsustainable [12]. Globally, food consumption and production is responsible for around 25% of total greenhouse gas emissions, mainly through manure (CH_4 and N_2O) and energy use throughout the food system [8].

1.2 Aims of this report

The aims of this report are to describe:

- the environmental sustainability of different types of food (chapter 3)
- the environmental sustainability of Dutch food consumption pattern (chapter 4)
- policies and private initiatives that influence the environmental sustainability of food production and consumption (chapter 5)
- management perspectives for more sustainable food consumption (chapter 6)

The current report was prepared within the scope of the knowledge synthesis 'Safe, Healthy, and Sustainable Diets'. This is a strategic project conducted by the Dutch National Institute for Public Health and the Environment (RIVM), describing and integrating the current knowledge on healthy, safe and sustainable foods and diets, with a focus on the Netherlands. As part of this knowledge synthesis, various background reports have been prepared. This background report on ecological sustainability provides basic information on the topic.

1.3 Sustainability is…

The FAO applies a broad definition for sustainable diets (or in other words: sustainable food consumption patterns) as 'diets protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources' [13]. In the Netherlands, the following definition of sustainable eating patterns is used: *"Duurzame voedselpatronen zijn voedselpatronen met een lage milieubelasting, die bijdragen aan voedselveiligheid en gezondheid voor de huidige en toekomstige generaties" [14].*

Our report focusses on the environmental sustainability of foods and diets and thus on use of resources and environmental impacts.

When people are asked to define a sustainable food or a sustainable diet, most seem to agree that when it comes to farming, buying foods, cooking and eating, sustainability is a good thing. However, the definition of sustainable foods and sustainable diets from the consumer perspective is ambiguous. Again, under the broad banner of food sustainability, many issues are mentioned, including environmental, health, social and ethical issues.

1.4 Content of this report

The framework and scope of this report are described in chapter 2. Our in-depth analysis of the environmental sustainability of the foods consumed in the Netherlands (see chapter 3) includes land, water and fossil energy use as well as the environmental impact on climate change (greenhouse gas emission in CO_2 equivalents). We have evaluated impact on soil quality via acidification and impact on fresh and marine water quality via eutrophication for a limited number of food groups. The sustainability of daily food consumption is discussed in chapter 4, mainly in relation to biodiversity loss (via land use) and climate change (via greenhouse gas emissions). Information on fair trade issues, organic farming, GMOs, animal welfare and local foods, is given in appendix 2. Chapters 5 and 6 describe the policies and private initiatives that aim to influence the environmental sustainability of the food system and their management perspectives for policy makers as well as supply chain actors (producers, retailers and consumers).

2 Framework and scope of this study

2.1 Framework: the world's issues related to food

Food systems emerged with the dawn of civilization, when agriculture, including the domestication of animals, set the stage for permanent settlements. This changed human culture; unlike earlier hunter-gatherers, agriculturalists did not need to be in constant motion to find new sources of food. The ability to produce a surplus of food also set the stage for the development of art, religion, and government. Since agriculture began, food systems have constantly evolved, each change bringing new advantages and challenges, and ever-greater diversity and complexity [15].

Nowadays, the global demand for food is rapidly increasing. The world's population has been projected to reach nearly ten billion people by the middle of this century and to peak at eleven billion by the end of the century [16]. Among the world's most pressing challenges is providing a growing population with safe, sufficient and nutritious food on a resilient planet. In our global food system, fundamental changes are needed to achieve the Sustainable Development Goals (SDGs) [4]. Simultaneously, there is increasing competition for critical resources such as land, biomass, energy and phosphorus (P) reserves. The challenge of feeding the world's population is even more striking, because several of the critical biophysical boundaries for earth system processes that determine elementary ecosystem services have been transgressed or are on the verge of being transgressed [1].

In the recent past, a large number of international organisations in the fields of 1) agriculture and food (FAO), 2) economic policies (World Bank, OECD), and 3) development aid (Oxfam) as well as companies (Rabobank, ING, McKinsey) have sounded the alarm bell about the problems already caused by the global food system and those which will emerge in the near future. Substantial questions have been raised about the ecological sustainability, human health and robustness of the global food system [17]. Although there is strong consensus about the nature and the importance of the problems, the viewpoints on how to solve them differ. On the one hand, there are advocates of intensification and scaling-up the agricultural system in combination with innovation. On the other hand, there are proponents for changing market structures, dismantling of agrifood monopolies, and strengthening the position of small farmers and local communities [17]. Both viewpoints have their advantages and drawbacks, and both can provide concrete management frameworks for policy makers at national, European and global levels, as well as for companies active in the agrifood sector, and for consumers.

2.2 The Dutch food system within the global food system

A food system includes all processes and the whole infrastructure involved in feeding a population: growing, harvesting, processing, packaging, transporting, marketing, consuming, and disposing food and food-related items. It also includes the inputs needed and outputs generated at each of these steps. A food system operates within, and is influenced by, social, political, economic, environmental and technological contexts. It also requires human resources that provide labour, research and education. A food system can be analysed on different scales (global, national, local).

The Netherlands has a strong position in the world's food system. The total Dutch agrifood sector – primary production (agriculture, livestock and fishery), the processing industry, distributors, retailers and catering industry – accounts for about 10% of total employment in the Netherlands [18], which is much greater than that of other countries in the EU). The Netherlands is an important node in the international food trade system. It is – partly due to transit – globally the second agricultural exporter [17].

Figure 2.1 provides a schematic representation of the position of the Netherlands in the global food system. It shows that there is a clear difference between the Dutch food production system and Dutch food consumption as such. Of the food consumed in the Netherlands, a significant part is imported from other countries. A large part of food produced in the Netherlands is exported to other countries.

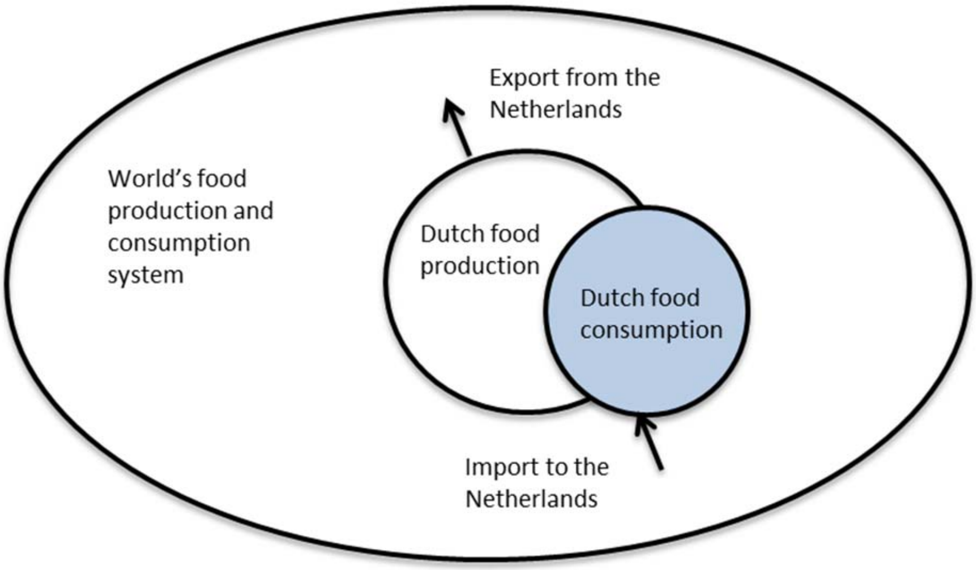

Figure 2.1. Schematic representation of the position of the Netherlands in the world's food system (not on scale).

Imports of agricultural product groups relate primarily to potatoes, fruit and vegetables, processed foods for human consumption, meat and live animals, grain products (wheat for bread), cocoa and cocoa products, and oils and fats [19]. The most important Dutch agricultural export products for consumption in 2015 were potatoes (ware and industrial), fruits and vegetables, processed foods (such as processed meat, fish and vegetables), meat and live animals, dairy products (mostly cheese) and eggs; figure 2.2 presents the for-net export values and proportions per food category.

In this knowledge synthesis, the focus is on Dutch food consumption, including imported food products from other parts of the EU/world if consumed by the Dutch population. It does not focus directly on the entire Dutch food production.

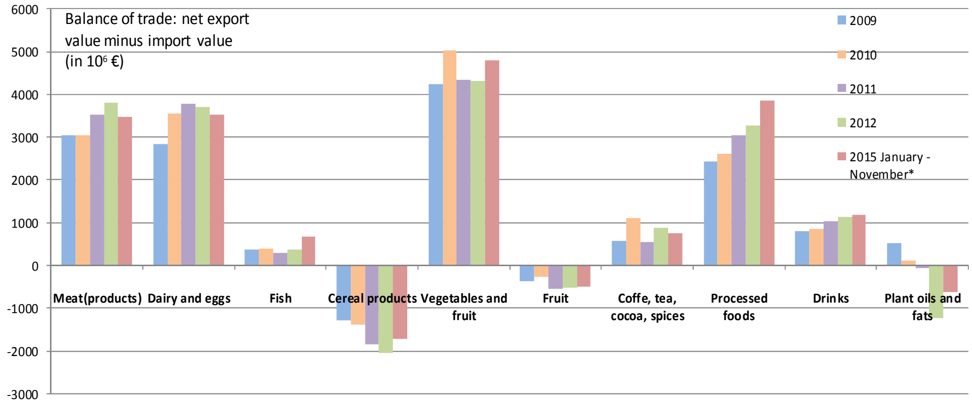

Figure 2.2. Balance of trade in the Netherlands according to SITC-class. 2009 - November 2015, Statline, CBS, accessed 16 February 2016.

2.3 Indicators to evaluate resource use and environmental impacts of food consumption

Indicators are needed to monitor the environmental sustainability of our food consumption. The set of most suitable indicators/metrics is still under discussion. Steffen's nine planetary boundaries (2015; see chapter 1) provide a framework for distinguishing nine types of environmental impact indicators, but these apply to environmental pressure in general, and thus not all of them are reliable for the food system. However, some certainly are applicable: e.g. biogeochemical flows of nitrogen and phosphorus indicate the problems of eutrophication and acidification in some parts of the world, and nutrient depletion from soils in other parts of the world. In addition, climate change effects, fresh water use, and biosphere integrity (biodiversity) are issues related to our food system (see Figure 1).

The EAT Initiative, the Sustainable Development Solutions Network (SDSN) and CGIAR Consortium established another set of integrated indicators for healthy diets from sustainable food systems, for the Sustainable Development Goals. They propose a set of 11 integrated indicators (not elaborated on here) for monitoring progress towards achieving healthy diets from sustainable food systems under the existing SDG framework.

A different set of indicators for establishing the sustainability of the food system has been proposed by UNEP and PBL, and is presented in Figure 2.3 (PBL, 2016; internal communication). The PBL/UNEP indicators differentiate between resource use (renewable and non-renewable) and environmental impacts (on soil, water and air quality) because of human interventions.

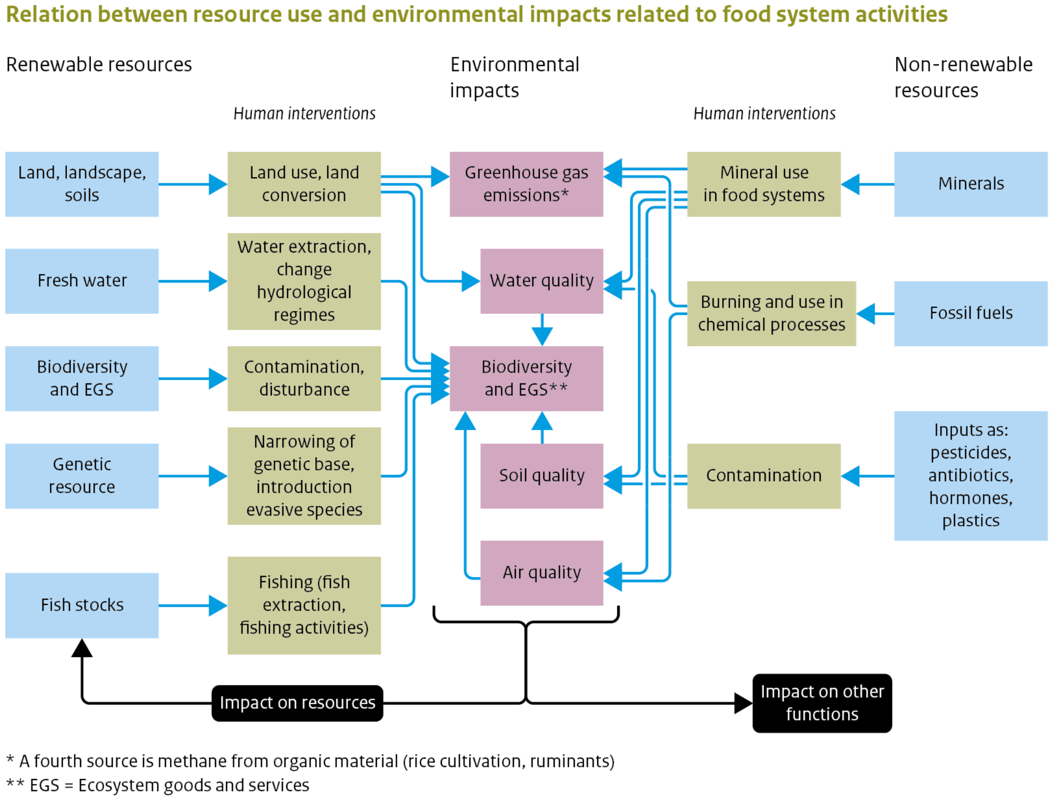

Figure 2.3. Relation between resource use and environmental impacts related to food system activities. Source: PBL.

2.3.1 *Framework and indicators chosen in this report*

The framework and indicators chosen in this report are based on the frameworks and indicator sets given above, where the life cycle chain of food products is used as starting point. This life cycle framework is depicted in Figure 2.4.a, and the environmental indicators concerning food production are shown in more detail in Figure 2.4.b.

A schematic overview of the food cycle is provided in Figure 2.4.a. In addition to agricultural production, it shows that there is a (sometimes long) life cycle before the food is available for consumption. Food has to be transported over longer or shorter distances; there might be several processing steps; there is distribution, storage, retailing and finally preparation in the consumption phase. During all steps of the life cycle, part of the food is being wasted.

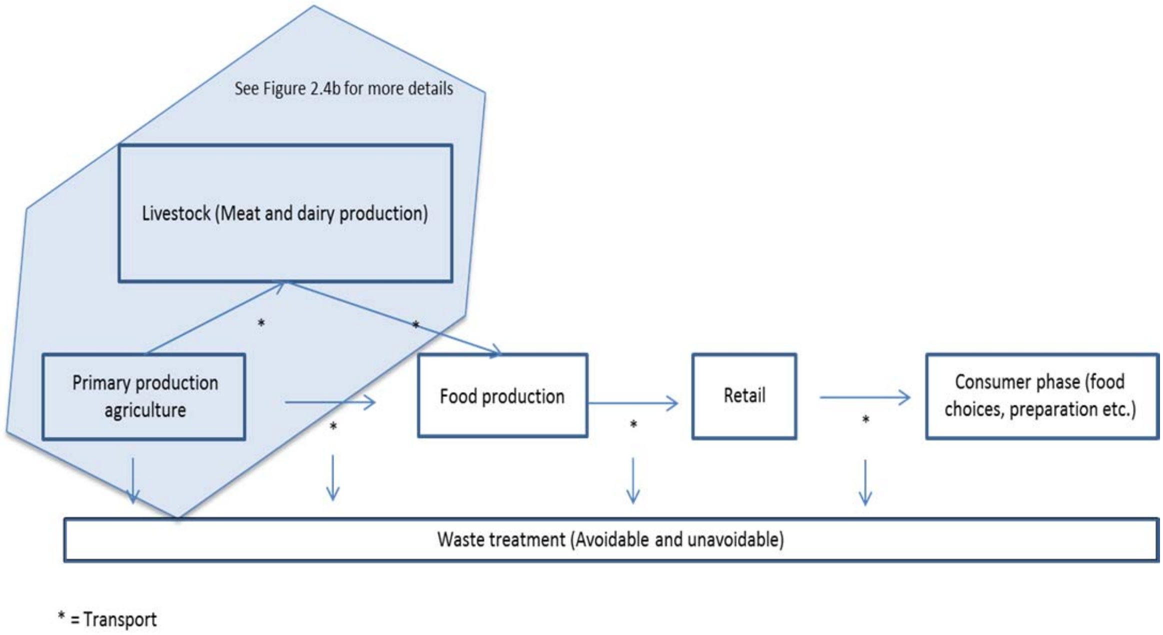

Figure 2.4.a. Schematic overview of the food supply chain from agricultural production to preparation of food by the consumer; this is the scheme applied in life cycle analysis.

In Figure 2.4.b, the first step of the food cycle, the agricultural and livestock production system, is presented in more detail. It shows the production of food products (vegetable and animal) on agricultural land. A brief sketch of the situation shows us that the agricultural activities have an influence on the soil, potentially leading to a decline in soil quality by loss of organic matter and structure, erosion, salinization and desertification. For agricultural activities, natural land is also turned into agricultural land, leading to deforestation and loss of natural areas.

The agricultural activities, including e.g. fertilizer production and transport, use energy (partly from fossil fuels) which leads to fossil fuel depletion and the emission of GHG. Additionally, pesticides and antibiotics are applied which partly end up in the environment. The overuse and misuse of antibiotics are key factors contributing to antibiotic resistance. Locally, the agricultural activities pose pressure on local biodiversity, both terrestrial and aquatic. The decline in animal pollinators is also an emerging problem resulting from the intensification of agricultural practices and from the use of pesticides [20].

Fish production is a special kind of ‘agriculture’, with specific pressures on the natural environment. There are two types of production systems, wild fishery and fish farming, each with its specific environmental pressures. Fisheries harvesting wild fish often lead to the problems of overfishing and direct aquatic ecosystem damage, e.g. by disruption of the seabed with trawlers [21, 22]. In fish-farming systems, antibiotics and hormones are applied, which partly end up in the natural ecosystem. Furthermore, fish excretions and uneaten fish feed lead to eutrophication, and pathogens are spread from fish farms into the natural environment. Moreover, some fish farms disrupt valuable coastal areas like mangroves.

The round arrows in Figure 2.4.b indicate important cycles: 1) nutrients and other (trace) elements (particularly N and P), 2) carbon, and 3) water. In an ideal world, these cycles are closed loops and supply and loss of the substances in an area are balanced. However, in the current worldwide agriculture and trade, imbalances in these cycles occur. In some parts of the world, these imbalances are expressed by nutrient and organic matter depletion and/or a depletion of phosphorus stocks and/or water scarcity. In other parts of the world on the contrary significantly high concentrations of nutrients N and P are released, leading to eutrophication problems in fresh and marine waters, groundwater and soil.

The disruption of the natural N-cycle is particularly alarming; this is mainly due to livestock production and the production of fertilizers. Nitrogen is one of the important building blocks of proteins in meat, dairy, eggs and fish; major constituents of the European diet. However, livestock production and fisheries have large environmental effects; they are a source of greenhouse gas emissions and certain forms of reactive nitrogen. Around 10% of EU greenhouse gas emissions are caused by livestock production [10]. Moreover, a large quantity of nitrogen fertilizer is needed each year to sustain the high production levels of grass, cereals and other crops. In Europe, more than 80% of this nitrogen input is lost, leading to various environmental problems, including the loss of terrestrial biodiversity, and to algae blooms in coastal waters. The Netherlands Environmental Assessment Agency (PBL) developed a construction of the European N-cycle in their report 'The protein puzzle' [10].

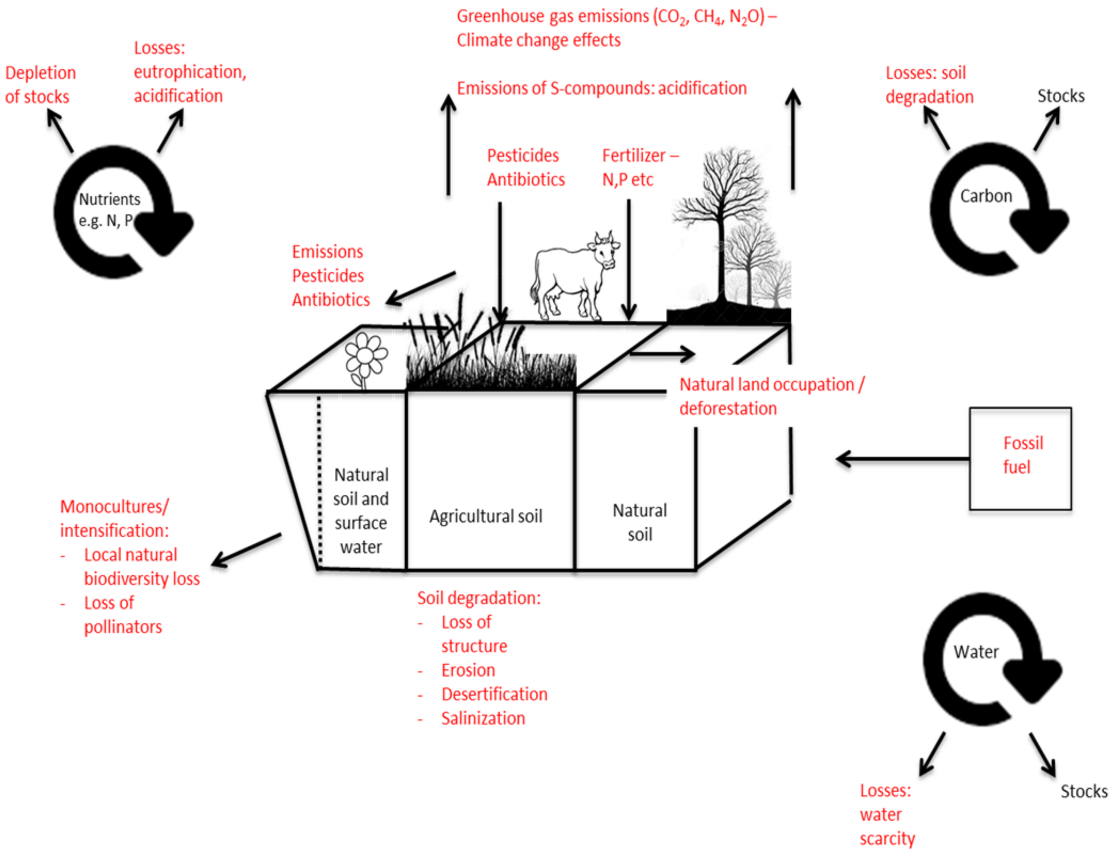

Figure 2.4.b. Schematic representation of the effects of the agricultural phase on resources (renewable and non-renewable), land(scape), soil, water and air quality and emissions. The terms in red are potential environmental problems emerging from agricultural activities.

From these schematic figures, a number of main sustainability aspects can be identified that are of importance for Dutch food production and consumption. It should be noted that the spatial scale of the different environmental effects differs, for example, greenhouse gas emissions lead to global problems due to climate change, whereas soil degradation is a local problem with spatial variation over the world. This spatial variation sometimes complicates the (quantitative) evaluation of some of the environmental sustainability aspects. Also, for some environmental aspects, well-accepted assessment methods are available, whereas for others these have not yet been developed.

2.4 Environmental sustainability indicators accounted for in this report

Of the environmental sustainability aspects listed in section 2.3, some are discussed in detail in this report; the main reason for not including the other aspects is a lack of information. The following aspects have been assessed, either quantitatively or qualitatively:

Use of resources (renewable and non-renewable)

- Land use
- Fresh water use (for a limited number of product groups)

Environmental impacts
- Greenhouse gas emissions
- Soil quality via acidification (for a limited number of product groups)
- Fresh water and marine water quality via eutrophication (for a limited number of product groups)
- Soil degradation (for a limited number of product groups; qualitative assessment)

The use of fossil fuel is not addressed separately, as the correlation with the indicator for greenhouse gas emissions is very high. However, both the indicator of fossil fuel use and greenhouse gas emissions may show positive environmental effects when energy use is shifted from fossil sources to an increased use of renewable energy sources (e.g. sun and wind). Currently, the proportion of renewable energy used in agriculture in the Netherlands is low compared to other European countries.
Due to a lack of data, the human and eco-toxic effects of pesticides and antibiotics in agriculture are not assessed here, but are described per product group in chapter 3. Indirectly, the toxic effects of pesticides and antibiotics are reflected through the aspect of local biodiversity loss/local ecosystem disruption.

Local biodiversity/ecosystem disruption aspects are touched upon when discussing different agricultural practices, like organic farming, farming with genetically modified products, and local production, but only qualitatively due to the lack of sufficient quantitative data.

Definitions
Use of resources (renewable and non-renewable)
Land use is defined as the number of square meters of land area that is needed per year for the total supply chain of food products. A distinction is made in two mechanisms: 1) use of a certain area of agricultural land, 2) transformation of a certain area of (natural) land to make it suitable for agriculture and food production processes. Both mechanisms are combined in one indicator in this report.

Water use is defined as the amount of water that is consumed in the full life cycle of a product. It thus covers irrigation water, including the amount of irrigation water that evaporates or is discharged to rivers and the sea, as well as the water that is eventually incorporated in products. Also, it includes the amounts of water needed in the processing, transport, retail, consumer and disposal phases.

Environmental impacts
Emissions of GHG resulting from human activities lead to increased warming of the earth (climate change); the amount of GHG emitted is commonly used as a measure of climate change. The most important emissions in the food life cycle are CO_2, CH_4 and N_2O. In this study, all emissions are recalculated into CO_2 equivalents, following the IPCC-guidelines.

Soil **acidification** is the build-up of hydrogen cations, also called protons, reducing the soil pH. This happens when a proton donor is added to the soil. The donor can be an acid, such as nitric acid and sulphuric acid (both acids are common components of acid rain). Many nitrogen compounds, which are added as fertilizer, also acidify soil in the long term because they produce nitrous and nitric acid when oxidized in the process of nitrification. For the current study, acidification in the food product life cycle was estimated using ReCiPe [23]. In this method, an atmospheric distribution model in combination with a dynamic soil acidification model calculates the distribution of acidifying emissions. All acidifying emissions are recalculated into SO_2 equivalents.

Eutrophication is the ecosystem's response to the addition of artificial or natural nutrients (mainly phosphates from detergents, fertilizers, or sewage) to an aquatic system. One example is the 'bloom' or great increase of phytoplankton in a water body as a response to increased levels of nutrients. Negative environmental effects include hypoxia, the depletion of oxygen in the water, which may cause death of aquatic animals. In this report, we distinguish between freshwater and marine eutrophication. For the current study, eutrophication caused by the food product life cycle was estimated using ReCiPe [23]. The model calculates the direct transport of nutrients from agricultural land to surface water, as well as the runoff via soil and ground water and the atmospheric deposition of nutrients on surface water.

With **soil degradation**, the soil quality decreases due to soil erosion, salinization, nutrient depletion and desertification. This is an increasing problem in agricultural areas, particularly in Africa, parts of South America and Southeast Asia. One of the causes of soil degradation is that modern agricultural techniques remove an increasing number of nutrients and amount of organic matter from the soil. The assessment of the impact of soil degradation has not yet been incorporated in the standard (LCA-)methods. The RIVM developed a first semi-quantitative indicator on the severity of soil nutrient depletion in different countries and for different crops. In this study, the emphasis was on the loss of phosphorus with the harvesting of crops. Phosphorus is, after nitrogen and potassium, an important nutrient for agricultural crops. We chose phosphorus, since its behaviour in soils is easier to understand than that of nitrogen, and more data are available than for potassium [24].

The indicator of **local biodiversity loss/ecosystem disruption** covers a number of effects of agricultural management practices that influence the functioning of the natural ecosystems in the direct environment surrounding agricultural (production) areas. Although the causes and effects are diverse, they all eventually lead to the disruption of the existing dynamic balance present in healthy natural ecosystems. Unfortunately, the different causes of and effects on local biodiversity losses due to our food consumption cannot yet be quantified. However, differences in food production methods (e.g. organic vs. conventional farming) have different effects on local ecosystems, which can be well-described, qualitatively.
Main issues (both terrestrial and aquatic) related to local biodiversity loss and/or ecosystem disruption are:

- Disruption of the soil ecosystem. The agricultural activities influence the soil, potentially leading to a decline in soil quality by e.g. loss of structure, erosion, salinization and desertification.

This has a negative influence on the flora and fauna present in the soil.

- In agriculture, many pesticides and antibiotics are applied, which partly end up in the natural environment. Locally, these emissions may cause (eco)toxicological pressure on the local ecosystems, both terrestrial and aquatic.
- The removal of natural habitats of many flora and fauna species is an emerging problem resulting from the intensification of agricultural activities: large monocultures are formed causing tree groups, field borders, bushes, shrubs, relief etc. to disappear. The decline in animal pollinators is also a problem, resulting from the intensification of agriculture and from pesticide use [20].
- Invasive species may be introduced in an area due to agricultural activities, which may imbalance the natural ecosystem, potentially leading to plagues. Breeding new plant varieties and the use of genetically modified organisms leads to a shift in the genetic structure of ecosystems, which sometimes has negative effects on the ecosystem's stability.
- Fish production forms a special kind of 'agriculture', with specific pressures on the natural environment. One can distinguish wild fishery and fish farming systems, both with specific environmental impacts. Fisheries harvesting wild fish often lead to the problems of overfishing and direct aquatic ecosystem damage, e.g. by disruption of the seabed with trawlers. In fish-farming systems, antibiotics and hormones are applied, which partly end up in the natural ecosystem. Fish excretions lead to eutrophication, and pathogens are easily spread from fish farms into the natural environment. Furthermore, fish farms sometimes disrupt valuable coastal areas like mangroves.

3 Environmental sustainability of foods in the full life cycle and its different life cycle phases

In Figure 2.4.a, the total supply chain of food products is shown: from production to consumption and waste. In this chapter, the environmental impacts associated with each of the stages in this supply chain are discussed, based on the existing literature. A summary of relevant environmental impacts per food group and per life cycle stage is given in Table 3.2

From 2015 onwards, the RIVM has developed a detailed Life Cycle Inventory (LCI) database within the framework of the ReCiPe model [25]. Using the data and the model, a future monitoring system has been set up to monitor the resource use and environmental impact of the foods consumed most in the Netherlands (per kg of food). This is determined using LCAs. Indicators used are resource use (land and water use) and environmental impacts likes global warming, marine and terrestrial eutrophication, acidification, and soil depletion. The results available from this monitor [25] are included in sections 3.1 and 3.2. Furthermore, some aspects of agricultural production methods that influence local biodiversity (e.g. organic farming, use of GMO) are reflected on in section 3.1. More background information on these issues is given in appendix 2.

3.1 Resource use and environmental impacts per kg of food

Figures 3.1a-f shows the average environmental impacts and standard deviations (per kg product) for the full life cycle of the assessed food groups.
The food groups currently reported on are meat, cheese, fish, dairy, fruit, vegetables, bread and potatoes [25].

Resource use

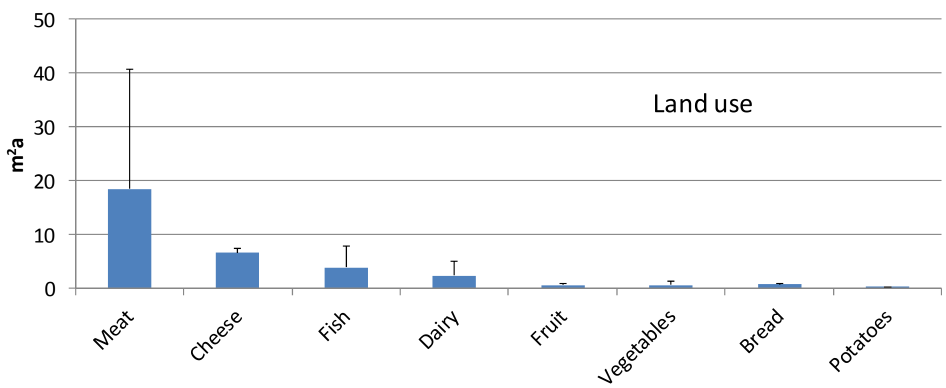

Figure 3.1.a. Land use per kg product of different food groups (in m^2 per year). Values are means, with their standard deviations represented by vertical bars.

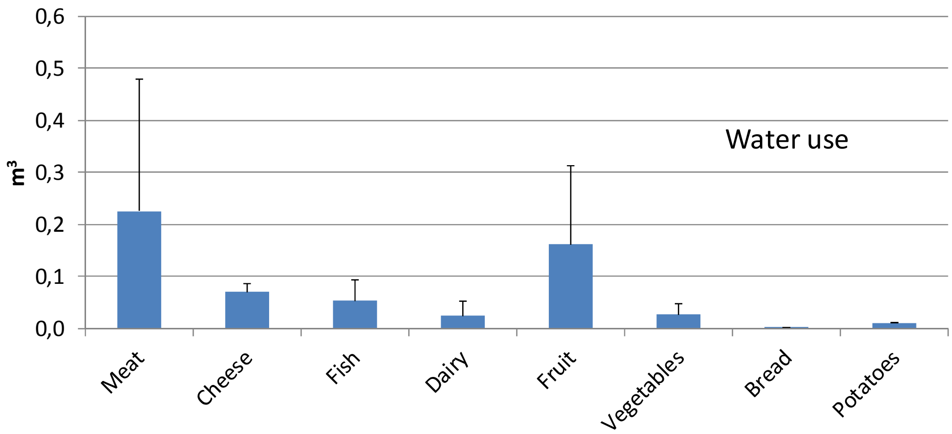

Figure 3.1.b. Water use per kg product of different food groups (in m^3). Values are means, with their standard deviations represented by vertical bars.

Environmental impacts

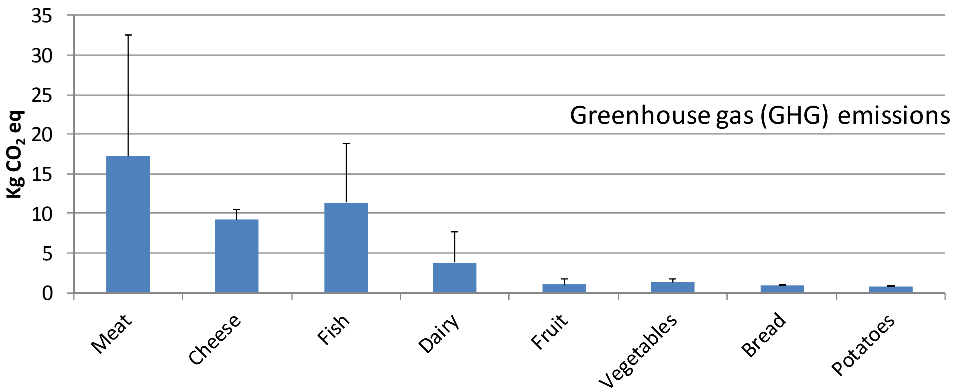

Figure 3.1.c. Greenhouse gas emissions per kg product of different food groups (in kg CO_2-eq). Values are means, with their standard deviations represented by vertical bars.

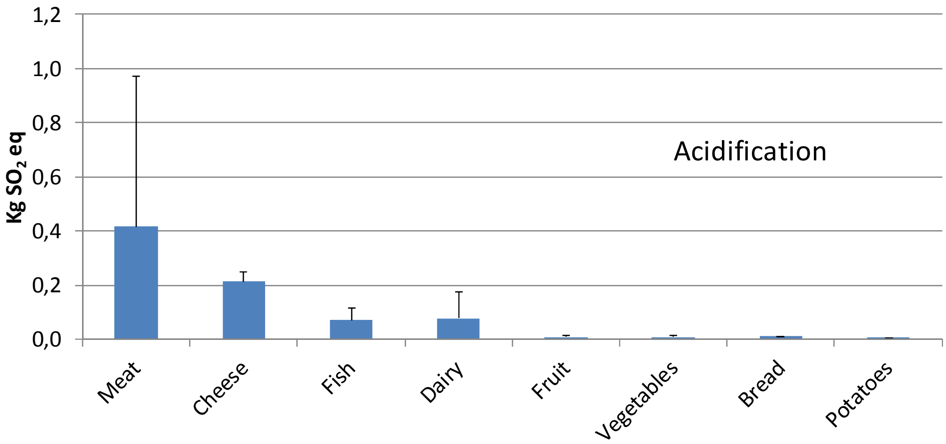

Figure 3.1.d. Acidification per kg product of different food groups (in kg SO_2-eq). Values are means, with their standard deviations represented by vertical bars.

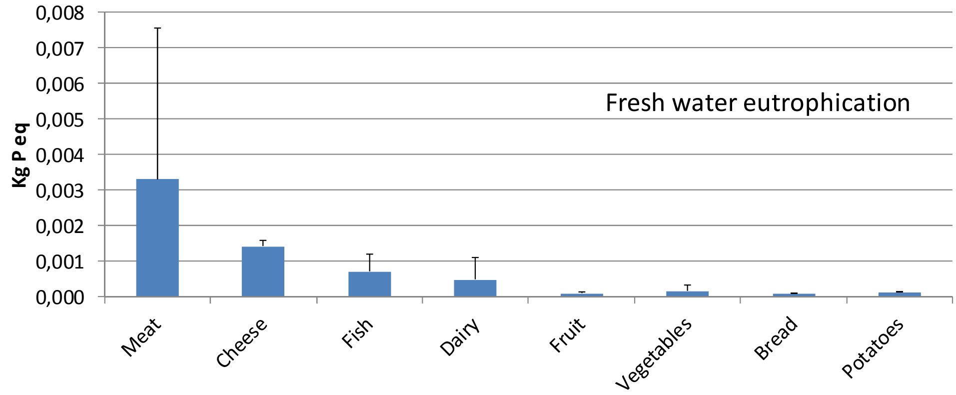

Figure 3.1.e. Fresh water eutrophication per kg product of different food groups (in kg P-eq). Values are means, with their standard deviations represented by vertical bars.

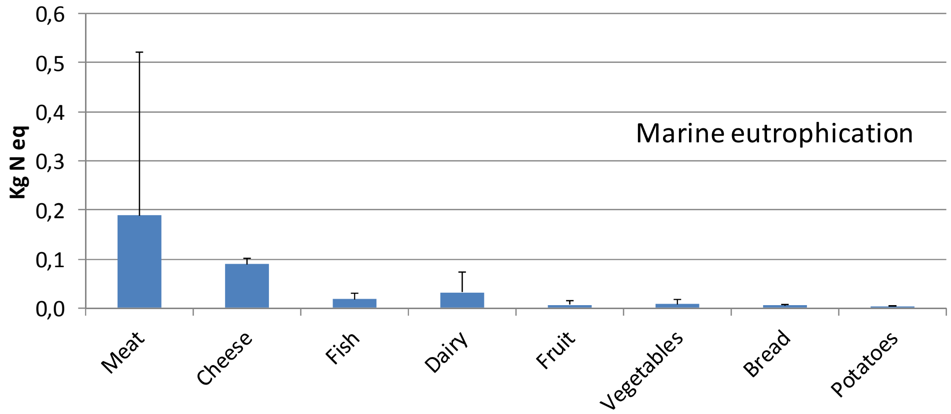

Figure 3.1.f. Marine eutrophication per kg product of different food groups (in kg N-eq). Values are means, with their standard deviations represented by vertical bars.

For these environmental impact categories, as well as for the resource use category 'land use', the ranking of the different food groups is the same. For all these impact categories, meat has by far the highest impact, followed by cheese, fish and dairy (excluding cheese). The food groups fruit, vegetables, bread and potatoes score low on these environmental impacts per kg of food. For the aspect of water use, after meat, fruit is the largest water consumer.

Regarding water use, tropical fruit like mandarin, peach and kiwifruit require relatively large amounts of irrigation water. The water use for vegetables is lower than for fruit, but is not negligible, it is more or less equal to that of dairy.

Meat in more detail
Since meat has a relatively large impact, and since there are significant differences in the environmental impact of different types of meat, this food group was further subdivided into three main types of meat: beef, pork, and chicken. Figures 3.2a-f show for these different meat types the average environmental impacts (per kg product) through their full life cycle [25].

Resource use

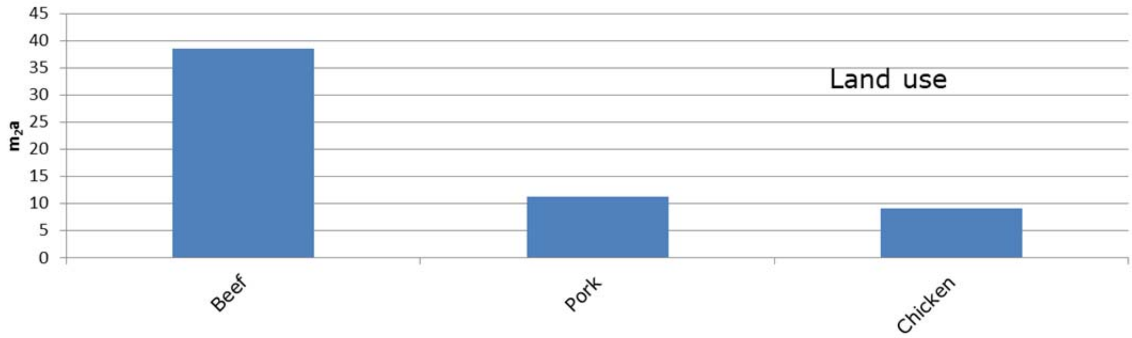

Figure 3.2.a. Land use per kg product of different meat groups (in m^2 per year). Values are means.

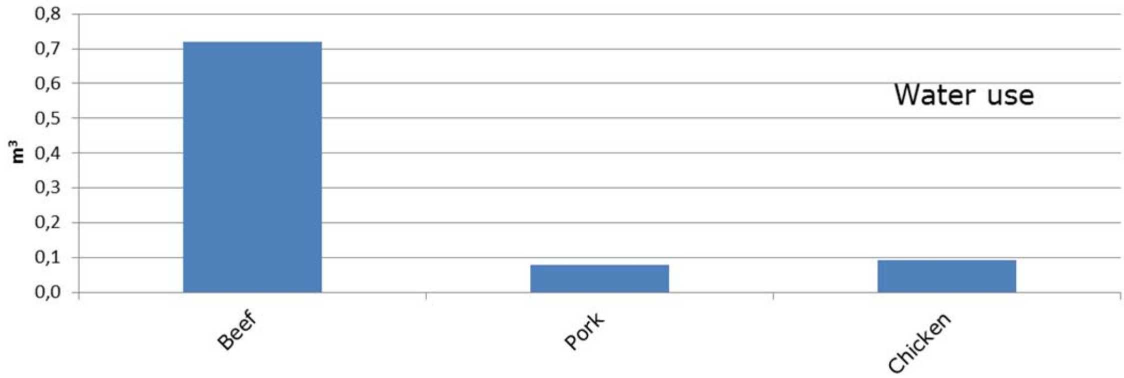

Figure 3.2.b. Water use per kg product of different meat groups (in m^3). Values are means.

Environmental impacts

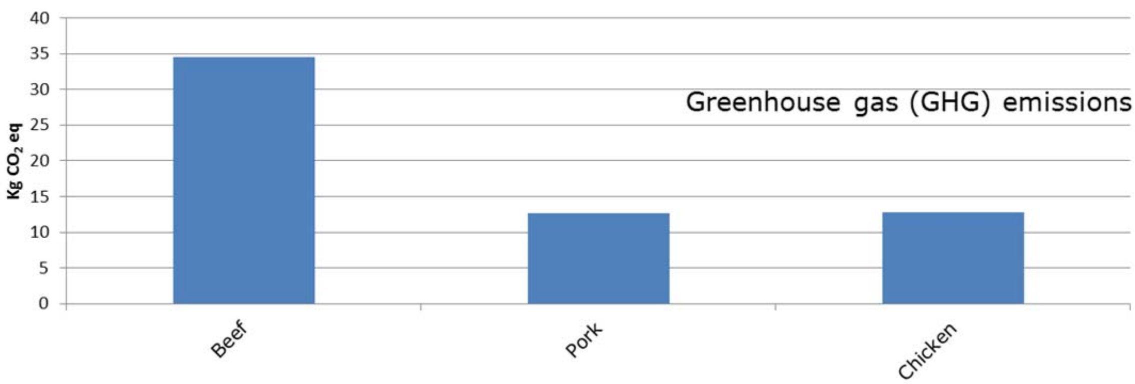

Figure 3.2.c. Greenhouse gas emissions per kg product of different meat groups (in kg CO_2-eq). Values are means.

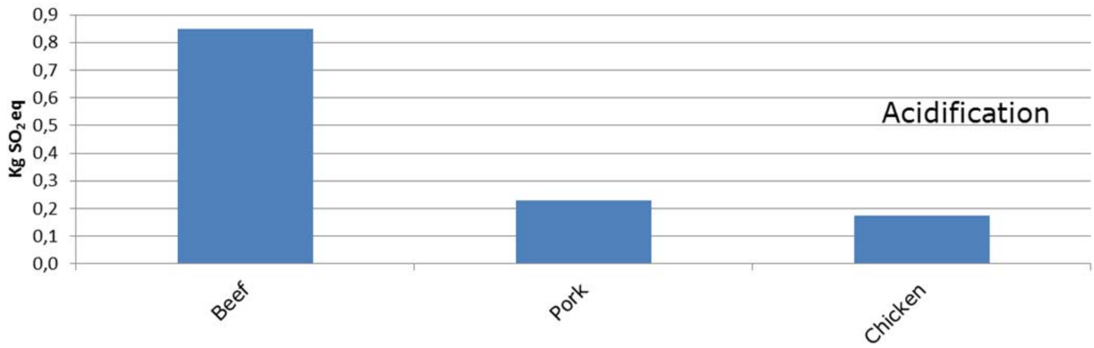

Figure 3.2.d. Acidification per kg product of different meat groups (in kg SO_2-eq). Values are means.

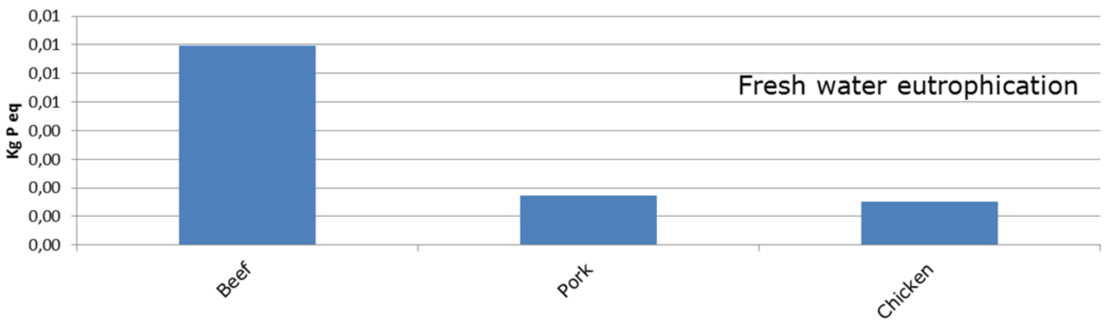

Figure 3.2.e. Fresh water eutrophication per kg product of different meat groups (in kg P eq). Values are means.

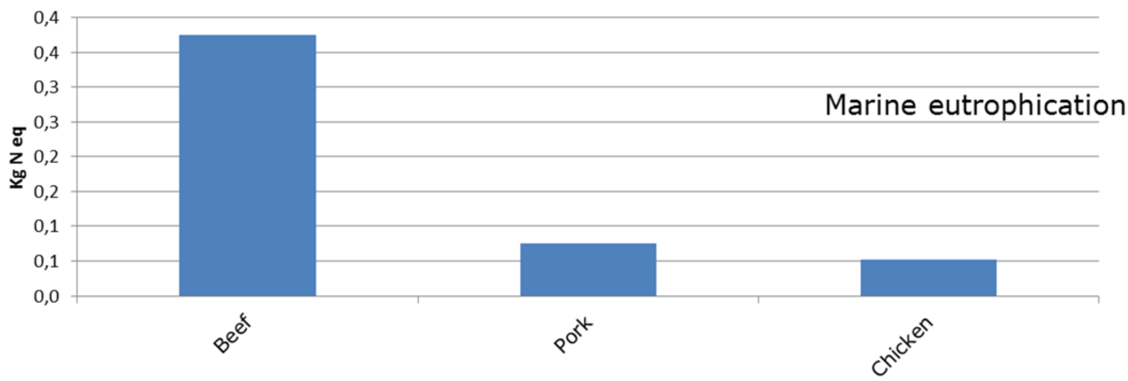

Figure 3.2.f. Marine eutrophication per kg product of different meat groups (in kg N-eq). Values are means.

For all six environmental impacts studied, beef has the highest impact. Chicken and pork meat score relatively low compared to beef for all environmental impacts shown here.

One of the main causes of the variations in environmental impacts of the meat types are the differences in the environmental pressures of the production of feed, firstly caused by the type of feed. Cow-feed (particularly maize, oat and sugarcane) requires e.g. much more water than the other livestock feed types [25]. The second cause of these variations in environmental impacts is the difference in the efficiency of animals to convert feed into meat (mass). Cows need relatively high amounts of feed to produce 1 kg of meat compared to chicken and pork [25].

Soil degradation
For the impact category 'soil degradation', no quantitative measure on a global scale was available. However, based on the type of product and country of origin, estimates could be made whether soil degradation may occur for this specific type of crop at a specific location. The foods with this 'red flag' indication are listed in Table 3.1. Bananas for the Dutch market mostly come from Ecuador, Columbia and Costa Rica. For each of these countries, the RIVM analyses [24] show that the banana production may lead to soil degradation.
Feed used for the production of meat for Dutch consumption comes from all parts of the world [26]. In many countries in Africa, Middle and Southern America, Asia, and Eastern and Southern Europe, the growth of wheat, soy, sugar(cane) and maize leads to soil depletion. To a lesser extent, the same applies for the production of fish feed for fish farms, and for the growth of wheat for Dutch bread production [27].

Table 3.1. Overview of the food products with corresponding food groups and country of origin that potentially lead to (severe) soil degradation (particularly phosphorus depletion), according to Hollander, Zijp [24].

Food group	Product	Country of origin
Fruit	Banana	Ecuador Colombia Costa Rica
Meat Dairy and cheese Fish (farmed)	Feed: Wheat Sugar cane and sugar beet Rape seed and oil palm Soy Maize	Various countries in Africa, Middle and Southern America, Asia, Southern and Eastern Europe
Bread	Wheat	Various countries in Africa, Middle and Southern America, Asia, Eastern Europe, France

Local biodiversity loss /ecosystem disruption
Independent of the type of food produced, agricultural practices lead to disruption of the natural ecosystem in the direct surroundings. Different agricultural management practices influence the local ecosystem to a greater or lesser extent. In general, for all agricultural products it can be stated that when a shift is made from conventional to organic farming, the amount of land needed per kg of product increases (extensive agriculture), whereas the impacts of pesticides, acidification and eutrophication decrease [28]. Moreover, large monocultures often lead to the removal of natural habitats and disruption of the soil ecosystem by heavy machines. By lowering the impacts mentioned above and because of the fact that organic farms are usually smaller scale farms, organic farming is beneficial for the local biodiversity in the farmland, compared to conventional farming [e.g. 29].

The use of genetically modified organisms (GMO) in agriculture, which is not permitted in organic agriculture, has great benefits. It often leads to an increased yield (reduced amount of land needed per ton yield) and a reduction in the use of pesticides. However, negative influences from GMOs on the environment may occur: the spread of GMOs threatens the natural biodiversity, and GMOs can pass on their characteristics to related crops, which may be harmful.

Fish production forms a special kind of 'agriculture', which puts specific pressures on the local aquatic ecosystem. Each of the two fishery systems, wild fishery and fish farming, has specific environmental impacts. Fisheries that harvest wild fish often lead to problems of overfishing and direct aquatic ecosystem damage, e.g. by disruption of the seabed with trawlers. In fish-farming systems, antibiotics and hormones are applied, which partly end up in the natural ecosystem. Fish excretions and uneaten feed lead to eutrophication, and pathogens like the salmon lice easily spread from fish farms into the natural environment. Moreover, fish farms sometimes disrupt valuable coastal areas.

Figures 3.3a-b show the average GHG emissions (in CO_2 eq) and corresponding standard deviation for the full life cycle of all food groups (per kg product). These figures were linked to food consumption data in order to evaluate the environmental impact of Dutch diets (chapter 4). As described above, meat and cheese cause the highest GHG emissions per kilogram of food. However, variation within food groups was sometimes large; for example, within the food group 'meat', beef had a much larger impact than chicken. Of the drinks (expressed per kg), production of dairy drinks involved the highest GHG emissions [30].

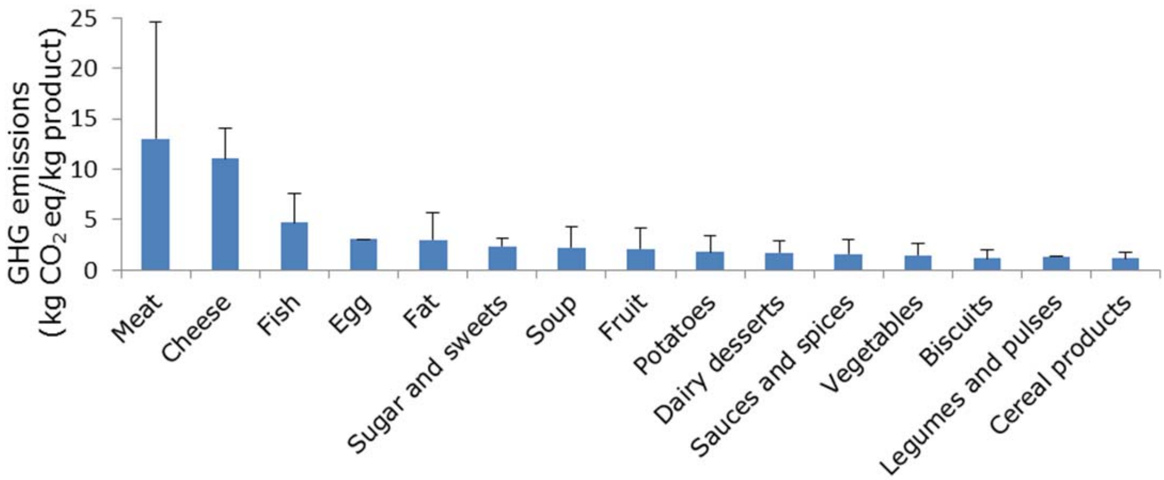

Figure 3.3.a. Average GHG emissions (in kg CO_2 eq/kg product) for different food categories in the Dutch diet. Values are means, with their standard deviations represented by vertical bars [30].

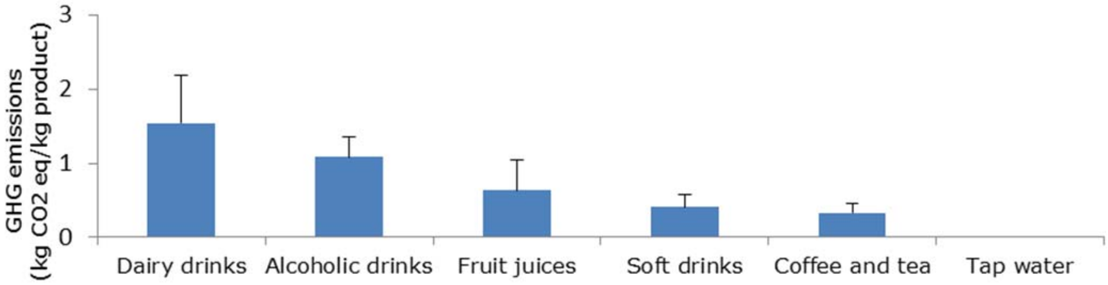

Figure 3.3.b. Average GHG emissions (in kg CO_2 eq/kg product) for different drink categories in the Dutch diet. Values are means, with their standard deviations represented by vertical bars [30].

3.2 Environmental impacts per life cycle stage

3.2.1 Food production and processing phases

For many food products, the primary production phase (agricultural phase) is the phase that causes the largest environmental burden (see Figure 3.4). For example, the primary production phase usually requires a large area of land, high inputs of water, energy and fertilizers, and it causes high emissions of GHG, nutrients and pesticides into the environment. The type and intensity of the different environmental impacts differ strongly per food group. Therefore, an overview of the environmental issues in the primary production stage is discussed separately for each of the main food groups.

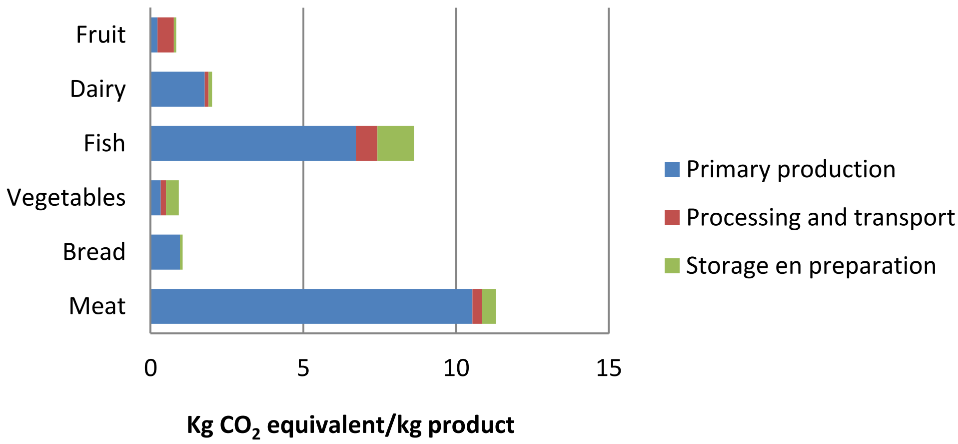

Figure 3.4. Contribution of three different life cycle stages to the total emission of greenhouse gasses (expressed in CO_2 eq) for different food groups, the food at P50 of a certain food group is chosen for this figure [25].

The discussion on the environmental impacts of food production below is based on LCA studies on various foods and food groups and studies that evaluate impacts on sector level with input-output analyses. Most of the reviewed literature focusses on the EU or country level.

Meat
It is generally accepted that meat production has the largest environmental impact of all food groups, particularly beef [31]. The primary production stage of meat, including the production of feed, has a highly significant environmental impact. Feed production, e.g. soy, is the primary contributor to land use and land transformation, and covers almost half of the GHG emissions related to meat production [32]. The main sources of GHG emissions due to feed production are fertilizer production and use, concentration of feed, and use of diesel and electricity. In addition, eutrophication, acidification and pesticide use are issues in feed production, with a severity comparable to crop production for human consumption. However, in addition to feed production, other issues related to animal husbandry lead to environmental pressures: methane excreted by animals (particularly cows, that have a digestive system giving high methane emissions) contributes to global warming; emissions from manure (ammonia) contribute significantly to the acidification and eutrophication of the soil and surface water; and the energy use at farms.

Extensive beef production appears to result in lower GHG emissions per unit produced and per unit of land needed than intensive production [33]. For extensive as well as intensive beef production, it should be noted that there is a complex interconnected relationship between beef and milk production, with surplus calves and meat from culled dairy cows being an important contributor to beef production. Almost half of EU beef production is derived as a co-product of the dairy sector [34].

The overall environmental impacts of pork, lamb and chicken meat are lower than that of beef, but still relatively high. For pigs, the feeding regime in the pig-rearing stage is the main contributor to environmental impacts, principally due to the use of fertilizers in the cultivation of cereals used in the pigs' diet [35]. In this stage of pork production, the eutrophication impacts are especially significant, mostly due to leakage of the phosphates and nitrates from pig manure to the water. The farm's facilities (heating for piglets and illumination on the farm) is a large factor in energy consumption. The processing of meat at the slaughtering stage, including transport and packaging, has comparatively low impacts [36].

Fish
Several studies apply LCA techniques to fish production and processing. These all conclude that fish production (whether wild fish or fish farming) is the life cycle stage that is the most significant source of environmental impacts, also for processed fish products like 'fish fingers' [e.g. 37, 38, 39]. The energy demands of different fishing methods differ widely. Thrane [38] suggests that there is a 15-fold difference between the most energy efficient fishing method used in Danish fishery (purse seining) and the least energy efficient fishing method (beam trawling). In the case of farmed fish, terrestrial land use for feed production also causes an environmental impact. It must be recognized that conventional LCA does not cover some of the critical environmental impacts of fisheries and fish farming, notably their impacts on fish stocks and marine (seabed) ecosystems. Other issues related to fish farming not covered by LCA are landscape impacts, the escape of fish

and interactions with other fauna, the spread of pathogens, and the use of antibiotics [28] [40].

Meat substitutes
Different foods can serve as a protein source (and as a source of iron, zinc, vitamin B12) for humans and thereby serve as a substitute for meat in the daily menu. Protein rich vegetables such as pulses and soy beans (including tofu and tempeh made from soy) are well known vegetarian products, but also 'vegetarian burgers' etc. based on e.g. fungi, chickpeas or dairy exist.
Analyses in e.g. the PROFETAS project on the potential environmental impacts associated with 'novel protein foods', derived principally from pea flour, support the idea that vegetable protein sources have lower environmental impacts than animal protein sources when assessed on the basis of a similar amount of protein consumed [41]. The PROFETAS analysis found that environmental impacts of protein consumption would be significantly lower for all impact categories considered, including land use, water use, eutrophication and pesticide use as well as global warming and acidification, if the protein was in the form of these novel protein foods than if it was in the form of pork. Furthermore, locally, legumes (beans and peas) can improve soil by nitrogen fixation.

Broekema & Blonk [42] performed a comparison of the GHG emissions, land use and fossil fuel use of 12 different meat-replacing products available on the Dutch market. The scores of the different products with regard to GHG emissions and land use are comparable and are all lower than for meat, except for products based on milk protein, the latter having relatively high GHG emissions and land use impacts, comparable to meat production [43].
For soy, and meat substitutes that are based on soy, land transformation is a main issue. During the last decades, in many areas, particularly Southern America, tropical forests have been (and are still being) removed to make way for soy plantations. Luckily, several governments and organisations now recognize this problem, which has resulted in the establishment of the Round Table on Responsible Soy Production (RTRS). RTRS is a civil organisation that promotes responsible production, processing and trading of soy on a global level (www.responsiblesoy.org). Globally, an increasing share of soy production is currently RTRS-certified, and the livestock farming sector is starting to look for more sustainable alternatives to soy as feed.

Dairy products
As an illustration, the products 'milk' and 'cheese' are discussed in this section. The impacts of other dairy products, like yoghurt and ice cream, are mainly defined by the primary production of milk, and therefore are largely comparable to the impacts of milk.

Milk
Results of the input-output based assessment of environmental impacts carried out in the EIPRO project suggest that the EU milk production causes 5% of all the eutrophication impacts in Europe [44]. A number of milk LCA studies [e.g. 45, 46, 47] highlight two particularly important stages of the milk production and consumption systems: i) primary production; and ii) packaging and transport. The two less significant

stages are processing and consumption. In the whole production and consumption system of milk, primary production is the largest contributor to global warming, acidification, eutrophication effects and fossil fuel consumption (e.g. natural gas for the production of synthetic fertilizer used for pasture and fodder crops, diesel for tractors, and fossil fuel energy use on the farm).
The main environmental impacts of milk (and cheese) processing are the high consumption of water, the discharge of effluent with high organic loads, and the consumption of energy [48].

In the period 2008-2013, GHG emissions in the Dutch dairy farming sector were stable at around 1.25 CO_2 equivalent per kg of milk delivered. There was no clear upward or downward trend in GHG emissions per kg of milk for the period 2008-2013. Because of the increase in production volume in this period, the total emissions from the dairy farming sector increased from 14.5 to 15.5 megatons of CO_2 equivalents. If dairy processing is included, the total emissions in 2013 amounted to 17.1 megatons [49].

Cheese
The largest input to cheese is milk: 10 kg milk per 1 kg cheese is a typical ratio for hard (e.g. Gouda type) or cheddar type cheese [46]. Berlin's LCA study Berlin [46] shows that within the cheese production and consumption system, primary production contributes 94% to the global warming impact, 99% to acidification, and 99% to eutrophication. The impact of packaging production and transport is lower for cheese than for milk or yoghurt; however, the cheese production stage is more energy intensive than the equivalent stage in milk production [28].

Carbohydrate-rich foods
Generally, the basic carbohydrate-rich foods (maize, wheat, potatoes etc.) have a low GHG footprint, with the exception of rice, for which the production in paddies often requires irrigation and generates high levels of methane [50]. However, there are other environmental issues related to the production of carbohydrate-rich foods, i.e. fertilizer use, pesticides, and the use of irrigation water. Also, production of these foods in intensive monocultures worldwide has damaging effects on a range of ecosystem services [e.g. 51].
For both bread (wheat etc.) and potatoes, the agricultural stage of the life cycle contributes most to eutrophication [28, 32]. For potatoes, pesticide use (toxicity) is also a significant issue [52] (CBS Statline; visited 1 December 2015). Several LCA studies [53, 54] on bread production identify the primary production stage of bread as being of significant importance for almost all impact categories. An exception is the impact category of photo-oxidant formation, to which the processing stage (baking) contributes the most.

Fruit and vegetables
With regard to GHG emissions, robust and field-grown produce such as brassicas, root vegetables and the harder fruits (e.g. apples) generate relatively low impacts. Produce that is either fragile (e.g. lettuce and berries), grown in protected conditions (e.g. tomatoes grown in heated greenhouses), requires refrigeration (e.g. salads) or requires very rapid and energy intensive modes of transport (e.g. green beans, berries from

the Southern Hemisphere) are more GHG intensive. However, low GHG emissions may not always indicate an absence of other environmental impacts. While citrus fruit is not GHG intensive, the reliance on irrigation, which can exacerbate water stress in producing regions, can be an issue, while for bananas, pesticide use is an issue [55, 56]. Milieu Centraal developed a fruit and vegetable calendar (in Dutch: 'groente- en fruitkalender') indicating the environmental sustainability of fruit and vegetables, including seasonality (https://groentefruit.milieucentraal.nl/; visited 1 February 2016).

In the Netherlands, the types of fruit most often consumed are apples, bananas, mandarins, oranges, peaches, kiwifruit, grapes and strawberries. De Valk, De Hollander [25] show that the production phase contributes the most to all types of environmental impact. Fruit produced in tropical areas has a relatively large impact on acidification, mainly due to (sea) transport over large distances. Examples are bananas, grapes, kiwifruit and oranges. Growing fruit in heated greenhouses, which occurs for part of the strawberries consumed in the Netherlands, causes a relatively high GHG emission. The largest environmental burden of fruit consumption in the Netherlands is caused by bananas and oranges, due to the combination of impact per kg and the large quantities consumed [25].

A special group of vegetables is those grown in greenhouses, for example, tomatoes and cucumbers.
Stanhill [57] and Torrellas, Antón [58] analysed the energy requirements of various tomato production methods. The calculated energy demand varied from 1.5 MJ/kg for open-field cultivation in California to almost one hundred times this number, 137 MJ/kg, for greenhouse cultivation in South East England. Unheated systems, whether open-field or covered, all had energy requirements below five MJ/kg, so heating increases the environmental burden considerably.

Fats and oils
Of the two types of fats, animal fats and plant-based fats and oils (e.g. sunflower oil, palm oil). butter is the most commonly consumed animal fat. Butter is, to a certain extent, a by-product of dairy production, where it is a means of turning surplus fat into a sellable product. Milk is the main component of butter and so the information on milk is relevant. Realizing that butter production requires six times more raw milk than milk for household consumption, the primary production of milk is the most energy intensive part of the life cycle, responsible for the highest GHG emissions. Furthermore, considerable energy consumption is related to processing (heating and cooling) and refrigeration of butter. Deep-frying fats or oils are a special group of fats and oils, since with deep-frying, most fat is not consumed, but wasted or recycled (e.g. as fuel) after use. For a correct sustainability assessment, the treatment of used deep-frying fat should be considered.

For oils (particularly palm oil) in tropical areas, the issue of land use and land transformation (conversion of e.g. rainforests into agricultural land) is a major issue. Large areas of tropical forest and other ecosystems with high conservation values have been cleared to make room for vast monocultures of oil palm plantations – destroying critical habitats for many endangered species. In some cases, the expansion of plantations has led to the eviction of forest-dwelling people (www.WWF.nl, 2015; visited 1 December 2015). However, governments, producers and NGOs are aware of these issues and this has resulted in the establishment of a Round Table on Sustainable Palm Oil (RSPO). The RSPO is a non-profit association that brings together palm oil producers, processors and traders, consumer goods manufacturers, retailers, banks and investors, and environmental and social non-governmental organisations (NGOs) to develop and implement a global standard for sustainable palm oil (www.wwf.panda.org; visited 1 December 2015). A small but increasing number of RSPO member companies have been certified by the RSPO and their products now carry the RSPO label. In addition to land use, typical agricultural issues like pesticide use and fertilizers (energy use, eutrophication and acidification) are also relevant for oil producing crops.

Drinks (alcoholic and non-alcoholic)
The environmental significance of the production of drinks is, in general, not quite as high as that of food production, but it is not negligible. Packaging is a relatively important life cycle stage for many drinks, particularly when glass bottles are used [59]. Four product groups are discussed below in more detail: beer, wine, carbonated soft drinks and mineral water, and coffee.

Beer
In an LCA of Spanish beer conducted by Hospido, Moreira [60], production and transport of raw materials used in beer production (barley, hops) were found to contribute to over one third of the total climate change impact of the beer production life cycle. In addition, eutrophication is a significant environmental impact of the agricultural subsystem, linked to the release of nitrogen and, to a lesser extent, phosphorous, from the production and use of fertilizers. During primary processing, energy consumption has been identified as the most important environmental impact within the brewery, contributing to 30% of the global warming potential of the life cycle [60]. In a Dutch study, the impact of the brewery phase accounted for 45-50% of the total global warming potential [61]. Impacts of wastewater from brewing are most significant with respect to eutrophication potential [62]. Packaging of beer in non-returnable bottles or cans results in a significantly higher environmental impact (GHG emissions and energy use) than deposit bottles or draught beer [61].

Wine
Viniculture takes place in wine-growing regions around the world in moderate climate zones: Europe, Northern and Southern America, South Africa, Australia and New Zealand (www.wijn.nl/site/MARKTONDERZOEK/Auto_Wijninvoercijfers_CBS.php; visited 1 October 2015).
GHG emissions and energy use cause the largest environmental impact in wine production. The life cycle phases that contribute most to the environmental impact are the production of grapes, and packaging and transport [61]. The growth of grapes requires a relatively large surface area, causing a large impact on land use compared to other beverages. Within different types of wine, there is a large difference in the environmental impact. The differences are caused by variation in growth

and harvest, and by variation in the impact of different types of packaging and thus transport. The 'Bag-in-Box' packaging scores much better on fossil energy use and GHG emissions than the glass bottle [61].

The share of wine with a sustainability label like Fair Trade and EKO is growing in the supermarkets in the Netherlands. Outside of the Netherlands, several initiatives have been introduced for sustainable wine production, like the certificate for sustainable wine in California (www.sustainablewinegrowing.org; visited 1 October 2015), and the Australian Wine Carbon Calculator that helps wine farmers in the analysis and reduction of their carbon footprint (http://www.wfa.org.au/entwineaustralia/carbon_calculator.aspx; visited 1 October 2015).

Carbonated soft drinks and mineral water
The results of e.g. the EIPRO project suggest that the soft drink sector is environmentally significant: the study attributes 0.9% of Europe's global warming impacts to 'bottled and canned soft drinks', as well as 1.2% of its photochemical ozone creation potential, 0.8% of its eutrophying emissions, and 0.9% of its acidifying emissions.
One of the most important ingredients of soft drinks is sugar, which mainly originates from sugar beet and sugar cane. Sugar beet grown in Europe usually does not need any irrigation; however, sugar cane in e.g. Australia often does, where the quantity of water pumped has a very large influence on energy consumption [63]. Other impacts related to the primary production of sugar are eutrophication and pesticide use. The agricultural stage of sugar production is the main contributor to the environmental impact of beverages [61]. The primary environmental impacts related to sugar processing are energy and water consumption [64]. It must be recognized that conventional LCA does not cover a critical environmental impact of sugar processing, which is the use of limestone in the sugar purification process. Limestone of good quality needs to be mined and transported over large distances.
The main environmental impacts of bottled (mineral) water are associated with transport and packaging.

Coffee
Cultivation of coffee and preparation by the consumer are the most significant stages in the life cycle of coffee [65]. There is however a large difference in the environmental impacts for different types of coffee cultivation [66]: the traditional method which is an 'integrated agro-forestry system' uses little agrochemicals, whereas the sun-grown approach involves high use of agrochemicals, but also gives higher yields per hectare. Also, there are different ways of processing that cause different types of environmental impact. The traditional 'dry' manner of transforming coffee berries into green coffee has a lower environmental impact than 'wet' processing, which consumes 67 litres of water per kg coffee and generates large volumes of effluent [66].

There are a number of sustainability labels for coffee; almost half of the coffee consumed in the Netherlands is labelled in this way (http://www.oxfamnovib.nl/ons-doel.html; visited 1 February 2016).

Processed/composite foods and snacks
This is a very broad group of products, with many different ingredients and processing methods. In general, the environmental impact of processed/composite foods and snacks largely depends on i) the environmental impacts of the different ingredients and ii) the additional impacts related to the processing of the basic ingredients into composite products, mostly energy use. Energy use in processing factories varies largely between the different food groups and industries; it is beyond the scope of this report to describe the different processing industries in detail. As an example, tomato ketchup is one of the processed foods that has been studied in detail using LCA. The results provide some indication of the relative significance of life cycle stages other than primary production. The conclusion of the study is that both processing and packaging of tomato ketchup make contributions to the product's global warming impact that are at least as great as the contribution from agricultural production [67]. This conclusion does not apply to all processed foods, but in general, the relative contributions of the processing and packaging stages to global warming for this food group are higher than for unprocessed foods.

3.2.2 *Transport and retail phases*
In general, the transport and retail phases of food products have a relatively low contribution to the total environmental impact of products, although transport by air has a significantly higher per-kilometre impact than transport by truck, train or ship; one kilometre of air transport causes an average of 7-11 times more CO_2 emissions than one kilometre of transport by train (https://www.milieucentraal.nl/vervoer/; visited on April 18 2016). Also, the smaller the distance between production and consumption locations, the lower the use of fossil fuels and the emission of GHG related to transport.

For some product groups, transport is relevant when determining the environmental impact of the life cycle. Compared to other products, the transportation phase is relatively important for fresh products (that require transport on the day of production), like bread or milk. Several LCA studies [53, 54] on bread production identify the transportation stage as having an influence on almost all environmental impact categories. A number of milk LCA studies [e.g. 45, 46, 47] highlight transport as an important stage of the milk production and consumption system, however, the impact of transport in the life cycle of milk is highly dependent on the distance between dairy farms and factories.

For potatoes, in addition to the primary production phase, storage contributes significantly to the total energy demand in the potatoes' life cycle [32]. This is also true for storage of fresh fruit and vegetables. For frozen vegetables, storage during distribution, retail and in consumers' homes are main contributory stages to total energy demand [68].

3.2.3 *Consumer phase: food preparation and storage*
Many LCA analyses only include the production phase or the production and processing phases of a food product's life cycle. Little information is available about the environmental impacts of foods' post-retailing [28]. However, it has been demonstrated that the phases of storage and preparation of foods by consumers usually have a minor contribution to

the total environmental impact. Exceptions may be the food groups of which the environmental impact of the production stage is relatively low compared to other food groups, and/or products that require a long cooking (or other type of heating) time. This can e.g. be seen in Figure 3.4 [25]. The green parts of the bars indicate the contribution of the preparation stage to the total GHG emission of different food groups. It is clear that the contribution of the preparation stage to the total GHG emission is relatively low compared to the contribution of the production stage in all cases, and in some cases also compared to that of the processing and packaging stage.

Different types of preparation differ in their environmental impact. Baking and frying have a higher environmental impact per unit of time due to the relatively high temperature. However, for some products/recipes, the total amount of energy used may be higher in cooking, due to the relatively long boiling time of some specific products. For example, baking requires on average 600-3500 watt per kg product, whereas boiling, on average, requires only 550 watt per kg product, but this value can easily be doubled or tripled for long boiling times [69].

Preparation is also a relatively important component of the environmental impact of some types of drinks. Particularly for coffee, besides the production stage, the preparation by consumers mainly determines its environmental impact; this contributes 30-40% to the total emission of CO_2 equivalents. The preparation of one litre of espresso coffee requires more energy than the same amount of filter coffee [61].

The environmental consequences of storage depend on the time the product is stored for, the type of storage and the storage devices used. Ambient storage requires no energy, as opposed to the considerable energy use required by refrigerated and frozen storage [69].

3.2.4 Food losses and waste

We can distinguish unavoidable and avoidable food losses and waste. Unavoidable food losses and waste are the inedible remnants of agricultural products like peels, bones, shells etc. Worldwide, almost one third of the edible food produced for human consumption is wasted, while this could be avoided [70]. A variety of definitions exist for what is considered ‘food waste’. In addition, different studies use different methods, which can affect estimates of food loss and waste. Food losses and waste take place in every phase of the life cycle, from the primary production phase until the consumption phase.

The most recent estimates for food loss and waste in the EU-28 (in 2012) are from the EU-FUSIONS project, including both edible food and inedible parts associated with food [71]. Around 173 kilograms of food is wasted per person in the EU-28 per yr. The total amounts of food produced in EU for 2011 were around 865 kg / person. This would mean that in total we are wasting 20 % of the total food produced. Food waste estimates in the different phases of the food chain are 18 kg per person for the primary production (10% of total food waste), 33 kg for the processing (19% of total food waste), 30 kg for the retail and food service (17% of total food waste), and 92 kg for consumer phase (53% of total food waste) (see figure 3.5) [71]. In the Netherlands, between 2009 and 2013 the yearly amount of food wasted did not change [72].

Van Westerhoven [73] calculated that there is an avoidable food waste of 47 kg per person per yr in the consumption phase for the Netherlands. Foods wasted the most per person per year in descending order (based on weight), are dairy (milk type), vegetables and fruits, potatoes, rice, pasta, bread, meat, and cheese, fats and sauces [73] (see figure 3.5, in bar chart). Of the avoidable waste, 27% consisted of prepared foods. This waste leads to relatively higher energy costs than foods wasted earlier on in the food chain, as energy has already been used for transport, packaging and preparation of the food. The average kilogram of food wasted by the consumer equals a waste of 1.3 liters of gasoline [74] .

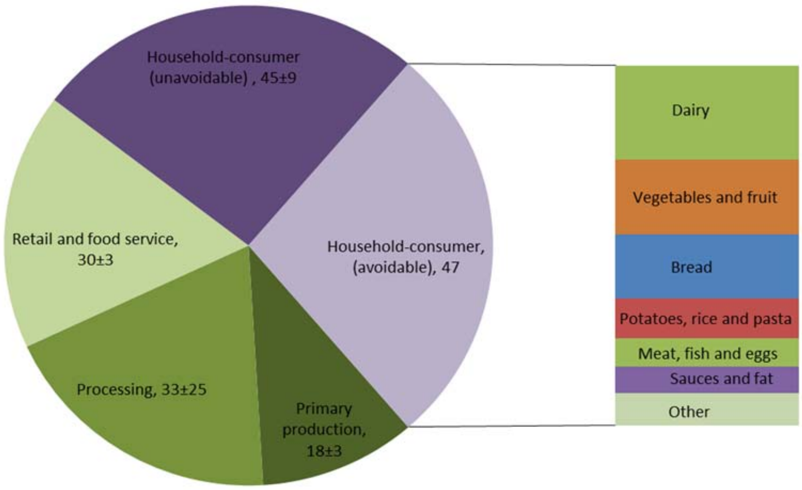

Figure 3.5. In pie chart: Food waste in the food supply chain in the EU-28 in 2012 (in kg per person with 95%confidence interval). Adapted from: [71].
In bar chart: Avoidable food losses through the rubbish bin and sewer in the Netherlands (in kg per person per year), main foods. Adapted from: [73].

Table 3.2. Overview of the main environmental impacts of different food groups during the different life cycle stages.

Food group	Agricultural production	Processing	Transport and retail	Consumer phase Preparation/ storage/waste
Carbohydrate-rich foods	Phase with largest impact, but compared to other food groups relatively low impact on GHG emissions and energy use. Exception is rice. Other main issues are fertilizers, pesticides, irrigation water, soil degradation and local biodiversity loss caused by monocultures.	Photo-oxidant formation (ozone layer disruption) during baking process of bread.	Transport has a significant contribution to GHG emissions, particularly for fresh products (bread).	Waste by disposal of bread (and prepared cereals) is significant. For potatoes, and, to a minor extent, grain products, the preparation stage forms a significant part of the total impact.
Fruit and vegetables	Low GHG emissions for robust and field-grown produce. Produce that is either fragile, or grown in protected conditions, is much more GHG intensive. Tropical crops and tomatoes: irrigation can exacerbate water stress in producing regions. Pesticide use is an issue for many crops/fruit.	Crops that require refrigeration (e.g. lettuce) are energy intensive. Food losses during processing and storage may be relatively large for fragile and/or tropical crops.	Crops that require very rapid and energy intensive modes of transport are energy intensive. Relatively large losses during retail and transport. Crops consumed in season and/or transported by sea or land cause relatively low GHG emissions.	Waste at consumer stage is relatively high, but large differences in losses: fragile fruit and crops have relatively large losses compared to robust fruit and crops. For vegetables, the storage and preparation stage forms a significant part of the total impact.

Food group	Agricultural production	Processing	Transport and retail	Consumer phase Preparation/ storage/waste
Dairy products	Primary production stage has the largest environmental impact. High environmental impact across a range of indicators (GHGs, water use, land use, local biodiversity, eutrophication, acidification).	High consumption of water; discharge of effluent with high organic loads. High consumption of energy.	Transport may be significant for total GHG emissions, depending on distance of dairies to retail.	Waste at consumer stage relatively high due to limited shelf life.
Meat products	Typically high environmental impacts across a range of indicators. Feed production is the primary contributor to land use, and covers almost half of the GHG emissions. Animals excrete methane which contributes to global warming. Emissions from manure (ammonia) largely contribute to the acidification and eutrophication potential, and energy use at farms is high. Beef has the largest environmental impact of all meat types. Animal welfare is an issue.	Processing at slaughtering stage has relatively low environmental impacts.	Refrigerated transport may be significant for total GHG emissions.	Refrigerating and preparation have relatively high energy demands and cause significant GHG emissions.

Food group	Agricultural production	Processing	Transport and retail	Consumer phase Preparation/ storage/waste
Fish	Stocks of many fish species depleted, overfishing. Damage to sea(bed) and coastal ecosystems. Aquaculture causes environmental problems concerning pesticides, antibiotics, pathogen spread and eutrophication.	Cooling and freezing (on board) cause high energy use and emissions of ozone depleting substances.	Sea ships are energy intensive and cause large amounts of GHG emissions.	-
Meat substitutes	Issues are related to the primary production of the different ingredients. Plant-based products are relatively low in environmental impacts compared to dairy-based products. See also "Consumption".	-	-	Environmental impacts of protein consumption when consumed as meat substitutes are lower than when consumed as meat, for land use, water use, eutrophication and pesticide use, as well as global warming and acidification.
Fats and oils	For butter, the primary production of milk is the most energy intensive part and it also has the highest GHG emission of the total production system. For tropical oils, the issue of land use and land transformation (e.g. destruction of rainforest) is a major environmental problem.	For butter, considerable energy consumption is related to processing (heating and cooling) and refrigeration.	-	-

Food group	Agricultural production	Processing	Transport and retail	Consumer phase Preparation/ storage/waste
Drinks (alcoholic and non-alcoholic)	Primary production of ingredients (e.g. barley, sugar) cause one third of total GHG emissions and energy use. Irrigation, eutrophication and pesticide use are other environmental issues.	Processing stage is relatively important concerning energy use and photo-oxidant formation (ozone depletion). Manufacturing of packaging materials is relatively energy intensive.	Transport stage relatively important concerning GHG emissions.	Energy use for refrigeration relatively high in hospitality sector.
Convenience foods and snacks	Issues are related to the primary production of the different ingredients.	Processing stage relatively important concerning energy use (e.g. heating, cooling).	Variable	Usually not much loss in consumption phase due to long preservation times.

3.3 Key findings

- For many food products, the production phase (agricultural phase) causes the largest environmental burden. For example, the production phase usually requires a large area of land, high inputs of water, energy and fertilizers, and it results in high GHG, nutrients and pesticides emissions. The type and intensity of the different environmental impacts differ strongly per product group.
- The different ‘hotspots’ concerning environmental burden per food group and per life cycle stage are summarized in Table 3.2. In general, meat production, particularly beef, has a large impact on almost all environmental impact categories. In addition, cheese production has a large impact per kg of food, and fruit production especially on water use.
- In general, the transport and retail phases of food products have a relatively low contribution to the total environmental impact of products, although transport by air has a significantly higher impact per kilometre than transport by truck, train or ship. Nonetheless, for some product groups, transport is relevant when determining the environmental impact of the life cycle, i.e. for fresh products, bread or milk, that require transport on the day of production.
- Food losses and waste take place at every phase of a food’s life cycle. The consumer phase results in the largest losses. The yearly amount of avoidable food waste in the Netherlands in this phase was estimated to be 47 kilos per person in 2013. Dairy, vegetables, fruit, potatoes, rice, pasta and bread are most often wasted.

4 Environmental sustainability of Dutch food consumption

4.1 Introduction/methodology

In this section, we focus on estimates of GHG emissions as well as on land use for daily diets published in international peer reviewed publications. In this chapter, we focus on the calculations performed with Dutch food consumption data, either from food consumption surveys or from an epidemiological cohort study, and compare our data with calculations performed in other European countries.

For the evaluation of the GHG emission caused by the Dutch diet [30, 75] LCAs were performed for the 254 most commonly consumed food items (Blonk Consultants data set, version 2012). The LCA included primary production, processing, use of packaging, transport, storage, preparation, cooking, and incineration of waste products. The amounts of food wasted were considered in the mass balance of the LCA analyses. Emissions and avoided emissions due to incineration and composting of food waste were not included. Foods with the highest (frequency of) consumption in the Dutch National Food Consumption Survey (DNFCS) 2007–2010 were selected for the LCA analyses [30]. An experienced dietitian extended the LCA-based GHG emissions database for the 254 most frequently consumed foods to the other reported food codes in the DNFCS 2007–2010. Extrapolations were based on the ingredient compositions of the foods, similarities in production system, and similarities in type of food and variety. For example, for solid cheese, the available GHG value for a certain type of commonly consumed solid cheese with was applied to all other types of solid cheese.

4.2 Environmental sustainability of daily diets

The GHG emissions of *daily* diets for children and adults range between 3 kg CO_2 eq for girls and 5 kg CO_2 eq for men, with boys and women falling in between [30]. Daily GHG emissions due to food consumption are about 30% higher for adult men than for women [30], which can be explained by men's higher energy needs.

Considerable differences between individuals may exist (see Figure 4.1). For example, the GHG emissions per day for men can vary between 3.2 and 6.5 kg.
Land use for daily diets shows a similar distribution across the different age-gender groups, ranging from a median of 3 m^2*year/person-day for girls to a median of 5 m^2*year/person-day for men.

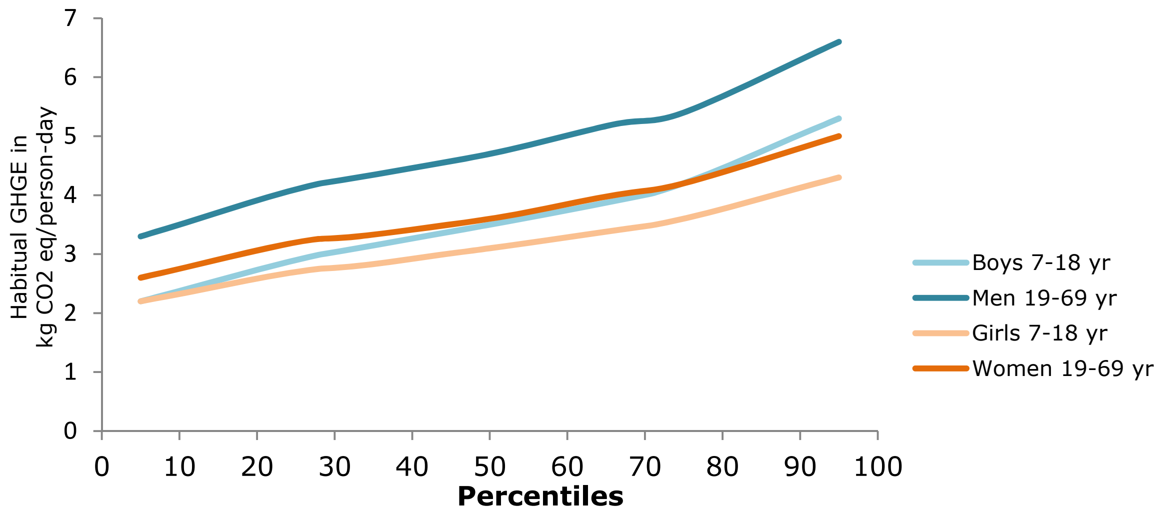

Figure 4.1. Mean habitual GHG emissions of daily diets of the Dutch population aged 7-69 yr. (DNFCS 2007-2010), weighted for socio-demographic factors, season and day of the week (n=3819).

GHG emissions for a day's consumption highly correlates (r=0.77) with daily energy intake (see Figure 4.2, data from the EPIC cohort). At a similar level of dietary energy intake, environmental impact of diets may vary considerably because of different food choices (see Figure 4.2 and Monsivais, Scarborough [76]). For example, diets containing 10 MJ per day may vary from 2 to 7 kg CO_2 equivalents per day. In addition to energy intake and age and gender, a higher environmental impact of the usual diet is associated with smoking and higher activity levels [75]. Educational level, waist to hip ratio, and body mass index (BMI) differed only slightly between the highest and lowest quartiles of GHG emissions and land use [30].

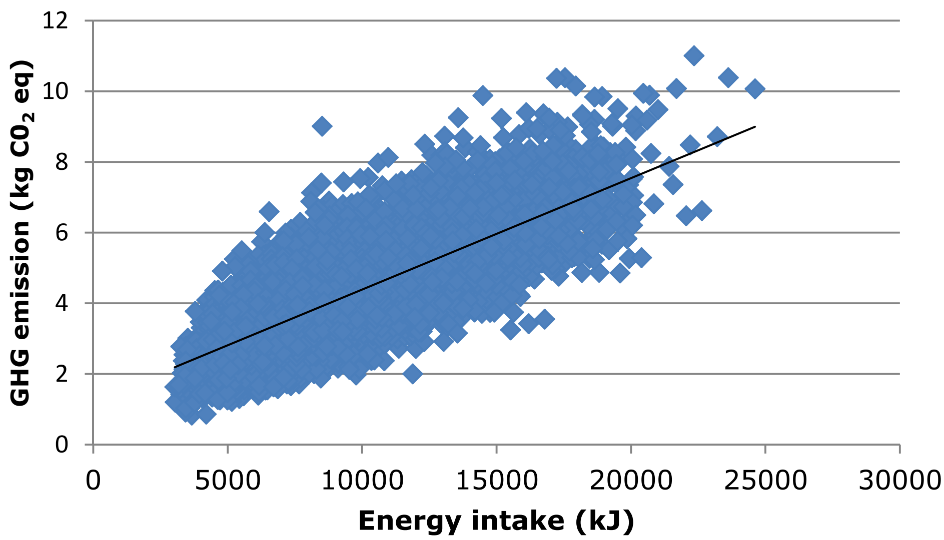

Figure 4.2. Correlation between daily energy intake and GHG emission (in kg CO_2 eq) of daily diets (data from EPIC-NL cohort study).

To determine the most important food groups for daily GHG emissions, we aggregated EPIC-Soft food groups: meat, fish and egg consumption were combined; potatoes, vegetables, legumes, pulses and fruits were combined; fats, soups and sauces were combined; and sugar, sweets and biscuits were combined. Dairy products were classified as dairy drinks, dairy desserts and cheese. Drinks were aggregated into two groups: drinks with and drinks without alcohol (Figure 4.3; Temme, Toxopeus [30]).

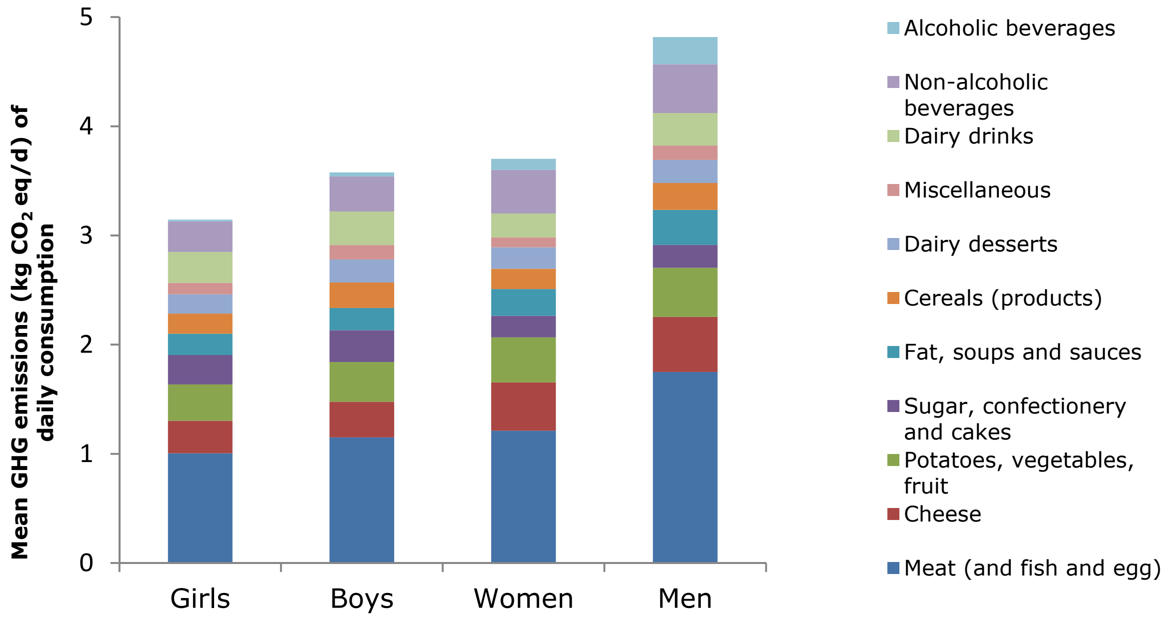

Figure 4.3. Mean GHG emissions for a day's consumption (in kg CO_2 equivalents (CO_2 eq)/d) for Dutch girls and boys (7-18 yr.), women and men (19-69 yr.), and major contributing sources [30].

About 40% of the GHG emissions of daily diets stemmed from meat and cheese consumption, with a similar percentage in girls, boys, women and men (Figure 4.3). For all age and gender groups, the contribution of drinks (including dairy drinks) to daily GHG emissions was approximately 20%. For children about half of this stemmed from dairy drinks; for adults this was about a third. Other major contributing drinks were soft drinks in girls and boys (about 0.30 kg CO_2 eq), brewed coffee and tea and soft drinks in adults (0.40 kg CO_2 eq for women and 0.45 kg CO_2 eq for men) and alcoholic beverages in men (0.25 kg CO_2 eq). Potatoes, vegetables and fruits contributed approximately 9% to the GHG emission of daily diets [30]. In the category meat, fish and eggs, GHG emissions are predominantly attributed to meat consumption, since the average Dutch fish and egg consumption is relatively low [77]. Mean GHG emissions from fish consumption are estimated to be 0.09 kg CO_2 eq per person per day, which is 2% of the total daily GHG emission resulting from food consumption [40]. However, with regard to fish consumption, other direct environmental indicators such as overfishing, bycatch, and disruption of coastal ecosystems need to be considered as well.

During the day, the GHG emission load of food consumption is highest at dinner and for in between meal consumptions (i.e. snacks and drinks). More than half of the total daily GHG emissions relate to food consumed at dinner, with meat (and especially beef) being the largest contributor (65%; Figure 4.4, [78]). The GHG emissions related to the consumption of beverages are mainly caused by consumption in the evening (classified in the group of snacks). Per day, a lower intake of animal-based foods will reduce GHG emissions with 0.3 kg CO_2 equivalents (for a 37 gram lower intake of pork or a 27 gram lower intake of cheese). Not drinking or replacing sugar or alcohol containing drinks by tap water will reduce GHG emissions by, on average, 0.3 kg CO_2 equivalents for children and up to 0.7 kg CO_2 equivalents for men.

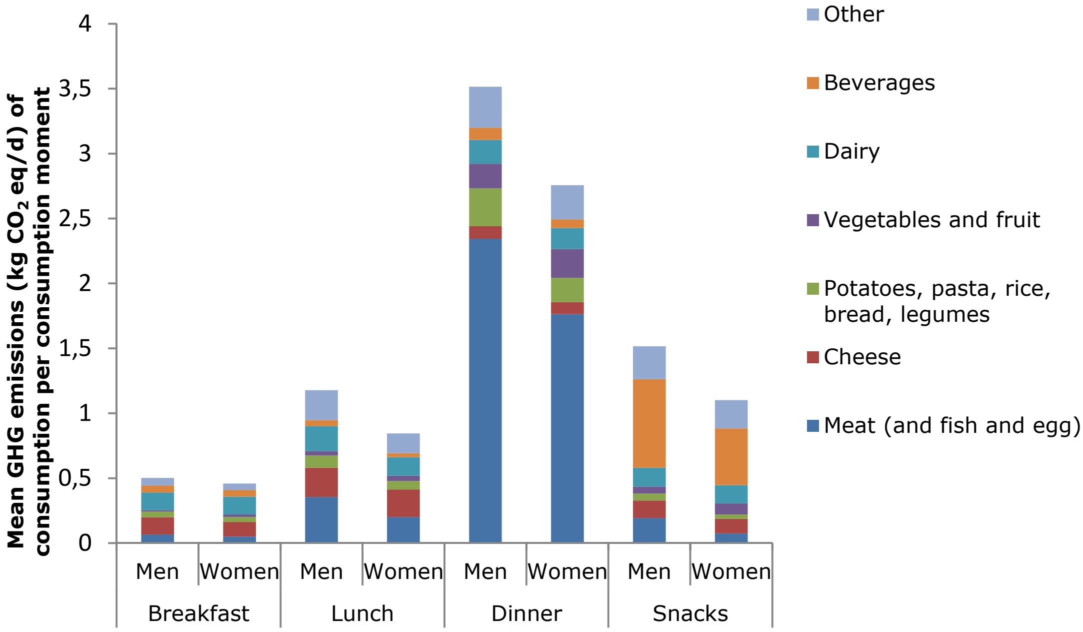

Figure 4.4. Mean GHG emissions (kg CO_2 eq) of food groups during different consumption moments for adult men and women, with a dietary pattern high in GHG emissions.

When stratifying the population according to a diet low, intermediate and high in GHG emissions, individuals with high GHG emissions from their diet consumed more (in quantity of foods and especially drinks) than their counterparts of similar sex and age with diets causing low GHG emissions. In addition, the types of foods eaten and types of beverages drunk differed. The main differences found between high and low GHG emissions diets are meat, cheese and dairy consumption, as well as in soft drinks (girls, boys and women) and alcoholic drinks (men). Of these, that of (type of) meat consumption determines the differences in GHG emissions the most; GHG emission load caused by the consumption of meat more than doubled in the high-GHG emissions dietary pattern. In the intermediate-GHG emissions group, animal-based foods (meat, cheese and dairy) constituted around half of the total dietary GHG emissions; in the high-GHG emissions dietary pattern that is 60% [30]. Although not calculated, it is expected that results for land use will be similar.

When stratifying the population for social economic class (SES), GHG emissions differed for specific food groups. For a day's consumption, GHG emissions were similar in the low, intermediate and high SES groups. Although the total amount of meat consumed was lower in the high SES group compared to the low SES group, the consumption of beef was higher, especially in men.
In the high SES group, GHG emissions due to the consumption of vegetables and fruiting vegetables (+25%), fruit juices (+33%) and fish (+31%) were higher compared to the low SES group. Among men, the GHG emissions due to soft drinks was 60% lower in high versus low SES groups. These differences may indicate a need for different approaches to lower the environmental impacts of diets of high and low SES groups [79].

The estimates of GHG emissions for the general population reported above are in line with previous research based on LCA and individual food consumption data. Current average GHG emissions due to food consumption in Europe are estimated to be between 4.1 and 4.2 kg CO_2 eq/day in the Netherlands (previous estimate) and France, and up to 7.4 kg CO_2 eq/day in the UK [80, 81]. In the UK study [81], diet GHG emissions were standardised to a 2,000 kcal daily diet (the level used for guideline daily energy intake for adults in the UK).

Current estimates for average land use due to food consumption range from 5.5 to 5.8 m^2 per person per day for the average adult German [82] and UK diet [83]. This is comparable to the average diet in the Netherlands (DNFCS 1998), i.e. 5.3 m^2 per person per day, calculated by van Dooren, Marinussen [84] and is somewhat higher than the estimated 4 m^2 per person per day for the Dutch EPIC cohort. For Dutch young females, average land use due to food consumption was estimated to be 3.8 m^2 per day (2013); this was 4.4 m^2 for an adult diet (DNFCS 2007-2010) [85] [86].

4.3 Environmental sustainability of diets with less meat and/or dairy

Animal-based foods (meat and/or dairy) are major contributors to environmental impacts. Therefore, many studies have focused on high vs. low meat consumers, as well as the effect of hypothetical scenarios of meat and/or dairy replacements. The latter may not reflect *true* differences in consumption behaviour between subgroups of the population with different dietary patterns. The scenario studies can only be used to suggest directions and magnitudes of certain changes, for example of changing from a meat and/or dairy-based diet towards a more plant-based diet.

In a UK population, the estimated GHG emission of daily food consumption was 7.2 kg CO_2 eq per day for people consuming more than 100 grams of meat a day, 5.6 kg CO_2 eq per day for people consuming 50-100 grams of meat per day, and 4.7 kg CO_2 eq per day for people consuming less than 50 grams of meat per day. Vegetarians (consuming no meat and no fish) and vegans (no animal-based products such as meat, fish, eggs, dairy or cheese) had the lowest GHG emissions for a day's consumption with 3.8 and 2.9 kg CO_2 eq respectively [81]. The analyses were adjusted for age and sex and standardised to provide 2000 kcal a day. An earlier cross-sectional study using dietary intake data from the National Diet and Nutrition Survey of British Adults, specifically focused on red and processed meat intake [87]. Habitual red and processed meat intake was 2.5 times higher for the 5% consumers with the highest meat intake, compared to the 5% consumers with the lowest meat intake. The expected reduction in GHG emissions if consumers with the highest intake would match the intake of people with a low meat consumption was 1.23 kg CO_2 eq per person per day [87].

Hallström, Carlsson-Kanyama [88] reviewed the available modelling studies. The estimated reduction in GHG emissions by lower meat consumption ranged from 20-35% on a daily basis [84, 89, 90]. Since the average Dutch diet accounts for 3-5 kg CO_2 equivalents per day, this corresponds to a reduction of 0.6-1.8 kg CO_2 equivalents per person per day. From modelling studies for the Dutch adult population, it has been shown that replacing 30% of meat and dairy (including cheese) by plant-based foods, the estimated GHG emissions would be reduced by 14%. If all meat and dairy products were replaced by plant-based foods, a reduction up to 47% could be achieved compared with current dietary patterns [86] (see Figure 4.5). The change towards a lower meat and dairy consumption has also been studied on a European and global scale.

Westhoek, Lesschen [91] examined the large-scale consequences in the European Union of replacing 25–50% of animal-derived foods with plant-based foods (mostly cereals), assuming corresponding changes in production. They found that reducing the consumption of meat, dairy products and eggs in the European Union by 50% would result in a 25-40% reduction in GHG emissions per capita, a 23% reduction in use of (crop)land for food production, and a 40% reduction in nitrogen emissions. On a global level, Tilman and Clark [92] estimated per capita GHG emissions for five diets: 2009 global-average, 2050 global income-dependent, Mediterranean, pescetarian, and vegetarian. The environmental impacts of these diets were based on data from 120 publications, detailing 555 LCAs on GHG emissions for a total of 82 food items. All three alternative diets could reduce emissions from food production to below those of the projected 2050 income-dependent diet, with per capita reductions being 30%, 45% and 55% for the Mediterranean, pescetarian and vegetarian diets, respectively. The vegetarian and pescetarian diets, but not the Mediterranean diet have lower per capita GHG emissions than the 2009 global-average [92].

The reductions found are mainly dependent i) on the quantity and type of meat included in the diet and ii) on the environmental impact of the replacement foods [88]. The amount of red meat and especially ruminant meat (e.g. beef and lamb/sheep) seems to be a decisive parameter for environmental impact estimates. For example, the replacement of all beef by poultry and pork can reduce the GHG emissions by up to 35%, whereas moderate reduction (up to 20%) in total meat intake (including poultry) seems to have a negligible effect [88]. In the modelling studies, diets without meat and dairy or vegan diets (without any animal foods) held the largest potential for GHG emission reduction (by 25-55%) [88]. The reduction of land use through lower meat and dairy consumption may be as large as 55% (in vegan diets). However, complete avoidance of animal-based foods might not be the most optimal solution both from an environmental ([93] [91] and human health point of view [30, 86]. For land use, Van Kernebeek et al. [93] and Westhoek et al. [91] indicated from scenario studies that there is an optimal point for meat(protein) consumption. Diets without any animal-protein foods even had a slightly higher land use compared to diets containing a modest amount (5-30%) of animal protein. This is because products that cannot be consumed by humans, such as straw and grass are used as animal feed [93]. It is worth noting that even if we reduce the environmental impact of Dutch food consumption by eating less animal-based foods, this will not automatically result in a more environnmentally friendly Dutch food system (production and consumption). For this to be achieved, the type/method of food production will have to change.

The environmental impact of the replacement foods is of importance for the result of the modelling studies. Choosing meat substitutes like cheese and air-transported fruit and vegetables has a high climate impact [94] and may result in similar GHG emissions compared with the reference diets.

The results (observed diet and/or modelling studies) at different levels (national, EU, global) point towards lower environmental impacts of diets with less meat (and dairy). Lowering/replacing the consumption of dairy has been less studied than the lowering/replacing of meat consumption. In areas with affluent diets, dietary changes could play an important role in reaching environmental goals. This applies to most environmental impact categories (for example GHG emissions, land use and nitrogen balance), although for eutrophication and acidification, no studies on daily dietary patterns are available. Diets with less animal-based foods (especially ruminant types of meat) or replacement by plant-based foods are preferable from an environmental sustainability point of view. Although consensus exists about lowering meat consumption to reduce environmental impacts, the total removal of meat and dairy from the diet does not seem to be favourable when looking for an optimum in environmental impacts [93] [95], as well as with regard to micronutrient intakes at the population level. The combination of sustainability, health and safety aspects is described in the integration report of the knowledge synthesis “Wat ligt er op ons bord” (What is on our plate).

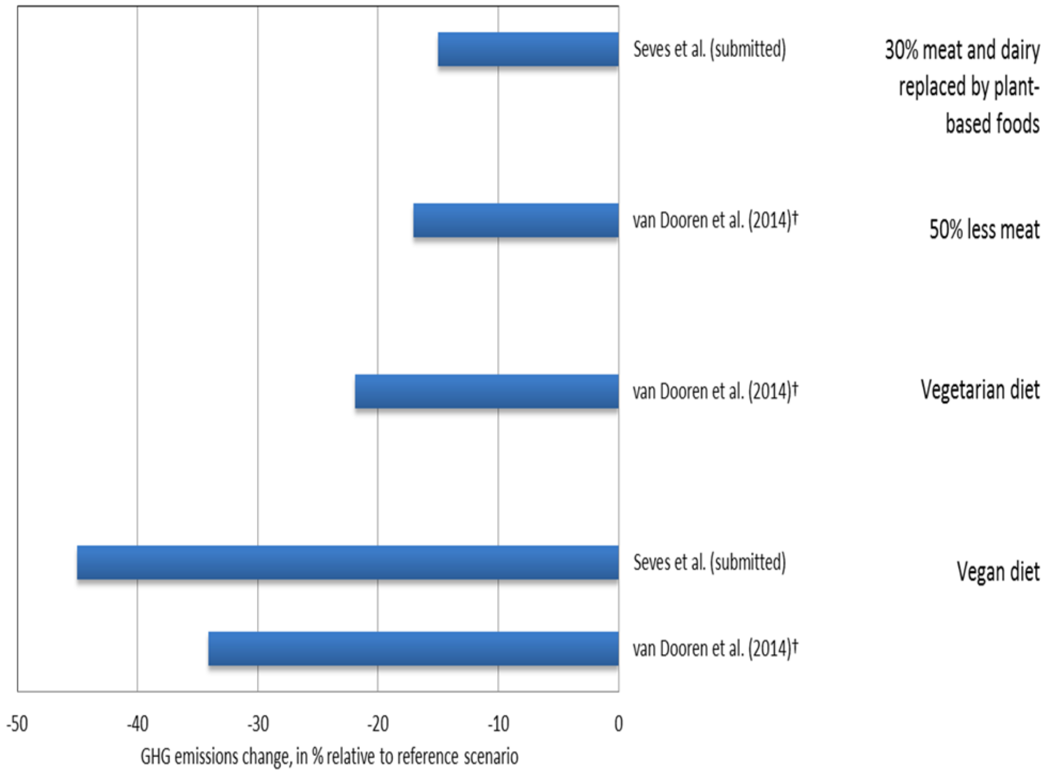

Figure 4.5. Impact of dietary change on GHG emissions of the Dutch diet, in % relative change in GHG emissions compared to the reference scenarios [84, 86]. The reference is food consumption in the Netherland in 2007-2010 [77].
† Based on consumption data of Dutch women only.

4.4 Environmental sustainability of diets complying with healthy diet guidelines

Food-based dietary guidelines express the principles of a balanced diet in terms of foods, and aim to reduce the prevalence of obesity and diet-related diseases. In 2015, the Health Council of the Netherlands published updated dietary guidelines, based on 29 systematic reviews on nutrients, foods and food patterns, and the risk of ten major chronic diseases in the Netherlands [96]. The Netherlands Nutrition Centre has developed food based dietary guidelines for the public, for men and women in all age categories [97] based on the dietary guidelines of the Health Council of the Netherlands [96] and age and sex specific dietary reference intakes (DRIs) for macro- and micronutrients. These guidelines were presented to the public in the form of a ‘Wheel of Five’ in 2016. They contain the recommended consumption in grams per day for 14 food groups: vegetables, fruits, bread, grain products, potatoes, fish, pulses, meat, egg, nuts and seeds, milk and milk products, cheese, oils and fats, and drinks.

Compared to previous versions recent guidelines place greater emphasis on a plant-based rather than a meat-based diet, and on consumption of unprocessed foods.

An earlier report ”Guidelines for a healthy diet: the ecological perspective” examined the 2006 Dutch dietary guidelines, and classifies them according to their potential synergies or conflicts with environmental objectives [98]. The study identifies recommendations with a positive impact both on health and for the environment, (i.e. a plant based diet and eating less food, in particular discretionary foods or 'snacks'). Potential conflicts are identified in which nutritional goals are at odds with the environment (i.e. eating more fish), and those recommendations which may be positive for the environment, but neutral for health.

In most dietary guidelines around the world, balancing energy intake with requirements is the most prominent message [99], from the perspective of reducing the disease burden of being overweight or obese. Eating only the necessary amounts of food has also been identified as a priority measure to reduce GHG emissions from the diet [31]. However, only a limited number of studies are available that associate environmental impacts of diets with aspects of energy balance and body weight. Vieux and colleagues [100] showed that when caloric intakes were reduced to meet individual energy needs, the GHG emissions associated with the diet can be reduced by up to 10% [100]. In many other modelling studies, estimates are adjusted for energy intake. In this way the effect of food choice can be studied within a standardised energy intake.

A recent UK study [76] showed that individuals whose diets comply better with guidelines for healthy diets, e.g. the Dietary Approaches to Stop Hypertension (DASH) diet, have a lower associated emission of GHG. The DASH diet emphasizes that plant-based foods are a proven way to prevent and control hypertension and other chronic diseases. The greatest accordance with the DASH dietary targets was associated with 17% lower GHG emissions compared to the diets with the lowest accordance (5.6 compared to 6.7 kg CO_2 equivalents/day). Among the DASH food groups, GHG emissions were most strongly and positively associated with meat consumption, and high GHG contained less unrefined grain foods [76]. In addition, higher accordance with the DASH diet was associated with higher dietary costs, with the mean cost of diets in the top quantile of DASH being 18% higher than that of diets in the lowest quantile ($P < 0.0001$).

Calculations from *modelling* studies showed that meeting healthy diet guidelines may reduce GHG emissions by 0-35% and land use with 15-50% compared to the average currently observed food consumption in a population [88]. The impact largely depends on what is considered a healthy diet and to what extent currently observed diets (mostly taken as a reference) already comply with dietary guidelines. In 5 of the 14 healthy diet scenarios, the GHGE reduction potential was less than 10% [88]. A recent scenario study [101] evaluated the effect on GHG emissions of changing the current Dutch diet to a diet according to the Wheel of Five guidelines (corresponding with the current diet as close as possible). Changes in GHG emission ranged from -13% for men aged 31-50 years to +5% for women aged 19-30 years. Replacing meat in this diet and/or consuming only foods with relatively low GHG emissions resulted in average GHG emission reductions varying from 28-46%. Food based dietary guidelines do not substantially reduce dietary GHG emissions compared to the current diet, unless additional dietary changes are made. GHG emissions associated with diets adhering to food based dietary guidelines may be reduced with around a third when these diets do not contain meat or when only foods with relatively low associated GHG emissions are chosen within each food group. These findings may be used to expand food based dietary guidelines with information on how to reduce the environmental impact of healthy diets.

Only a small percentage of the Dutch population comply with the previous dietary guidelines [77], both with respect to the quantity (e.g. amount of energy consumed) and the quality of the diets (e.g. amount of fruit and vegetables consumed). Observed food intakes deviate significantly from the recommendations in the previous Wheel of Five, in particular for fruit and vegetable consumption, intake of dairy, and consumption of energy-dense, nutrient-poor foods (soft drinks, alcohol and snacks). Women's diets more often comply to the dietary guidelines than do those of men.

Most of the modelling studies described above postulate hypothetical policy scenarios and have not explicitly investigated whether the proposed diets are realistic. More studies are appearing that have used optimization techniques to remain as close as possible to the existing dietary patterns [102]. If the UK dietary intake is optimized to comply with the WHO recommendations while staying as close to the current diet as possible, an estimated reduction of 17% in GHG emissions could be achieved [103] [102]. The optimized diets are lower in red meat, dairy, and eggs, consumption of soft drinks is largely reduced and replaced by water/tea, and the consumption of sweets and savoury snacks is also reduced. On the other hand, the consumption of cereals, vegetables and fruit will increase [102]. Further reductions of up to around 40% could be achieved by making realistic modifications to the diets so that they contain fewer animal-based foods, processed snacks and soft drinks, while containing more fruit, vegetables and cereals. Modifications leading to reductions in the GHG emission beyond 40% will not be possible without making radical changes to the diet, potentially reducing the nutritional quality of the diet [102].

4.5 Key findings

- Considerable differences may exist between individuals when it comes to the environmental impact of food consumption. Daily GHG emissions due to food consumption depend on both the quantity and the type of food and drinks consumed, and are determined by age, gender, energy needs and energy expenditure.
- Overconsumption drives unnecessary environmental impacts, and contributes to overweight and obesity. Balancing energy intake with requirements reduces GHG emissions by around 10% on a population level.
- Meat and cheese consumption constitute 40% of the total GHG emissions of daily Dutch diets. The contribution of drinks (including dairy drinks) to daily GHG emissions is approximately 20%.

- GHG emissions of food and beverage consumption are highest during dinner and in between the three main meals (e.g. consumption of drinks, snacks and cheese).
- Changing to a diet without meat and/or dairy has the largest potential for GHG emission reductions (25-55%). Replacing animal-based foods with plant-based foods reduces resource use and climate change impact.
- Complete avoidance of meat and dairy consumption might not be the most optimal solution from an environmental point of view (land use and biodiversity aspects).
- Changing towards a healthier diets (complying with healthy diet guidelines) does not automatically result in a lower environmental impact. To reach this, additional actions are needed, such as lowering meat consumption and/or choosing only those foods with a relatively low environmental impact from each food group. Research is needed to develop environmentally friendly and healthy diet guidelines.

5 Policies and private sector initiatives influencing the sustainability of the Dutch food system

5.1 Introduction: the Dutch situation

In 2014, the Scientific Council for Government Policy (WRR) published a report on the current status of the Dutch food system and future perspectives, which formed the starting point for a new political discussion on the future of our food system [17]. Additionally, the food cycle was raised to a prominent position within the government's 'Circular Economy' programme. Traditionally, the Dutch government is strongly involved in the regulation of our food supply [104]; the Dutch agriculture and food sector owes its leading role to longstanding governmental support[17], which has principally focused on increasing productivity. However, this is no longer the only relevant aspect of the food system. Nowadays, the importance of the production and consumption of food is also related to its role in spatial planning, ecology, public health and social and animal welfare. Due to this shift in themes, policies concerning food are covered by many different policy areas, and there is no single coherent 'food policy' in the Netherlands. Food policy is spread across dossiers in our agricultural policy, public health policy, environmental protection policy, and trade policy areas [17]. Recently, the Dutch government made some first steps in formulating comprehensive policy on sustainable food systems. Their ambitions for making food consumption more sustainable are described in the 'Policy Document Sustainable Food' (Nota Duurzaam Voedsel) [105], its follow-up 'Policy Letter Sustainable Food Production' (Beleidsbrief Duurzame voedselproductie) [106] and the cabinet's response to the WRR report [107].

In this chapter, we do not aim to present a complete overview of the national and international food policies, but focus on specific policies that exist for creating a more sustainable food system. The chapter is structured so that it follows the whole supply chain of foods. This means that first the policies (both international and national) concerning food production are described, followed by the policies concerning transport, processing and retail. Finally, EU and national policies on food waste are provided; these occur at the end of the supply chain, but also at each of the other steps in the life cycle. The second part of this chapter deals with the consumer phase of the food system. As consumers are free in their food and diet choices, no real legislation has been formulated for this life cycle phase by the government. However, several private, (semi-)governmental and citizen's initiatives exist to create awareness and to stimulate a more sustainable diet and 'food behaviour' on the consumer side. We present an overview of some private initiatives that aim at increasing the sustainability of the Dutch food system (section 5.5).

5.2 Policies on sustainable food production

5.2.1 International policies on sustainable agricultural production

in 2014, a new EU 'Common Agricultural Policy – CAP' (in Dutch: 'Gemeenschappelijk Landbouw Beleid - GLB') was formulated for the period 2014-2020. EU member states may formulate their own agricultural policy within the boundary conditions of this CAP. In the CAP, the European Commission emphasises the need for the combination of high productivity and battling the challenge of climate change while increasing sustainability. The three focus points of the CAP are therefore: food supply, sustainable use of natural resources, and fair development of agricultural regions. Innovation is a central aspect of these three focus areas.

Within the CAP, the EU enables member states to provide financial support for farmers that move towards organic farming, to invest in research and innovation, to give more attention to the development of vulnerable agricultural areas, and to improve the employment and social development in rural areas [108]. In order to get full financial support from the EU, farmers need to implement crop diversification and ecologically valuable areas on 5% of their land. In addition, the CAP defines that on a national level, the amount of permanent grassland may not decrease by more than 5% [17].

Ecological sustainability refers to a number of elements: land use, resource and water use, emissions of GHG, acidification, eutrophication and biodiversity. Policies concerning ecological sustainability are mainly formulated at an EU level. Since the attention given to environmental pollution has grown since the 1970s and 1980s, a number of important European guidelines and directives have been implemented that aim to reduce the negative effects of agriculture on soil, water, and air quality, for example, directives in the area of nitrate and water pollution. Recently, ecological sustainability – particularly biodiversity – has obtained a more important position in the CAP, see above [17]. However, the agrifood sector has been almost fully excluded from the European climate policy (particularly the EU Emissions Trading System – the tradable rights for the emission of GHG).

The Sustainable Development Goals (SDGs) initiated by the UNDP, officially known as 'Transforming our world: the 2030 Agenda for Sustainable Development', are an intergovernmental set of 17 goals with 169 targets. The targets cover a broad range of sustainable development issues, such as making cities more sustainable, combatting climate change, and protecting oceans and forests.

The following goals are formulated with respect to a sustainable food system:

- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts
- Goal 14. Conserve and sustainably use the oceans, seas and marine resources
- Goal 15. Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss

5.2.2 *National policy on sustainable agricultural production*

The Dutch government has set its own policy for the agricultural sector based on the contours of the European CAP. Farmers can get financial support if they operate sustainably and responsibly. In this way, the government wants to stimulate innovation, sustainable production and animal welfare (www.rijksoverheid.nl, visited on 1 December 2015). In addition, national initiatives have been agreed to move the different agricultural sectors towards sustainable production systems:

Sustainable greenhouse farming: 'Visie op de tuinbouwsector'
Within the greenhouse farming sector, the goal is that from 2020 onwards, all newly built greenhouses will be carbon-neutral as well as economically cost-effective. The agreements between the government and the greenhouse sector on the climate and energy goals are described in the 'Greenhouse Farming' policy letter [109].

Sustainable livestock farming: 'Toekomstvisie Duurzame Veehouderij'
Since 2009, the Ministry of Economic Affairs (EZ) has participated in the 'Sustainable Livestock Farming Implementation Agenda' (Uitvoeringsagenda Duurzame Veehouderij). In this cooperation, companies, societal organisations, provinces and the ministry work together on six aspects of sustainable livestock farming (http://www.uitvoeringsagendaduurzameveehouderij.nl/; visited 1 December 2015):

- System innovations: sustainable stable systems
- Welfare and health of livestock: stimulating natural animal behaviour, reducing antibiotic use, minimising transport
- Embedding livestock farming in landscape and society: transparent production systems, interaction between farmer and citizen, landscape quality
- Climate and renewable energy + reducing emissions towards the environment: closing food and manure loops, energy savings, sustainable energy production, reducing emissions
- Chances for market and entrepreneurship: improving the economic perspective of entrepreneurs by creating more valuable products
- Sustainable consumption: creating more choices in the supply of sustainably produced products

Sustainable feed production
The 'Supply Chain Transition Responsible Soy' foundation (Stichting Ketentransitie Verantwoorde Soja) coordinates the purchase of sustainable soy for the feed and food industry. Sustainable soy is certified by the Round Table on Responsible Soy (RTRS) or organisations following comparable standards. The goal set for 2015 onwards is that 100% of the soy purchased for the Dutch market is produced sustainably. In addition, in the project 'Making animal feed more sustainable' (Verduurzamen Diervoeder), an inventory was made on available European protein sources for feed in the future, which may replace South American soy. Possible alternatives are Dutch Soy, Danube-soy, sunflower lumps, insects and algae.

Manure production
The high concentration of livestock in the Netherlands causes larger volumes of nitrogen residues than found in other European countries, which makes the manure legislation important in the Netherlands. Traditionally, policies concerning the limiting of manure production consist of a combination of (tradable) animal rights and manure production rights. Since 2014, obligatory manure processing was added to the legislation. This addition should lead to a reduction in air, water and soil pollution, while creating competitive advantages for the agricultural sector, without major environmental restrictions [110].

Within the context of the Sustainable Dairy Chain initiative, dairy processors and dairy farmers work together towards creating a futureproof and responsible dairy sector [111]. To enable this, the Sustainable Dairy Chain has formulated goals on four sustainability themes. In the area of GHG, phosphate [112] and ammonia, the increased production volume has jeopardized the agreements on emission ceilings [111]. As for pasturing, it has not yet been possible to reverse the declining trend. Progress has been made in the areas of antibiotic use, energy efficiency and use of responsible soy. Monitoring of animal welfare and biodiversity are still in development.

5.3 Policies on sustainable processing and retailing

5.3.1 EU policies on sustainable processing and retailing
In response to the internationalisation and increasing complexity of our food system, as well as the call from society for more information on the origin of products, there are a growing number of initiatives on 'chain management' of the food system, including the processing and retail phase of the food chain. Of great influence is GlobalGAP (former EuropGAP; an initiative of large European retail companies) and the British Retail Consortium (BRC). GlobalGAP focuses on four main issues: food safety, protection of the environment, labour rights, and animal welfare. It is a private, voluntary standard based on certification by a third party. A similar initiative has been set up by The Sustainability Consortium (TSC), a cooperation between large retailers and scientists on a worldwide scale, aiming at developing more sustainable food supply chains (www.sustainabilityconsortium.org). Consumers are unfamiliar with these standards as they are essentially business-to-business certificates. However, since the large European supermarkets have started to apply the GlobalGAP- and TSC-protocols, their influence has extended. Moreover, the standards not only apply to the retailers themselves, but also to their suppliers [17].

5.3.2 National policies on sustainable processing and retailing
The Dutch Ministry of Economic Affairs states that responsibility for making the food chain more sustainable is primarily a task for business partners. The government took an important step by founding the 'Alliance for Sustainable Food' (Alliantie Verduurzaming Voedsel), which is a cooperation between Centraal Bureau Levensmiddelenhandel (CBL, the branch organisation for supermarkets and food service companies), FederatieNederlandse Levensmiddelen Industrie (FNLI, the branch organisation for the food industry), Land- en Tuinbouw Organisatie Nederland(LTO, the branch organisation for farmers), Vereniging

Nederlandse Cateringorganisaties (Veneca, the branch organisation for catering companies) and Koninklijke Horeca Nederland (KHN, the branch organisation for the hospitality sector). The alliance focuses on integrally embedding sustainability throughout the whole food supply chain.

Moreover, the government initiated the 'Uitvoeringsprogramma Duurzame Veehouderij'. As part of this program, a project called 'Chain management (Ketenmanagement) should establish links between the market and the sustainability initiatives in agriculture. By stimulating production and availability of more sustainable products, the aim is to establish a respectable income for all stakeholders.

5.4 Policies on sustainable waste management

5.4.1 EU policies on waste reduction

The EU set the goal that by 2020 incentives to achieve a healthier and more sustainable food production and consumption are widespread, and will have driven a 20% reduction in the food chain's resource inputs. Disposal of edible food waste should be halved in the EU [113]. The policy involves a combined effort by farmers, the food industry, retailers and consumers to establish resource-efficient production techniques, sustainable food choices, and reduced food waste, which can contribute to improving resource efficiency and food security at a global level [114]. An EU-specific target on food waste reduction has been removed from the new Circular Economy Package adopted by the European Commission. The Commission is committed to helping member states reach the Sustainable Development Goals on food waste reduction [4].

The Communication of the European Commission in December 2015 (Closing the loop – An EU action plan for the Circular Economy) [115], announced the following actions:

- to reduce food loss and waste generation including the establishment of a multi-stakeholder platform dedicated to food waste prevention;
- development of a common EU methodology to measure food waste in the entire food value chain;
- clarification of EU legislation on waste, food and feed in order to facilitate food donation and ensure the safe use of former foodstuffs and by-products in feed production;
- exploration of options to improve the understanding and use of date-marking by all actors, including consumers.

5.4.2 National policies on waste reduction

The Dutch Ministry of Economic Affairs invested in 'small business research on food waste', an initiative for entrepreneurs to find innovative ways to prevent food waste [116]. Several supermarkets in the Netherlands are reducing the amount of prepackaged fruit and vegetables on offer, thereby reducing plastic waste, but also reducing potential food waste as consumers can buy the exact amount they need. New types of packaging can also play an important role in the reduction of food waste. The MAP-packaging (modified atmosphere packaging) for instance, is an airtight package with gases that delay the chemical breakdown of a product. Due to the longer shelf life of the product, more sustainable ways of transport can be used that require more time (e.g. by boat). The downside of this type of packaging is the higher cost [117]. Since fruit and vegetables are wasted the most in the Netherlands, reducing food waste from these food groups in will have the highest effect with regard to sustainability [73, 74].

In addition to increasing knowledge on food waste, raising awareness among food industries, retailers and consumers can also reduce food waste [118]. Figure 5.1, 'Moerman's ladder', depicts the order from most to least preferable ways of handling food waste. Prevention of food waste is considered the most sustainable option, while food waste ending up in a landfill is the least sustainable option.

Prevention (avoiding food waste)
Use for human consumption directly (e.g. food banks)
Conversion to human food (processing and re-processing)
Use in animal feed
Raw materials for industry (bio-based economy)
Conversion to fertilizer by fermentation (+ energy generation)
Conversion to fertilizer through composting
Use for sustainable energy production (objective is energy generation)
Burning as waste (objective is destruction, with possible associated energy generation)
Landfill (disposing of waste in landfills is prohibited in the Netherlands)

Figure 5.1. Moerman's ladder on the most to least preferable ways of handling food waste.

5.5 Initiatives for a more sustainable consumption phase

Consumer behaviour can be influenced through many different approaches. For example, consumers can be informed about the environmental impacts of their food choices through guidelines, public health campaigns, or labelling. Guidelines are potentially less likely to influence consumers directly, but they can provide a benchmark against which the food offer of manufacturers, catering companies, restaurants and public institutions such as hospitals and schools can be assessed, helping to provide an incentive for supply-side change [119].

In this section, we first explore the current development of incorporating sustainability messages into national food-based dietary guidelines. Thereafter, different kinds of interventions are described aimed at moving consumers towards more sustainable dietary choices.

5.5.1 Guidelines for a sustainable diet

Incorporating sustainability guidelines into dietary guidelines may stimulate a reduction of the environmental impact of food consumption. Several governmental institutes, health councils and nutritional institutes have started to explore this possibility and have added sustainability guidelines to the traditional health-based dietary guidelines. As such, they advise the general population about diets that are both beneficial for human health and the environment. Recently,

FAO undertook a web based review of national dietary guidelines worldwide, using
publicly available information [120]. In the report [120] , FAO considers the role of national level dietary guidelines in providing a steer on what dietary patterns that are both healthy and sustainable look like. Several national agencies and non-governmental organisations have created the so called 'Sustainable Dietary Guidelines' in an attempt to reconcile nutritional advice with environmental concerns [121]. Moreover, the Nordic Council of Ministers has provided an estimate of the nutritional changes required in order to achieve more sustainable dietary patterns [122], and the Health Council of the Netherlands has provided its government with recommendations based on available evidence regarding the health and environmental impacts of different foods [98]. In Italy, the Barilla Centre for Food and Nutrition has developed the 'Double Food – Environmental Pyramid model', a visual representation of the extent to which different food groups contribute to a healthy diet and their environmental impact [123]. Moreover, the German Dietary Guidelines developed a 'Sustainable shopping basket', a consumer guide for sustainable shopping [124].

The key messages in these reports largely agree on the dietary changes needed to direct consumers towards more healthy and sustainable dietary choices. Some reports merely focus on less animal-based and more plant-based foods, whereas others also included advice on energy intake, exercise and/or food waste. In general, the emphasis is on balancing foods in the diet, and not on eliminating certain types of products. The main messages, as described by the Dutch Health Council, National Food Agency Sweden (Swedish national dietary guidelines), Barilla Centre for Food and Nutrition (Italy), and WWF's LiveWell Plate can be summarised as follows:

- A sustainable healthy diet contains more plant-based foods, such as vegetables, legumes, fruit, wholegrain cereals, nuts and seeds (all guidelines).
- The amount of animal-based products, and especially meat, should be reduced (all guidelines). The Swedish guidelines recommend a reduction in consumption of red and processed meat, to no more than 500 grams a week [125].
- A balance between energy intake and energy expenditure is needed (Swedish national dietary guidelines), and can be achieved by reducing the consumption of non-basic foods, such as savoury snacks and sweets, sugary drinks and alcohol. These foods offer little advantage in terms of nutritional value (all guidelines).
- In addition, a few guidelines recommend increasing the intake of sustainable seafood choices from certified fisheries and certified aquaculture systems, and increasing the amount of healthy fats in the diet ([125] & Swedish national dietary guidelines). However, others also address the potential conflict in the case of fish and seafood between health benefits and environmental impacts (LiveWell, Health Council of the Netherlands, Swedish national dietary guidelines).
- Dairy products or alternatives should be eaten in moderation, from a sustainability perspective (Swedish national dietary guidelines).

- Food waste should be reduced [124].

In general, current sustainable food consumption recommendations largely focus on climate impact in terms of GHG emissions, and less on the effect of land use (change), water use, acidification, eutrophication and biodiversity loss [122].

When focussing on specific food groups as being more or less sustainable, there are still many products to choose from within each food group. This choice can also have a marked impact on sustainability, depending on how and where it was produced, which can also differ between countries. More specific recommendations, such as eating seasonal foods and choosing field-grown and 'robust' (less prone to spoilage) foods, are needed on a consumer level.

To develop dietary guidelines that incorporate sustainability specific suggestion of FAO may be followed [120].

5.5.2 Private sector initiatives to increase the sustainability of the food system in the Netherlands

In addition to the recommendations of the national health councils, raising consumer awareness and promoting behaviour change can be achieved through different approaches. Initiatives can be targeted at several determinants of food choice and consumption. One of the initiatives in the Netherlands, but also in the UK and United States, is the private initiative called Meatless Monday, which raises people's awareness about the growing meat consumption and encourages people to eliminate meat from their diet one day a week [126]. Recently, the Green Protein Alliance started to promote more healthy and sustainable food consumption. Members are Albert Heijn, BOON, GoodBite, HAK, Marley Spoon, Rechtstreex, RotterZwam, The Dutch Weed Burger, ValkVers - De Cantharel, Vegafit, Vivera, Natuur & Milieu and Het Planeet, with the support of the Ministry of Economic affairs and the Netherlands Nutrition Centre and Milieu Centraal.

Table 5.1 gives an indication – although not a complete overview – of several private initiatives in the Netherlands aimed at increasing the sustainability of the food system on a national or local level.

Table 5.1. Examples of Dutch initiatives stimulating a sustainable food system

Initiative	Description	Website(s)
Instock restaurant/ toko/truck	Collects food from supermarket Albert Heijn that is not suitable for sale due to for instance the odd appearance of a fruit or vegetable. The foods are still suitable for consumption. The toko sells ready to eat meals prepared from foods that would otherwise have been wasted.	www.instock.nl
Buitenbeentjes food box Albert Heijn	A food box for a fixed price with a week's worth of fruit and vegetables that can be bought in the supermarket. The fruit and vegetables are oddly shaped or not appealing enough to be sold in the regular fruit and vegetable section of the supermarket.	www.ah.nl/buitenbeentjes
Initiatives like Willem en Drees, Rechtstreex	Sell produce of Dutch (local) farmers directly to consumers, and aim to provide environmentally friendly, seasonal food for which the farmer receives a better price.	www.willemendrees.nl www.rechtstreex.nl
Food boxes such as the Freshbox, Streekbox, Beebox & De Krat	Subscription-based boxes with foods delivered at home. Recipes are usually included and the ingredients are pre-measured for each recipe. Some boxes only use local and/or organic foods and seasonality is taken into account.	www.beterbio.nl www.streekbox.nl www.beebox.nl www.dekrat.nl
Kromkommer	A brand that sells soups made from oddly shaped vegetables, to prevent food waste. They also had a pop-up store in which oddly shaped vegetables were sold, and where workshops and presentations about food waste were given.	www.kromkommer.nl

Initiative	Description	Website(s)
Taste before you waste	An initiative from Amsterdam. Volunteers collect oddly shaped fruit and vegetables and foods not suitable for sale from supermarkets and greengrocers. The foods are distributed amongst several initiatives that cook meals with them, or they are handed out for free along with information about food waste.	www.tastebeforeyouwaste.nl
The Foodiebag	Aims to reduce food waste on a consumer level in the hospitality industry. A spoon-shaped clip is placed on restaurant tables. When the customer desires to take home the left-over food after a meal, the clip can be attached to the plate and the kitchen will transfer the left-overs into the Foodiebag for the customer to take home.	http://verdraaidgoed.nl/projectportfolio/foodiebag
Koop een koe, samen een koe kopen, etc.	Farmers offer meat packages for consumers with different kinds of cuts from the cow. When a whole cow (usually special varieties like Blond d'Aquitaine or Gasconne) has been sold (approximately 32 packages), the cow is slaughtered. In this way the full potential of meat production from the cow is utilized. Similar initiatives exist for pork (Koop een varken) and chicken (Koop een kip).	www.Koopeenkoe.nl www.Sameneenkoekopen.nl
Questionmark	A mobile app that scores supermarket products on the aspects: environmental sustainability, human rights, animal welfare and health, so that consumers can make better informed choices.	www.thequestionmark.org

5.5.3 *Consumer phase: waste reduction*

Consumers can reduce waste by reducing their impulse purchases, checking which foods they already have in their fridge or cabinet, eating foods with a shorter shelf life first, and measuring portion sizes before cooking. In 2012, the rules for best-before dates for foods with a long shelf life changed in order to help the consumer to consume more consciously [116]. Also, the Netherlands Nutrition Centre (Voedingscentrum Nederland) started the campaign 'Hoezo50kilo' (Why 50 kilos) [127] and the WhatsApp Kitchen Assistant. These campaigns focus on ways to reduce food waste in the consumer phase. The campaigns provide information about food storage, portion sizes and recipes to use leftovers from previous meals in order to achieve less food waste. The Netherlands Nutrition Centre has also developed several tools for consumers, for instance apps with recipes and food storage advice, a flyer with information about buying, storing and cooking food to prevent waste, and an entire website devoted to recipes for leftovers. Table 5.1 shows more initiatives to reduce food waste and that aim for a more sustainable environment.

Consumers appear to have an interest in food waste reduction, however they tend to underestimate their own food waste. Lack of knowledge appears to be a substantial problem when it comes to food waste. Increasing knowledge about the consequences of food waste (environmental impact and wasting of money) and ways to reduce food waste will potentially have a positive effect [128].

5.5.4 *Labelling of food products*

Food labels provide guarantees about, for example, environmental friendliness or animal welfare in the production process of food products. As such, they help consumers in making well-defined sustainability choices when buying food. Many different food labels exist in the Netherlands, both national and international. Some labels exist for specific types of food, e.g. the MSC and ASC label for wild caught fish and farmed fish respectively. For these labels, criteria are defined that are specific to that sector. In addition, general labels have been introduced, e.g. the EKO label and Demeter label, which indicate whether a product was produced organically or biodynamically. Some labels also include fair trade criteria. An overview of the best-known and well-controlled labels concerning organic agriculture used in the Netherlands is given in Figure 5.2.

European label for organic products

EKO-label: Dutch label for organic products

Demeter-label: label for biodynamic agriculture

Figure 5.2. Overview of the best-known, well-controlled labels in the Netherlands concerning organic agriculture.

Also, there are a number of specific labels related to animal welfare. These can be general or product-specific, e.g. for eggs. The most commonly used labels on animal welfare in the Netherlands are given in Figure 5.3.

'Beter Leven keurmerk' (Better Living label):
3-level qualification system concerning animal welfare, provided by Dierenbescherming (organization for the protection of animals)

Label 'Vrije uitloop' for eggs: from free-range chicken with the possibility to go outside (conform European criteria)

MSC label: international label for sustainable and animal friendly fishing

Figure 5.3. Overview of the best-known, well-controlled labels in the Netherlands concerning animal welfare.

For the certification of local/regional foods, three clear levels of certification exist:
- European certification
- National certification
- Regional certification

Since 1992, the EU has had a certification policy on local products, aiming at stimulating the diversity in the agricultural productivity, protection of product names, and informing consumers on the specific character of certain products. There are three types of European certification: protected designation of origin (PDO), protected geographical indication (PGI), and traditional specialties guaranteed (TSG).

The 'Recognized regional product' (Erkend Streekproduct) is the only independent Dutch label for local foods. It not only guarantees the regional origin of products, but also guarantees environmentally responsible production processes and animal welfare. The label was developed in 2000 by the Ministry of Agriculture and is managed by the independent foundation Stichting Streekproduct Nederland (SPN, Foundation for Dutch Regional Products). Finally, there is independent certification on a regional level in the Netherlands for specific regions, e.g. Veluwe, Groene Hart or Zeeland. Most of the regional labels are also managed by the Stichting Streekproduct Nederland (SPN). In Figure 5.4, an overview of labels for local foods at EU, national and regional level is given.

European label for local/regional food

Dutch national label for local/regional food

Example of a regional label for local/regional food in the Netherlands

Figure 5.4. Overview of certified labels for local foods at EU, national and regional levels.

To identify fair trade products, a number of specific national and international labels have been introduced. In the Netherlands, Max Havelaar is the oldest and best-known of these labels (controlled by the Max Havelaar Foundation), but others have been developed in the past decade. Some examples of fair trade labels are given in Figure 5.5.

Max Havelaar/Fair trade: label for fair trade of tropical products

Rainforest Alliance: label for environmental and fair trade criteria in rainforest areas

Figure 5.5. Examples of certified labels for fair trade products.

The labels differ in the criteria they use for accreditation of a product and the controlling system for producers differs in quality and reliability. Moreover, some producers add 'surrogate' labels to their products, which are not in fact real labels with controlled criteria, which is misleading for consumers. Therefore, Milieu Centraal has developed the 'Label guide' (Keurmerkenwijzer), which helps consumers to recognize the different labels and informs them of which criteria they stand for (www.milieucentraal.nl/keurmerkenwijzer). In addition, the guide provides insights into whether a label is (externally) reviewed and to which extent the certified products are audited, which gives an indication of the reliability of the different labels.

5.6 Key findings

- Traditionally, the Dutch government is strongly involved in the regulation of our food supply. The Dutch agrifood sector strongly owes its leading role to longstanding governmental support. Nowadays the production and consumption of food is also important with regards to spatial planning, ecology, public health, and social and animal welfare. Due to this shift in themes, policies concerning food are covered by many different policy areas, and there is no single, coherent 'food policy' in the Netherlands.

- In 2014, a new EU 'Common Agricultural Policy – CAP' (in Dutch: 'Gemeenschappelijk Landbouw Beleid - GLB') was formulated for the period 2014-2020. Within the CAP, the EU enables the member states to: provide financial support to farmers that change towards organic farming; invest in research and innovation; pay more attention to the development of vulnerable agricultural areas; and to improve employment and social development in rural areas.
- National initiatives have been introduced to develop the food sector towards sustainable production systems, like 'Visie op de tuinbouwsector', 'Toekomstvisie Duurzame Veehouderij', initiatives on sustainable feed production and sustainable manure cycles.
- In response to the internationalisation and increasing complexity of our food system, as well as the call from society for more information on the origin of products, there are a growing number of initiatives on 'chain management' of the food system, including the processing and retail phase of the food chain. In Europe, GlobalGAP and the British Retail Consortium (BRC) are of great influence. In the Netherlands, the 'Alliantie Verduurzaming Voedsel' focuses on integrally embedding sustainability throughout the whole food supply chain.
- The EU set the goal that by 2020, disposal of edible food waste should be halved in the EU [114]. The Dutch Ministry of Economic Affairs invested in 'small business research on food waste', an initiative for entrepreneurs to find innovative ways of preventing food waste [116]. In addition to increasing knowledge, raising awareness among food industries, retailers and consumers can also reduce food waste [129].
- Consumer behaviour can be influenced through many different approaches. In general, the emphasis is on diets containing more plant-based foods, whereas the amount of animal products, and especially meat, should be reduced. Also, a balance between energy intake and energy expenditure is needed. Finally, some guidelines recommend increasing the intake of sustainable seafood.
- In addition to the recommendations by the national health councils, raising consumer awareness and promoting behavioural change can be achieved through many different approaches, including education on environmental sustainability in schools and universities.

6 Management perspectives for a more sustainable food system

6.1 Introduction

Both nationally and internationally, the awareness for the sustainability of our food system is growing. The USDA, for example, sketches three groups of stakeholders that have an influence on creating a more sustainable food system: i) the stakeholders in the production and retail chain, ii) the consumers, and iii) the policy makers, see Figure 6.1. To establish a more sustainable food system, they should together advocate the value of a transparent food system for producing healthy and safe food for everyone [121].

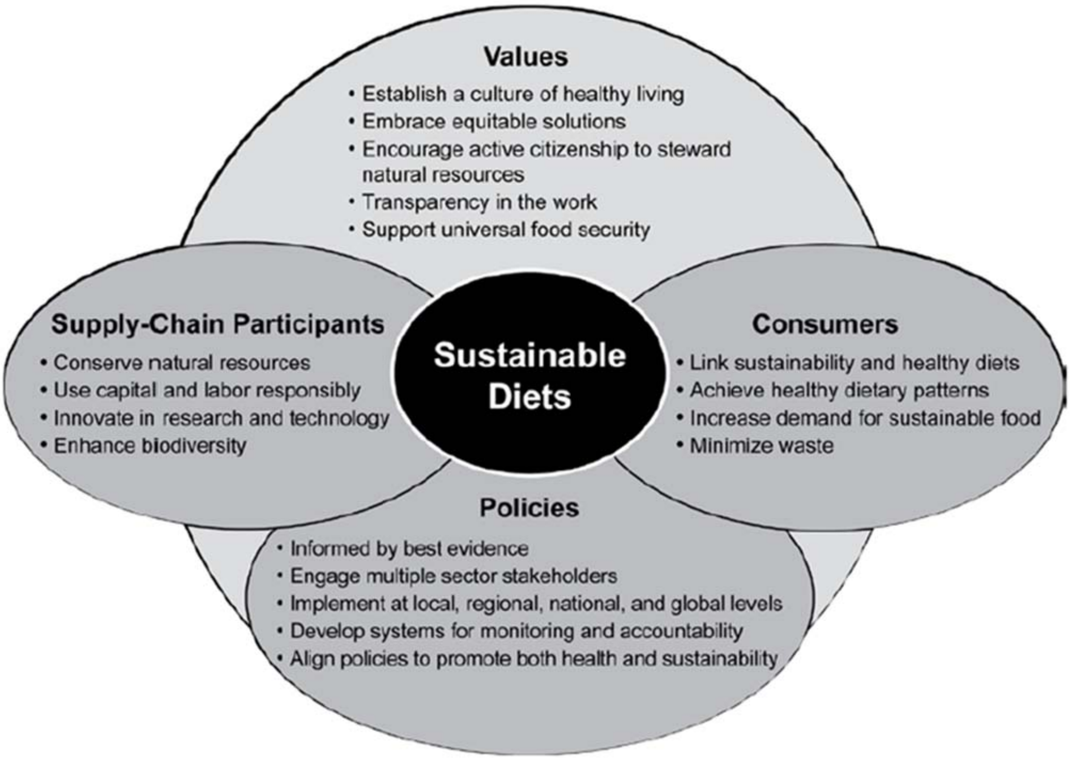

Figure 6.1. Elements of a sustainable food system. Source: USDA [121].

Thus, to come to more sustainable food consumption patterns in the Netherlands, changes are needed throughout the life cycle of food products, with all actors involved.
In their food policies, governments at an EU and national level should not only focus on food supply, but, more than is currently occurring, on the sustainable use of natural resources and fair development of agricultural regions. Technological innovations that lead to a more sustainable food system can be stimulated by governments, either with financial and fiscal measures or by facilitating contacts between the actors throughout the supply chain. Another role for the government is providing correct and transparent information to consumers on the

sustainability of their food consumption, and to provide suggestions on how to achieve a more sustainable consumption pattern. Additionally, cooperation with e.g. retailers may help. The focus has to be on a less animal-based and more plant-based food consumption pattern, as well as on a balanced energy intake, and on the reduction of food waste.

In the food production, processing and consumer phase, the use of energy (fossil fuels) can be reduced and fossil fuels can be replaced with cleaner energy sources. This will reduce GHG emission. Consumers, finally, should feel the responsibility to adapt a more (environmentally) sustainable food purchase, preparation and consumption pattern, either by the amounts and types of foods that they eat and drink, what they buy (e.g. packaging), how they prepare it, how they transport it, or by minimising their food waste.

6.2 Management perspectives along the food production and processing chain

One main policy and business approach to achieving food system sustainability must be on improving the environmental performance of food production. Sustainable intensification is defined as a set of techniques that enable food (sometimes more food) to be produced with less environmental impact and without incurring further land use change – the latter is critical since major biodiversity and carbon losses result from deforestation [130]. The concept of sustainable intensification is, however, still evolving and can be ideologically loaded – with some critics arguing that it is little more than 'greenwashing' for business as usual by industrialised intensive agriculture [131]. Moreover, it is recognized that measures are also needed to address the aspects of food security and its social and economic determinants; in other words. to improve the ability of poor people to produce their own food and/or to be able to access and afford food [132]. Sustainable intensification may be necessary, but it cannot be seen as a sufficient 'solution' for all the complex problems we face.

In addition to 'sustainable intensification', food producers can take responsibility by making their production processes more sustainable, e.g. by shifting to the use of renewable energy sources and by changing the types of products they produce. In the food (processing) industries as well as in retail, 'sustainable sourcing' of commodities and foods should be the standard, also with respect to social (fair trade) and animal welfare aspects.

Although they not necessarily do so, production-oriented approaches may also affect consumption patterns, through at least four pathways [130]:

1. Changes in production practices may alter the costs of production, thereby influencing the consumer price, which in turn affects demand. For example, policies to increase livestock productivity can lower production costs; if reflected in the product's retail price, this may trigger increases in consumption, and this may have both health and environmental consequences.
2. Changes in production practices (resulting from regulations, fiscal measures or voluntary agreements) may alter the environmental

profile of a food in such a way that identified trade-offs between health and sustainability may be overcome. Sustainable aquaculture, which potentially substitutes for harvesting wild fish, is a possible example; health and environmental objectives may become more closely aligned.

3. Production methods may alter the nutrient content of a food, thereby changing its nutritional role in the diet. Such foods can potentially substitute for others that may have a higher environmental impact; alternatively, greater or lesser amounts of the food in question may need to be consumed to meet nutritional requirements, meaning that more or less may need to be produced, with subsequent environmental implications.

A change in the types of food produced, such as an increase in the supply or diversity of fruit and vegetables, may affect availability and accessibility, and thus consumption patterns.

Finally, and less directly, where changes in production practices are combined with communication of those changes, such as through an ethical or environmental label, changes in purchase behaviour may be the result. This is relevant not just because a label may influence the level of consumption, but also because insights can be gained into how consumers respond to labels and the associated messaging.

6.3 Management perspectives for policy makers

Governments can have a steering role for both producers and processors in the supply chain (section 6.2) as well as for consumers (section 6.4). Technological innovations that lead to a more sustainable food production and distribution system on the one hand, and sustainable consumption on the other, should be stimulated by governments. There are several ways to stimulate developments:

1. Fiscal measures. Taxes and/or subsidies may be effective mechanisms to regulate production and consumption, either independently or combined. These are effective as price is one of the primary influencers of people’s consumption habits [133]. Some studies note that government revenues gained from taxes could in turn be used for environmental sustainability and/or public health services. Taxes are thus effective in two ways, and this may help to increase public acceptability [134]. Moreover, taxes may enforce efforts to educate consumers: being aware that a product has been taxed because it is unhealthy or unsustainable discourages purchases [135].
2. Facilitating contact between the actors throughout the supply chain. Bringing together producers, retailers and consumers may lead to strong cooperation that results in significant changes to the food system.
3. Providing correct and transparent information to consumers on the sustainability of their food consumption, and providing suggestions on how to achieve a more sustainable consumption pattern; cooperation with e.g. retailers may help. Providing transparent information can for example be done via education programmes, governmental labels and/or information campaigns. School-based interventions, such as the introduction of school

meal standards, the banning or restriction of certain foods and drinks, provision of fruit in schools and gardening schemes, show promising and positive results [130].
4. Setting policy goals for reduced environmental impacts of the Dutch food consumption and discussing how these goals can be met together with the food sector. An example could be a more sustainable public procurement with respect to food. This strategy should include monitoring, as proposed by De Valk et al [25].

6.4 Management perspectives for consumers

Consumers are free in their food choices, but they can be influenced by, for example, governmental campaigns, price setting, and through supply via public procurement. A growing number of people are aware of the need to shift towards a more sustainable food consumption pattern. Consumer demand has a strong influence on the production chain.

If consumers want to change towards a more sustainable diet, the highest impact can be achieved by [25]:

1. consuming less animal-based and more plant-based foods: it is generally accepted that the consumption of meat (particularly beef) has a relatively high environmental impact. Also from a health perspective, it is advisable to reduce the amount of red meat consumed.
2. consuming less food: many people eat too much, leading to obesity in some parts of the world. Eating less will lead to a lower demand for food production. Reducing the amount of food people consume, will therefore not only benefit human health, but also the environment.
3. reducing waste: a great amount of food is wasted throughout the life cycle of food products. By wasting less, we reduce the need for food production.
4. consuming more seasonal foods from local producers reduces the environmental impact from transport and heating greenhouses.

6.5 Concluding remarks

Given the scale and urgency of the food sustainability problem, no single approach will achieve the changes we need in the time we have. A mix of approaches – regulatory, fiscal, voluntary, and context and information oriented – is required. Changes may also not be immediate, or if immediate, they may not be sustained; and they may have a different impact on different population groups. Hence, changes need to be monitored over time and across sections of the population, and robust evaluation methods should be incorporated into the initial design of interventions.

6.6 Key findings

- To come to more sustainable food consumption patterns in the Netherlands, changes are needed throughout the life cycle of food products, and all actors should be involved.
- Governments can play a steering role for both producers and processors in the supply chain, and for consumers. They can

implement fiscal measures, facilitate contact between the actors throughout the supply chain, or adopt a more sustainable public procurement. Other beneficial measures are providing correct and transparent information to consumers on the sustainability of their food consumption, and providing suggestions on how to achieve a more sustainable consumption pattern.

- If consumers want to change towards a more sustainable diet, the greatest impact can be achieved by principally focusing on consuming less animal-based and more plant-based foods, consuming less food in general, reducing waste, and consuming more seasonal foods.

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References

1. Rockström, J., et al., *Planetary boundaries: exploring the safe operating space for humanity.* Ecological Society, 2009. **14**(32).
2. Steffen, W., et al., *Planetary boundaries: Guiding human development on a changing planet.* Science, 2015. **347**(6223).
3. Rockstrom, J., G.A. Stordalen, and R. Horton, *Acting in the Anthropocene: the EAT-Lancet Commission.* Lancet, 2016. **387**(10036): p. 2364-5.
4. UNDP, *Sustainable Development Goals* U.N.D. Programme, Editor. 2015.
5. Buhl, J., *Revisiting Rebound Effects from Material Resource Use. Indications for Germany Considering Social Heterogeneity.* Resources, 2014. **3**: p. 106-122.
6. Leismann, K., et al., Resources 2013. **2**: p. 184-203.
7. Røpke, I., *Theories of practice — New inspiration for ecological economic studies on consumption.* Ecological Economics, 2009. **68**: p. 2490-2497.
8. UNEP, *Food Systems and Natural Resources. A Report of the Working Group on Food Systems of the International Resource Panel.* , H. Westhoek, Ingram J., Van Berkum, S., Özay, L., and Hajer M., Editor. 2016.
9. Sutton, M.A., et al., *Our nutrient world: the challenge to produce more food and energy with less pollution*. 2013, Centre for Ecology and Hydrology,: Edinburgh
10. Westhoek, H., et al., *The protein puzzle*. 2011, PBL Netherlands Environmental Agency: The Hague.
11. Bos, J.F.F.P., A.L. Smit, and J.J. Schröder, *Is agricultural intensification in The Netherlands running up to its limits?* NJAS - Wageningen Journal of Life Sciences, 2013. **66**: p. 65-73.
12. International Food Policy Research Institute (IFPRI) *GLOBAL FOOD POLICY REPORT -synopsis*. 2016.
13. FAO, *Definition of sustainable diets. International scientific symposium: biodiversity and sustainable diets united against hunger, Rome, 3–5 November 2010*. 2010, FAO Headquarters: Rome, Italy.
14. Voedingscentrum. *Factsheet Duurzaam Eten*. 2012 [cited 2013 26 Augustus]; Available from: http://www.voedingscentrum.nl/professionals/factsheets.aspx.
15. Hueston, W. and A. Mc Leod, *Improving Food Safety Through a One Health Approach: Workshop Summary*, in *National Academies Press (US)*. 2012: Washington DC.
16. UN, *World Population Prospects: The 2010 Revision, Standardvariants. Updated: 28 June 2011*. 2011, United Nations,.
17. WRR, *Naar een voedselbeleid*. 2014, Amsterdam University Press: Amsterdam.
18. Van Leeuwen, M.G.A., et al., *Het Nederlandse agrocomplex 2013*. 2014, LEI Wagenningen UR: Wageningen.

19. WUR. *Agrarische export van Nederland stijgt, handelsoverschot neemt af*. 2016 accessed 21-01-2016]; Available from: http://www.agrimatie.nl/ThemaResultaat.aspx?subpubID=2232&themaID=2276&indicatorID=3425&sectorID=3436.
20. Smith, M.R., et al., *Effects of decreases of animal pollinators on human nutrition and global health: a modelling analysis.* The Lancet, 2015. **386**(10007): p. 1964-1972.
21. Agardy, T., *Effects of fisheries on marine ecosystems: a conservationist's perspective.* ICES Journal of Marine Science, 2000. **57**(3): p. 761-765.
22. Goñi, R., *Ecosystem effects of marine fisheries: an overview.* Ocean and Coastal Management, 1998. **40**: p. 37-64.
23. Goedkoop, M., et al., *ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation*. 2009.
24. Hollander, A., M. Zijp, and H. Van Wijnen, *A spatially explicit LCA-indicator for P-depletion in agricultural soils*. 2015, RIVM: Bilthoven.
25. De Valk, E., A. De Hollander, and M. Zijp, *Milieubelasting van de voedselconsumptie in Nederland*. 2016, RIVM: Bilthoven.
26. Broekema, R., L. Kuling, and J. Scholten, *Life Cycle Inventories of dairy and animal products consumed in the Netherlands. Guidance document*. 2015, Blonk Milieuadvies: Gouda.
27. Kuling, L., *Bread LCI's*. 2015, Blonk Milieuadvies: Gouda.
28. Foster, C., et al., *Environmental impacts of food production and consumption: a report to the Department for Environment, Food and Rural Affairs.* . 2006, Manchester Business School. Defra, London.
29. Haas, G., F. Wetterich, and U. Köpke, *Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment.* Agriculture, Ecosystems and Environment, 2001. **83**(1-2): p. 43-53.
30. Temme, E.H.M., et al., *Greenhouse gas emission of diets in the Netherlands and associations with food, energy and macronutrient intakes.* Public Health Nutrition, 2015. **18**(13): p. 2433-45.
31. Garnett, T., *What is a sustainable healthy diet? A discussion paper*. 2014, Food Climate Research Network: Oxford.
32. Williams, A.G., E. Audsley, and D.L. Sandars, *Determining the environmental burdens and resource use of agricultural and horticultural commodities.* , in *Defra Research project*. 2006, Defra, Bedford: Silsoe.
33. Casey, J.W. and N.M. Holden, *Greenhouse gas emissions from conventional, agri-environmental scheme, and organic irish suckler-beef units.* Journal of Environmental Quality, 2006. **35**(1): p. 231-239.
34. Cederberg, C. and M. Stadig, *System Expansion and Allocation in Life Cycle Assessment of Milk and Beef Production.* International Journal of Life Cycle Assessment, 2003. **8**(6): p. 350-356.
35. Núñez, Y., et al., *Comparative life cycle assessment of beef, pork and ostrich meat: A critical point of view.* International Journal of Agricultural Resources, Governance and Ecology, 2005. **4**(2): p. 140-151.

36. Hakansson, S., P. Gavrlita, and X. Bengoa, *Comparitive life cycle assessment of pork vs. tofu.*, in *Life Cycle Assessment 1N1800*. 2005: Stockholm.
37. Ziegler, F., et al., *Life Cycle assessment of frozen cod fillets including fishery-specific environmental impacts.* The International Journal of Life Cycle Assessment, 2003. **8**(1): p. 39-47.
38. Thrane, M., *LCA of Danish fish products: New methods and insights.* International Journal of Life Cycle Assessment, 2006. **11**(1): p. 66-74.
39. Ellingsen, H. and S.A. Aanondsen, *Environmental impacts of wild caught cod and farmed salmon - A comparison with chicken.* International Journal of Life Cycle Assessment, 2006. **11**(1): p. 60-65.
40. Seves, S.M., et al., *Sustainability aspects and nutritional composition of fish: evaluation of wild and cultivated fish species consumed in the Netherlands.* Climatic Change, 2016. **135**(3): p. 597-610.
41. Aiking, H., J. de Boer, and J. Vereijken, *Sustainable protein production and consumption: Pigs or peas?* 2006, Dordrecht: Springer.
42. Broekema, R. and H. Blonk, *Milieukundige vergelijking van vleesvervangers.* 2009, Blonk Consultants: Gouda.
43. Milieu Centraal. *Alles over energie en milieu in het dagelijks leven - Voeding.* . 2016 [cited 2015 December, 1]; Available from: https://www.milieucentraal.nl/voeding/.
44. Tukker, A., et al., *Environmental Impact of Products (EIPRO).* 2006, EC Joint Research Centre-IPTS: Seville, Spain.
45. Cederberg, C. and B. Mattsson, *Life cycle assessment of milk production—a comparison of conventional and organic farming.* Journal of Cleaner Production, 2000. **8**(1): p. 49-60.
46. Berlin, J., *Environmental life cycle assessment (LCA) of Swedish semi-hard cheese.* International Dairy Journal, 2002. **12**(11): p. 939-953.
47. Hospido, A., M.T. Moreira, and G. Feijoo, *Influence of farm size on the uncertainty of milk cycle inventory data*. 2003.
48. COWI Consulting Engineers and Planners, *Cleaner production assessment in dairy processing*. 2000, United Nations Environment Programme (UNEP) Division of Technology Industry and Economics,: Copenhagen.
49. LEI Wageningen UR. *Agrimatie Melkveehouderij*. [cited 2016 February, 1]; Available from: www.agrimatie.nl/melkveehouderij.
50. Williams, A., et al., *Are potatoes a low-impact food for GB-consumers compared to rice and pasta?* 2013, Cranfield University: Cranfield.
51. Sutton, M., et al., *The European Nitrogen Assessment: Current problems and future solutions*. 2013: Cambridge University Press.
52. De Zwart, D., *Ecological effects of pesticide use in The Netherlands: modeled and observed effects in the field ditch.* Integr. Environ. Assess. Manage., 2005. **1**(2): p. 123-134.
53. Andersson, K. and T. Ohlsson, *Life cycle assessment of bread produced on different scales. .* International Journal of LCA 1999. **4**(1): p. 25-40.

54. Braschkat, J., et al., *Life cycle assessment of bread production a comparison of eight different scenarios. Life cycle assessment in the agri-food sector.* , in *Proceedings from the 4th International Conference, 6–8 October, Denmark*. 2003, Danish Institute of Agricultural Sciences Bygholm, Denmark. p. 9-16.
55. Garnett, T., *Fruit, vegetables and UK greenhouse gas emissions: exploring the relationship. Working Paper Produced as Part of the Work of the Food Climate Research Network.* , F.C.R.N.C.f.E.S.U.o. Surrey, Editor. 2006.
56. Stoessel, F., et al., *Life cycle inventory and carbon and water foodprint of fruits and vegetables: Application to a swiss retailer.* Environmental Science and Technology, 2012. **46**(6): p. 3253-3262.
57. Stanhill, G., *The energy cost of protected cropping: A comparison of six systems of tomato production.* Journal of Agricultural Engineering Research 1980. **25**(2): p. 145-154.
58. Torrellas, M., et al., *LCA of a tomato crop in a multi-Tunnel greenhouse in Almeria.* International Journal of Life Cycle Assessment, 2012. **17**(7): p. 863-875.
59. Koroneous, C., et al., *Life cycle assessment of beer production in Greece.* Journal of Cleaner Production 2005. **13**(4): p. 433-439.
60. Hospido, A., M.T. Moreira, and G. Feijoo, *Environmental analysis of beer production.* International Journal of Agricultural Resources, Governance and Ecology, 2005. **4**(2): p. 152-162.
61. Pluimers, J., et al., *Milieuanalyse van dranken in Nederland*. 2011, Blonk Milieuadvies: Gouda.
62. Talve, S., *Life cycle assessment of a basic lager beer.* International Journal of Life Cycle Assessment, 2001. **6**(5): p. 293-298.
63. Renouf, M., *Life cycle assessment (LCA) of sugar cane production in Queensland. Interim results of work part of a broader research project – Evaluating the environmental implications of product diversification in the Australian sugar industry.* 2006, DEFRA: London.
64. Vaccari, G., et al., *Overview of the environmental problems in beet sugar processing: possible solutions.* Journal of Cleaner Production 2005. **13**(5): p. 499-507.
65. Salomone, R., *Life cycle assessment applied to coffee production: Investigating environmental impacts to aid decision making for improvements at company level.* Food, Agriculture and Environment 2003. **1**(2): p. 295-300.
66. Pelupessy, W., *Environmental issues in the production of beverages: global coffee chain*, in *Environmental-friendly food processing*, B. Mattsson and U. Sonessen, Editors. 2003, Woodhead Publishing Limited Cambridge, England. p. 95-115.
67. Andersson, K., T. Ohlsson, and P. Olsson, *Screening life cycle assessment (LCA) of tomato ketchup: A case study.* Journal of Cleaner Production, 1998. **6**(3-4): p. 277-288.
68. Ligthart, T.N., A.M.M. Ansems, and J. Jetten, *Eco-efficiency and nutritional aspects of different product/packaging systems: An integrated approach towards sustainability*. 2005, TNO: Apeldoorn.

69. Marinussen, M., et al., *De milieudruk van ons eten een analyse op basis van de voedselconsumptiepeiling 2007-2010*. 2012, Blonk Milieuadvies: Gouda.
70. FAO, *Food Wastage Footprint: Impacts on Natural Resources—Summary Report*. 2013, Food and Agriculture Organization: Rome.
71. Stenmarck, A. and et al, *Estimates of European food waste levels*. 2016: Stockholm.
72. Bos-Brouwers, H., et al., *Monitor Voedselverspilling; Update 2009-2013 & mogelijkheden tot (zelf) monitoring van voedselverspilling door de keten heen*. 2015, Wageningen UR: Wageningen.
73. Van Westerhoven, M., *Bepaling Voedselverliezen Huishoudelijk Afval in Nederland. Vervolgmeting 2013*. 2013, CREM: Amsterdam.
74. Milieu Centraal, *Brondocument Voedselverspilling*. 2012, Milieu Centraal. p. 58.
75. Biesbroek, S., et al., *Reducing our environmental footprint and improving our health: greenhouse gas emission and land use of usual diet and mortality in EPIC-NL: a prospective cohort study.* Environ Health, 2014. **13**(1): p. 27.
76. Monsivais, P., et al., *Greater accordance with the dietary approaches to stop hypertension dietary pattern is associated with lower diet-related greenhouse gas production but higher dietary costs in the United Kingdom.* American Journal of Clinical Nutrition, 2015. **102**(1): p. 138-145.
77. Van Rossum, C.T.M., et al., *Dutch National Food Consumption Survey 2007-2010. Diet of children and adults aged 7 to 69 years*. 2011, RIVM: Bilthoven.
78. van de Kamp, M.E., S.M. Seves, and E.H.M. Temme, *Reducing meat consumption during dinner and changing the type of drinks consumed lead to lower greenhouse gas emissions of Dutch diets*. 2016, RIVM: Bilthoven.
79. van Bussel, M., et al., *Socioeconomic differences in aspects of healthy, sustainable and safe food consumption among adults in the Netherlands*. 2016, RIVM: Bilthoven.
80. Vieux, F., et al., *High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults.* Am J Clin Nutr, 2013. **97**(3): p. 569-83.
81. Scarborough, P., et al., *Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK.* Clim Change, 2014. **125**(2): p. 179-192.
82. Meier, T. and O. Christen, *Environmental impacts of dietary recommendations and dietary styles: Germany as an example.* Environ Sci Technol, 2013. **47**(2): p. 877-88.
83. Arnoult, M.H., et al., *Modelling the likely impact of healthy eating guidelines on agricultural production and land use in England and Wales.* Land Use Policy, 2010. **27**(4): p. 1046-1055.
84. van Dooren, C., et al., *Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns.* Food Policy, 2014. **44**(0): p. 36-46.

85. Temme, E.H.M., et al., *Replacement of meat and dairy by plant-derived foods: Estimated effects on land use, iron and SFA intakes in young Dutch adult females.* Public Health Nutrition, 2013. **16**(10): p. 1900-1907.
86. Seves, S.M., et al., *Are more environmentally sustainable diets with less meat and dairy nutritionally adequate?* . 2016, RIVM: Bilthoven.
87. Aston, L.M., J.N. Smith, and J.W. Powles, *Impact of a reduced red and processed meat dietary pattern on disease risks and greenhouse gas emissions in the UK: a modelling study.* BMJ Open, 2012. **2**(5).
88. Hallström, E., A. Carlsson-Kanyama, and P. Börjesson, *Environmental impact of dietary change: a systematic review.* Journal of Cleaner Production, 2015. **91**: p. 1-11.
89. Berners-Lee, M., et al., *The relative greenhouse gas impacts of realistic dietary choices.* Energy Policy, 2012. **43**(0): p. 184-190.
90. Hoolohan, C., et al., *Mitigating the greenhouse gas emissions embodied in food through realistic consumer choices.* Energy Policy, 2013. **63**: p. 1065-1074.
91. Westhoek, H., et al., *Food choices, health and environment: Effects of cutting Europe's meat and dairy intake.* Global Environmental Change, 2014. **26**(1): p. 196–205.
92. Tilman, D. and M. Clark, *Global diets link environmental sustainability and human health.* Nature, 2014. **515**(7528): p. 518-22.
93. Van Kernebeek, H.R.J., et al., *Optimising land use and consumption of livestock products in the human diet with an increasing human population in the Netherlands.* Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector, 2014: p. 1439-1444.
94. Carlsson-Kanyama, A. and A.D. Gonzalez, *Potential contributions of food consumption patterns to climate change.* American Journal of Clinical Nutrition, 2009. **89**(5): p. 1704S-1709S.
95. Westhoek, H., et al., *Food choices, health and environment: Effects of cutting Europe's meat and dairy intake.* Global Environmental Change, 2014. **26**: p. 196-205.
96. Kromhout, D., et al., *The 2015 Dutch food-based dietary guidelines.* Eur J Clin Nutr, 2016. **70**(8): p. 869-78.
97. The Netherlands Nutrition Centre, *Richtlijnen Schijf van Vijf (Guidelines Wheel of Five)*. 2016: The Hague.
98. Health Council of the Netherlands, *Guidelines for a healthy diet: the ecological perspective*. 2011, Health Council of the Netherlands: The Hague.
99. WHO, *Diet, nutrition and the prevention of chronic diseases*. 2003, World Health Organization: Geneva, Swiss.
100. Vieux, F., et al., *Greenhouse gas emissions of self-selected individual diets in France: Changing the diet structure or consuming less?* Ecological Economics, 2012. **Volume 75**: p. 91–101.
101. van de Kamp, M.E., et al., *Food based dietary guidelines do not substantially reduce environmental impact unless consumption of meat or high GHG emission foods is reduced*, in *To be submitted*. 2017, RIVM: Bilthoven.

102. Green, R., et al., *The potential to reduce greenhouse gas emissions in the UK through healthy and realistic dietary change.* Climatic Change, 2015. **129**(1): p. 253-265.
103. Milner, J., et al., *Health effects of adopting low greenhouse gas emission diets in the UK.* BMJ Open, 2015. **5**(4): p. e007364.
104. De Haas, M., *Two Centuries of State Involvement in the Dutch Agro Sector. An Assessment of Policy in a long-term Historical Perspective*, in *WRR webpublicatie*. 2013, WRR: Den Haag.
105. Ministerie van LNV, *Nota Duurzaam voedsel. Naar een duurzame consumptie en productie van ons voedsel*. 2009, Ministerie van Landbouw Natuur en Voedselkwaliteit: Den Haag.
106. Ministerie van EZ, *Beleidsbrief Duurzame voedselproductie*. 2013, Ministerie van EZ (Economic Affairs): Den Haag.
107. Ministerie van EZ, *Voedselagenda voor veilig, gezond en duurzaam voedsel*. 2015, Ministerie van EZ (Economic Affairs): Den Haag.
108. European Commission, *Overview of CAP Reform 2014-2020.* 2013, European Commission: Brussels.
109. Dijksma, S., *Beleidsbrief tuinbouw*, M.v.E. Zaken, Editor. 2013: Den Haag.
110. Kamer, T., *Kamerstuk 33 322, nr. 3*. 2012: Den Haag.
111. Reijs, J.W., et al., *Sectorrapportage Duurzame Zuivelketen, prestaties 2014 in perspectief*. 2016, Wageningen UR - LEI: The Hague.
112. EZ, M., *Definitieve fosfaatproductie in 2015*. 2016: The Hague.
113. European Commission, *Sustainable food consumption and production in a resource-constrained world.*, in *3rd SCAR Foresight Exercise*. 2011: Brussels.
114. European Commission, *Roadmap to a Resource Efficient Europe*. 2011.
115. European Commission, *Closing the loop – An EU action plan for the circular economy*. 2015, EU commission: Brussels.
116. Ministerie van Economische Zaken Landbouw en Innovatie, *Factsheet Preventie Voedselverspilling*. 2012: Den Haag.
117. Soethoudt, J.M., et al., *Houdbaarheidsdatum, verspilde moeite?* 2012, Wageningen UR Food & Biobased Research: Wageningen.
118. Gustavsson, J., et al., *Global Food losses and waste - Extent, causes and prevention*. 2011, FAO: Rome.
119. Bailey, R. and D.R. Harper, *Reviewing interventions for healthy and sustainable diets*. 2015, Chatham House: The Royal Institute for International Affairs: London.
120. Gonzalez Fischer, C. and T. Garnett, *Plates, pyramids, planet. Developments in national healthy and sustainable dietary guidelines: a state of play assessment*. 2016: Rome.
121. USDA, *Scientific report of the 2015 Dietary Guidelines Advisory Committee*. 2015, USDA.
122. Nordic Council of Ministers, *Nordic Nutrition Recommendations 2012. Integrating nutrition and physical activity*. 2014, Norden: Copenhagen.
123. Ruini, L.F., et al., *Working toward Healthy and Sustainable Diets: The "Double Pyramid Model" Developed by the Barilla Center for Food and Nutrition to Raise Awareness about the Environmental and Nutritional Impact of Foods.* Frontiers in Nutrition, 2015. **2**: p. 9.

124. German Council for Sustainable Development, *The Sustainable Shopping Basket: A guide to better shopping. Retrieved from http://www.nachhaltigkeitsrat.de/uploads/media/Brochure_Sustainable_Shopping_Basket_01.pdf*. 2013.
125. National Food Agency Sweden, *Find your way to eat greener, not too much and be active. Available from: http://www.livsmedelsverket.se/globalassets/english/food-habits-health-environment/dietary-guidelines/kostrad-eng.pdf?id=8140* 2015, Livsmedelsverket: Sweden.
126. *Meatless Monday*. 2009 20-07-2015]; Available from: http://www.meatlessmonday.eu/.
127. Voedingscentrum. *Voorkom voedselverspilling 'Hoezo 50 kilo?'*. 2015 [cited 2015 May 18]; Available from: http://www.voedingscentrum.nl/nl/thema-s/hoe-voorkom-je-verspilling-Zo/over-de-campagne.aspx.
128. Janssen, E., et al., *Voedselverspilling in huishoudens Determinantenonderzoek*. 2010, ResCon, research & consultancy: Amsterdam.
129. Gustavsson, J., et al., *Global food losses and food waste.* Food and Agriculture Organization of the United Nations, Rom, 2011.
130. Garnett, T., et al., *Policies and actions to shift eating patters: What works? A review of the evidence of the effectiveness of interventions aimed at shifting diets in more sustainable and healthy directions*. 2015, Food Climate Research Network and Chatham House: Available from: http://www.fcrn.org.uk/sites/default/files/fcrn_chatham_house_0.pdf
131. FOEI, *A Wolf in Sheep's Clothing? An analysis of the 'sustainable intensification' of agriculture.*, F.o.t.E. International, Editor. 2012.
132. Loos, J., et al., *Putting meaning back into "sustainable intensification".* Frontiers in Ecology and the Environment, 2014. **12**(6): p. 356-361.
133. Konttinen, H., et al., *Socioeconomic disparities in the consumption of vegetables, fruit and energy-dense foods: the role of motive priorities.* Public Health Nutrition, 2012.
134. Brownell, K. and T. Frieden, *Ounces of prevention--the public policy case for taxes on sugared beverages.* The New England Journal of Medicine, 2009. **360**(18): p. 1805-1808.
135. Lacanilao, R.D., S.B. Cash, and W.L. Adamowicz, *Heterogeneous Consumer Responses to Snack Food Taxes and Warning Labels.* Journal of Consumer Affairs, 2011. **45**(1): p. 108-122.
136. Velthof, G.L., et al., *Integrated assessment of nitrogen losses from agriculture in EU-27 using MITERRA-EUROPE.* J Environ Qual., 2009. **38**(2): p. 402-17.
137. Pergola M., D.A.M., Celano G., Palese A.M., Scuderi A., Di Vita G., Pappalardo G., Inglese P., *Sustainability evaluation of Sicily's lemon and orange production: an energy, economic and environmental analysis.* J Environ Manage. , 2013. **128**: p. 674-82.
138. Nijdam, D., T. Rood, and H. Westhoek, *The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes.* Food Policy, 2012. **37**(6): p. 760-770.

139. Pairotti, M.B., et al., *Energy consumption and GHG emission of the Mediterranean diet: a systemic assessment using a hybrid LCA-IO method.* Journal of Cleaner Production, 2015. **103**: p. 507-516.
140. Röös, E., et al., *Evaluating the sustainability of diets-combining environmental and nutritional aspects.* Environmental Science & Policy 2015. **47**: p. 157-166.
141. Tukker, A., et al., *Environmental impacts of changes to healthier diets in Europe.* Ecological Economics, 2011. **70**(10): p. 1776-1788.
142. European Commission, *Product Environmental Footprint (PEF) Guide*. 2012, Joint Research Centre.
143. Wiedmann, T., et al., *Development of a methodology for the assessment of global environmental impacts of traded goods and services*. 2009, SKEP ERANET Project EIPOT commissioned by European Commission: York.
144. Inaba, R., et al., *Hybrid life-cycle assessment of CO2 emission with management alternatives for household food wastes in Japan.* Waste management and research 2010. **28**(6): p. 496-507.
145. True Price Foundation, *The business case for true pricing*. 2015, Deloitte, PwC, EY and True Price: Amsterdam.
146. Mattison, R., *The true cost of food*. 2015.
147. Bionext. *Alles over biologisch*. 22-05-2015]; Available from: www.bionext.nl/biologisch.
148. Campbell, B.L., S. Mhlanga, and I. Lesschaeve, *Perception versus Reality: Canadian Consumer Views of Local and Organic.* Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 2013. **61**(4): p. 531-558.
149. Willer, H. and J. Lernoud, *The world of organic agriculture. Statistics and emerging trends 2015*. 2015, Research Institute of Organic Agriculture (FiBL), Frick and IFOAM-Organics International: Bonn.
150. Bakker, J., *Monitor Duurzaam Voedsel 2013. Consumentenbestedingen aan duurzaam gelabelde producten*, André Brouwer/De Bomen, Editor. 2014, LEI Wageningen UR: Putten.
151. Schifferstein, H.N. and P.A.O. Ophuis, *Health-related determinants of organic food consumption in the Netherlands.* Food quality and Preference, 1998. **9**(3): p. 119-133.
152. Van der Jagt, P.D., P. Groen, and C. Kavvouris, *Consument aan het roer: onderzoek naar consumentenvoorkeur voor regionale producten in Wageningen en omgeving* in *Wetenschapswinkel*. 2013, Wageningen UR: Wageningen. p. 62.
153. De Lauwere, C., *Stoppen met couperen?; Varkenshouders over staartbijten en staartcouperen*. 2009, LEI Wageningen UR: Wageningen.
154. van Lier A., M.S.A., Bouwknegt M., Kretzschmar M.E., Havelaar A.H., Mangen M.J.J., Wallinga J., de Melker H.E., *Disease burden of 32 infectious diseases in the Netherlands, 2007-2011.* PLoS ONE, 2016. **11**(4): p. e0153106.
155. DeWeerdt, S., *Is local food better?* Worldwatch Institute, 2009. **22**(3).

156. Martinez, S., *Local food systems; concepts, impacts, and issues*. 2010: Diane Publishing.
157. Hinrichs, C., *Embeddedness and local food systems: notes on two types of direct agricultural market.* Journal of Rural Studies 2000. **16**: p. 295-303.
158. Feenstra, G., *Local food systems and sustainable communities.* American journal of alternative agriculture, 1997. **12**(1): p. 28-36.
159. Jones, A., *An Environmental Assessment of Food Supply Chains: A Case Study on Dessert Apples.* Environmental Management 2002. **30**(4): p. 560-576.
160. Bell, D. and G. Valentine, *Consuming geographies : we are where we eat*. 1997, London: Routledge.
161. Max Havelaar. *Wat is Fairtrade?* 2015 [cited 2016 February, 1]; Available from: http://maxhavelaar.nl/wat_is_fairtrade.

Appendix 1. Assessing the environmental impact of foods - methodologies

In this appendix, we first discuss the most common methodologies used to assess the environmental impact of foods: life cycle analysis (LCA), input-output analysis, and environmental pricing/costing.

A1.1 Life cycle analysis (LCA)

LCA is an instrument with which the environmental impacts of the production and/or use of a product are modelled from a life cycle perspective. This means that data are collected on all the emissions and resources needed for a consumer to be able to eat something, for example, an ice cream. Thus, from the production of feed for the cows that produce the milk, to the disposal of the packaging in which the ice cream came, and the energy needed to keep the ice cream frozen until consumption. A full life cycle is also called 'cradle to grave', which means that all processes, from the emissions and resources needed to grow a crop to the emissions and resources needed to treat the waste stream, are included. However, LCAs can also be performed from cradle to gate, which means that only the production of the products is taken into account and the consumption and disposal phase is neglected; or even from gate to gate, for example when two production processes are compared that have comparable ingredients.

In general, an LCA consists of an (iterative) process of four phases:

1. The goal and scope phase, to delineate the goal of the study and the life cycle stages that are taken into account (e.g. cradle to gate or grave), etc.
2. The inventory phase, where data are gathered on resource use and emissions
3. The impact assessment phase, in which the emissions are translated into impacts at midpoint and/or endpoint level
4. The interpretation phase, in which the results are interpreted in relation to the goal of the study

Endpoint is defined as: a marker at the end of the cause-effect chain that represents the impact on what we aim to sustain (biodiversity, human health, resources). Midpoints are the impacts that indicate a problem that eventually contributes to the impacts at endpoint, e.g. ozone depletion and climate change. Figure A1.1 shows the steps from the life cycle of a food product, to inventory, to impact assessment.

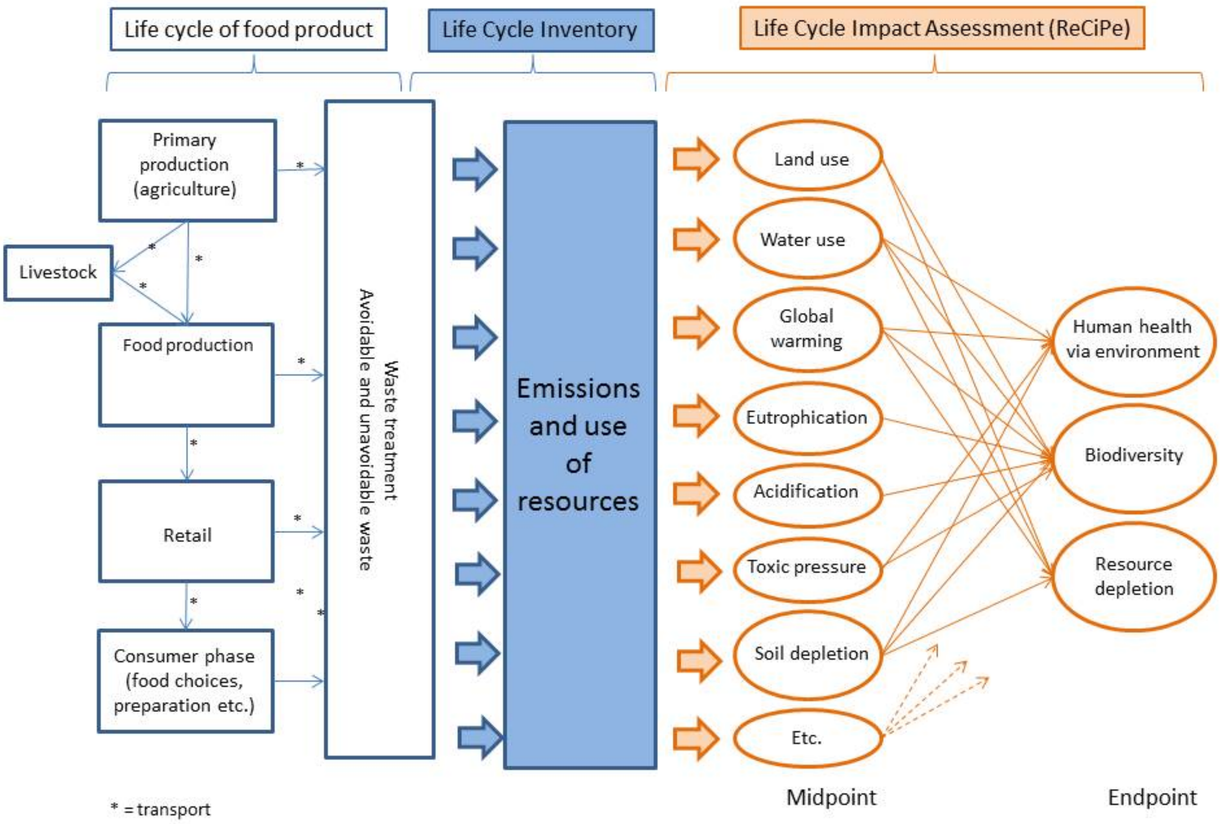

Figure A1.1. Visualization of LCA: define the system boundaries, gather data on emissions and resource use during the life cycle inventory phase, and translate these into impacts on midpoint and/or endpoint level.

Explanation of impact categories

In LCA, emissions are translated into impacts using an LCIA method. Emissions of different substances can contribute to the same type of impact. For example, CO_2, N_2O and CH_4 all contribute to global warming. To be able to sum the impacts of these different substances, characterization factors (CF) are derived.
A characterization factor expresses the impact of an emission (e.g. 1 kg CH_4) as the impact of a reference emission (e.g. in 1 kg CO_2 equivalents). For example, over a period of 100 years, 1 kg CH_4 has a 28-times higher impact on climate change than 1 kg CO_2, thus the CF of 1 kg CH_4 is 28 kg CO_2 eq. In the same way acidification is expressed in SO_2 eq, toxicity in 1,4DBeq (1,4 dichloorbenzene), and eutrophication in P eq.
The CFs are based on discipline-specific models, like the IPCC model for greenhouse gasses, and are available via LCIA methods, such as ReCiPe. The global warming potential of foods or diets is mostly referred to as carbon footprint, expressed in greenhouse gas emissions (GHG) (in kg CO_2 equivalents). This measure is, together with land use (in m^2yr), most widely used for evaluating the environmental impacts of foods and diets.

Another combined score, not calculated via the ReCiPe model, is the emission of nitrogen, including N_2O, NH_3, NO_x and NO_3. This is calculated with the MITERRA model on a deterministic and annual basis using emission and leaching factors [136]. Nitrogen emission data were the basis of the protein puzzle report. Nitrogen (N) is an essential element for plants and animals. Inputs of mineral fertilizer, crop yields and livestock farming in the Netherlands and Europe have increased markedly over the last century. As a consequence, losses of reactive N to air, soil and water have intensified as well. In the MITERRA-Europe model daily environmental impacts are calculated starting from the changes in livestock numbers, feed and land use.

In the literature, LCAs can be found on the production and consumption of many food products for example oranges [137], but also on food groups [138] and diets [e.g. 88, 139-141].
Most of these studies only cover the impacts on climate change and land use, and they have a cradle to gate perspective [88]. Compared to other types of products, it is relatively complex to perform an LCA on food products. The function of the product can vary (nutritional value, satisfaction, and flavour), there are often many processes involved with multiple outputs which require allocation (e.g. the milk, meat and leather of a dairy cow), and production is very location specific (heterogenic), as are some of the impacts (eutrophication, acidification, soil depletion, water depletion). Currently, many initiatives exist to discuss and support managing these issues, e.g. the research project LCImpact in which spatial explicit characterization factors for several impact categories are derived, the European Food Sustainable Consumption and Production Round Table that drafted the ENVIFOOD protocol (guidelines on how to approach the above-mentioned challenges, amongst others) and the release of food specific inventory databases: the Agrifootprint database by Blonk Consultants, the Agribalyse database of ADEME and, under development, the World Food LCA database of the Swiss Confederation, Agroscope and Quantis. These databases are valuable because they provide inventories (lists of emissions and resource needs per product) with comparable quality and choices between different products. Finally, under supervision of the European Commission, several working groups, consisting of LCA experts and members of the food industry, have proposed concrete choices on several product categories regarding the issues described above, in the so-called Product Environmental Footprint Category Rules (PEF-CR) [142].

A1.2 Input-output analysis

With an (environmentally extended) input-output analysis (EIOA), emissions to the environment and use of resources are allocated to sectors or product groups based on inter-sectoral economic flows. The monetary flows between sectors (food processing industry, transport sector, etc.) are available per country. Furthermore, EIOA uses data on inputs and outputs to and from the environment for each sector, gathered by national statistical offices, e.g. Statistics Netherlands.

The advantage of EIOA compared to LCA is the availability of relatively complete and consistent data [143]. Furthermore, there are no cut-offs like in LCA, all known emissions are allocated to a sector or product group. However, because EIOA is based on economic input-output tables, drawing conclusions on the level of products is tricky, i.e. most economic entities produce a wide variety of products. Thus on a product level, the product specific insights gained by e.g. an LCA are needed. Various authors have combined the advantages of EIOA and LCA, for example by using input-output tables to complete life cycle inventories [144].

Examples of tools using environmentally extended input-output tables are EIOLCA (http://www.eiolca.net/aurora-hybrid.html) and EXIOBASE (http://www.exiobase.eu/). As an example, Tukker, Goldbohm [141] used EIOA to analyse environmental impacts of the average EU diet and diets with less meat and dairy products.

A1.3 Environmental accounting/True pricing

Environmental accounting (or monetizing, true pricing or true costing) is a methodology that values (in e.g. € or $) the hidden environmental and social costs and benefits of products, as well as the effects of these costs on the financial return, now and in the future [145].
When performing a true pricing analysis for e.g. food products, like for LCA, a supply chain analysis is performed. In addition, a sectoral screening is performed to get better insights into the full sector. The supply chain analysis shows the financial, social and environmental costs throughout the supply chain of a product. The sector benchmark shows the average social and environmental costs of products in the sector at hand. Based on these analyses, it can be identified how the environmental and social costs of products can be reduced. The methodology of true pricing is quite new and under development; only a few true pricing studies are currently available on food products. One example is the analysis by the organisation TruCost [146]. They performed a true pricing analysis on three food products by examining the stages of production from farm and orchard to the supermarket shelf; for breakfast cereals, fruit juice and cheese. The embedded carbon, water, waste and pollution were calculated for generic products in each category. Then, Trucost calculated the 'natural capital' cost of each of these. For carbon they used the social cost; for water, a local issue, the volume of water required to produce the raw materials was correlated with local scarcity by gathering data on the location of production and pricing water accordingly. The analysis indicates that, on average, the true cost of a block of cheese should be 18% higher than the retail price; breakfast cereal should be 16% more expensive, and fruit juice 6% more expensive.

Appendix 2. Elaboration on some qualitative aspects related to the sustainability of foods and diets

There are several sustainability aspects related to food and the environment that cannot be directly coupled to specific foods or specific life cycle stages as presented in chapter 2. Nevertheless, these aspects play an important role in the total food production and consumption system, therefore they are reflected upon here.

A2.1 Organic foods and GMOs

A food product is organic when the food is grown without the use of chemical pesticides, chemical fertilizers or genetically modified organisms (GMOs), and with minimal use of antibiotics. In livestock farming there are criteria for animal welfare and in processing of organic products, no artificial flavourings and colourings may be added [147].

The global sales of organic foods have increased almost fivefold since 1999, up to 72 billion US dollars in 2013. In developed countries, consumers' concerns regarding food products have changed over the years, resulting in an increased demand for locally produced food and organic food products [148]. Of global organic food sales, Europe and North America generate over 90 percent. The sales of organic foods and drinks in Europe reached 31 billion US dollars in 2013 [149]. The Netherlands reached a total of organic retail sales of 840 million euros in 2013. With an average consumption worth 47.20 euro per capita in 2012, the Netherlands scored lower than the ten countries with the highest per capita consumption of organic foods (in euros, see Figure A2.1). In 2013, an increase of 50 million euros (5.4%) was seen for expenses made on organic produce. This increase is lower than the increases in previous years, as the out of home-sector hardly showed any growth. In the Netherlands, sales of organic dairy products increased by around 70% from 2009 to 2013, although a slight decrease in sales was noted in 2013 compared to 2012 (1.6%, see Table A2.1) [150].

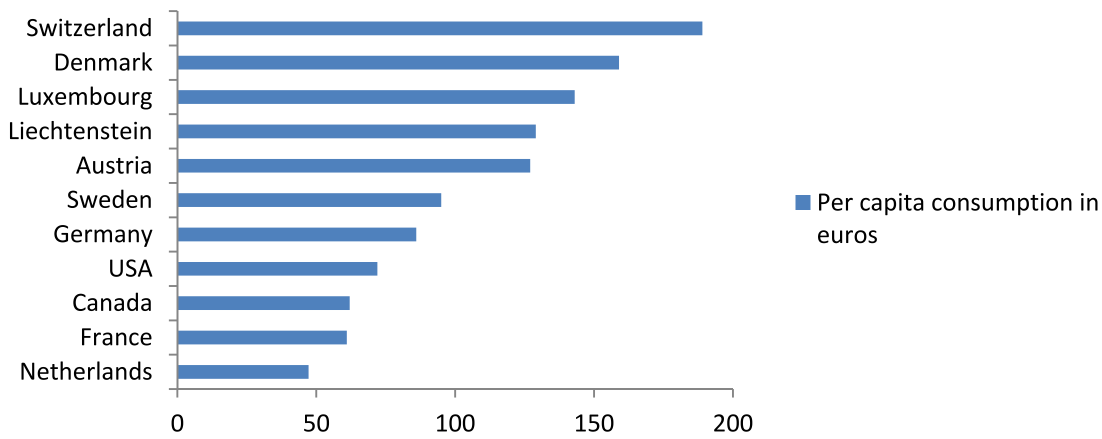

Figure A2.1. Per capita consumption of organic food in euros in 2012, for the ten countries with the highest consumption of organic foods and the Netherlands. Adapted from: FiBL AMI OrganicDataNetwork survey 2014.

Table A2.1. Expenses on organic foods in the Netherlands in 2012 and 2013, specified for different food categories. Source: [150].

Expenses on organic food, specified for several food categories			
	2012	**2013**	**Development**
Vegetables and fruit	177.1	187.7	6.0%
Bread, cereals and pastries	88.3	93.7	6.1%
Eggs	30.7	38.2	24.4%
Dairy	218.0	214.5	-1.6%
Coffee and tea	37.3	39.7	6.4%
Fish	6.9	7.4	7.2%
Meat	85.6	91.4	6.8%
Meat replacements	12.7	13.7	7.9%
Meat condiments	42.0	36.3	-13.6%
Non-perishables/other	235.8	261.7	11.0%
Total	934.2	984.2	5.4%

Dutch consumers indicate that they buy local and organic products for various reasons. They perceive them as reliable, having fewer transport miles, an absence of chemicals, a better taste, better quality and freshness, and as having benefits for the environment [151, 152].

If a product is certified organic, this does not necessarily mean it is produced in a sustainable way on all sustainability aspects. Organic is an official certification while sustainability is measurable but not officially certified. Organic farming, for instance, has no legislation on the amount of energy or energy sources it uses, on transport or on packaging. This means an organic farm can be less sustainable in some aspects than a conventional farm.

In general, for all agricultural products, it can be said that when a shift is made from conventional to organic farming, the environmental impact of land use increases (extensive agriculture), whereas the impacts of pesticides, acidification and (often) energy use decrease [28]. Moreover, organic farming can be beneficial for the local biodiversity of the farmland [e.g. 29].

The use of genetically modified organisms (GMOs) in agriculture can have great benefits. It often leads to an increased harvest (decrease of land use per ton yield) and a reduction in the use of pesticides. However, negative influences of GMOs on the environment may occur: the spread of GMOs threatens the natural biodiversity, and GMOs can pass on their characteristics to related crops, which may be harmful. Moreover, GMOs may cause allergic reactions in consumers and there are indications that some GMOs may be carcinogenic (www.milieuloket.nl; visited 1 October 2015).

A2.2 Animal welfare

Animal welfare is a sustainability indicator that lies somewhere between environmental and social sustainability. However, it is strongly linked to agriculture and the (local) environment, so it is relevant to this discussion. Animal welfare is the physical and psychological wellbeing of animals, which means that animals are free of hunger, thirst, physical discomfort, pain and illness. It also refers to their being able to conduct their natural behaviour and that they are free of stress and fear.

In animal husbandry, many animals are kept in so-called bio-industry or factory farms, which aim at producing meat products with the highest possible efficiency; the goal is to obtain a high production against the lowest possible costs. This is often associated with low animal welfare standards. Firstly, the animals are kept close together in large numbers. Due to this high concentration of animals, the animals show undesirable behaviour, which farmers try to counter with different types of interventions. Pigs for example show the tendency to bite each other's tails, which is prevented by cropping the tails [153]. To prevent cannibalism in chickens, their beaks are cut or burned.

Secondly, with large concentrations of high numbers of animals, diseases can easily break out. Antibiotics are often used to stop bacterial infections in groups of animals. Due to this large-scale use of antibiotics in the chicken sector, more and more ESBL-forming bacteria that are resistant to a large group of antibiotics reach consumers. These bacteria predominantly come from slaughtered chickens. 25% of the pig farmers in the Netherlands are infected with MRSA-bacteria, which do not respond to the common antibiotics. As long as these people are healthy, this is not problematic, but when they get in contact with vulnerable groups of people or when they get ill themselves, there is a risk. Another example is Q-fever, an infectious disease in humans that can be spread from intensive goat farms [154].

Animal welfare in the Netherlands has a legal basis in the 'Gezondheids- en welzijnswet voor dieren' (Gwwd art. 33, 1992; health and welfare law for animals). However, many NGOs like 'Dierenbescherming', 'Wakker Dier', 'Varkens in Nood', and 'Stichting Animal Freedom', but also some political parties, state that animal welfare in the bio-industry is not sufficiently protected by this legislation. The Ministry of Economic Affairs has set the goal to forbid all interventions like tail cropping in the bio-industry by 2023, which is one step forward in improving animal welfare standards at farms.

Organic farming explicitly accounts for animal welfare. The living space that animals have is larger on organic farms than it is on conventional farms, there are criteria for a minimum amount of daylight, and the animals have to be able to go outside when they want. Interventions like burning/cutting chicken beaks or cropping pig tails is not allowed in organic farming. Moreover, the animals should be fed with organically produced feed, and antibiotic use should be limited.

A2.3 Local/regional foods

Local or regional foods (Dutch: streekproducten) are products that are sold in the region of origin. Local food systems are networks of food production and consumption that aim to be geographically and economically accessible. There is no universally accepted definition of 'local' or 'regional' food. In general, a region is defined by a certain marked off physical, cultural-historical, or agricultural landscape system, but within the food sector, different definitions are applied [155].

However, independent of the strict definition of 'local' or 'regional' food products, a number of properties can be identified that characterize a local or regional food system. The idea of 'streekproducten' is that food is grown and harvested close to the consumers' homes and distribution distances are therefore much shorter [156]. In addition, it entails a direct market, where farmers sell their produce directly to consumers as opposed to through third parties. As a result, relationships develop in local food systems through face-to-face interactions, potentially leading to a stronger sense of trust and social connectedness between actors [157]. Some scholars suggest that local food systems are a good way to revitalize a community [158]. The decreased distance of food transportation has also been promoted for its environmental benefits [159]. Often, regional products are processed on a relatively small scale making use of traditional recipes. In addition, producers of local products usually are committed to animal welfare, local biodiversity and landscape issues.

Both proponents and critics of local food systems warn about drawbacks of local farming: it may lead to narrow inward-looking attitudes or 'local food patriotism', and price premiums and local food cultures can be elitist and exclusive [160].

Examples of local food systems include community-supported agriculture, farmers' markets and farm to school programs. They have been associated with the 100 Mile Diet and Low Carbon Diet, as well as the food sovereignty movement and Slow Food movement. Various forms of urban agriculture locate food production in densely populated areas not traditionally associated with farming. Garden sharing, where urban and suburban homeowners offer land access to food growers in exchange for a share of the harvest, is a relatively new trend, at the extreme end of direct local food production.

The random use of the term 'streekproduct' makes it difficult to get an idea of the exact identity of a product. Independent certification (available on EU, national and regional levels) may help consumers to select real local (and sustainably produced) products (www.streekproductenloket.nu).

A2.4 Fair trade

A fair-trade system helps farmers and workers in developing countries to improve their position in the trading chain, in order to get a better income and to enable them to invest in the future. Fair Trade is a worldwide organisation, as well as a label (see chapter 5).

The international Fair Trade organisation requires that small-scale, local farmers can organise themselves in a cooperation. As such, they have a stronger position on the world market and they can share investments. At the moment, worldwide, 1149 cooperations are a member of the Fair Trade system. Via the cooperation, the farmers can sell their products for a fair price; importers from developed countries always have to pay a minimum price. On the other hand, the farmers also have some obligations because of their participation in Fair Trade: production needs to be sustainable, which implies environmentally friendly farming, it needs to respect labour rights, and it is a transparent, democratic management system for the cooperation [161].
Well-known fair trade products are coffee, tea, chocolate and rice, but other food and non-food products are produced under the auspices of the worldwide Fair Trade organisation.

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