JRC Scientific and Technical Reports

Environmental impacts of diet changes in the EU

Authors: Arnold Tukker, Sandra Bausch-Goldbohm, Marieke Verheijden, Arjan de Koning, René Kleijn, Oliver Wolf, Ignacio Pérez Domínguez

EUR 23783 EN - 2009

JRC
EUROPEAN COMISSION

Institute for Prospective Technological Studies

Institute for Prospective Technological Studies

Environmental impacts of diet changes in the EU

Arnold Tukker, Sandra Bausch-Goldbohm, Marieke Verheijden *(TNO-NL)*

Arjan de Koning, René Kleijn *(CML)*

Oliver Wolf, Ignacio Pérez Domínguez *(JRC, IPTS)*

with support of Frederik Neuwahl and José M. Rueda-Cantuche *(JRC, IPTS)*

2009

JRC
EUROPEAN COMISSION

EUR 23783 EN

The mission of the JRC-IPTS is to provide customer-driven support to the EU policy-making process by developing science-based responses to policy challenges that have both a socio-economic as well as a scientific/technological dimension.

European Commission
Joint Research Centre
Institute for Prospective Technological Studies

Contact information
Address: Edificio Expo. c/ Inca Garcilaso,3. E-41092 Seville (Spain)
E-mail: jrc-ipts-secretariat@ec.europa.eu
Tel.: +34 954488318
Fax: +34 954488300

http://ipts.jrc.ec.europa.eu
http://www.jrc.ec.europa.eu

JRC 50544

EUR 23783 EN
ISBN 978-92-79-11774-9
ISSN 1018-5593
DOI 10.2791/88996

Luxembourg: Office for Official Publications of the European Communities

Printed in Spain

Table of contents

Summary

Introduction

In June 2006, the European Council adopted its revised sustainable development strategy. Key priorities included the topic of sustainable consumption and production (SCP) and the related environmental product policy. In 2004, the Joint Research Centre's Institute for Prospective Technical Studies (IPTS) launched the 'Environmental impacts of products' (EIPRO) study. This study was published in 2006 and showed that food (particularly meat and dairy products), mobility and housing, including energy-using products, cause the majority of environmental impacts related to final consumption expenditure. As a follow-up to EIPRO, IPTS launched the 'Improvement of products' (IMPRO) series of studies. These aim to analyse how the environmental performance of products and services in the three aforementioned areas can be improved.

The IMPRO study on meat and dairy products presented a systematic overview of the life cycle of meat and dairy products and their environmental impacts, covering the full food chain. It provided a comprehensive analysis of the improvement options that allow reducing the environmental impacts throughout the life cycle, and assessed the different options regarding their feasibility as well as their potential environmental and socioeconomic benefits and costs. The report showed that meat and dairy products contribute on average 24 % to the environmental impacts from the total final consumption in the 27 Member States of the European Union (EU-27), while constituting only 6 % of the economic value. The main improvement options were identified in agricultural production, in food management by households (avoidance of food wastage), and in power savings.

In the IMPRO study, improvement options were explored along the food supply chain, assuming that dietary habits remain constant. However, results of EIPRO and IMPRO research indicate that changed dietary habits have the potential for improved environmental impacts as well. IPTS therefore launched a study analysing the environmental impacts of diet changes in the EU-27.

For the development of alternative diets, recommendations for healthier nutrition served as a guideline, because evidence has been gathered throughout the past decades that dietary habits can have an important effect on human health. As recommendations from the World Health Organization (WHO), the European Food Safety Authority (EFSA) and other relevant sources indicated the need to reduce consumption of red meat and dairy products to reduce negative health impacts, the design of alternative diets for this study could be directly developed on that basis.

The overall aim of the study was, in summary, to:

- quantify currently prevailing diets in the EU-27;
- develop alternative diets with positive health impacts;
- analyse, quantify and compare environmental benefits related to these diets; and
- identify policy options for the dissemination of healthy diets.

The study was carried out by the Netherlands Organisation for Applied Scientific Research (TNO), the Institute of Environmental Sciences (CML) and the Institute for Prospective Technical Studies (IPTS).

Currently prevailing diets in the EU-27

The first task was to asses the prevailing diets in the EU-27. Amongst the different available and suitable data sources, the Food and Agriculture Organisation (FAO) food balance sheets (FBSs) were applied. They provide a consistent data set across the EU-27 countries, with a high level of detail in individual food products, and also give comprehensive insight diet characteristics like fat, protein and energy content. Due to the dietary variety across EU-27 countries, it was not realistic to develop one representative European diet. In order to come to a manageable number of representative diets, European countries were clustered into groups with similar diet patterns. This approach resulted in five clusters of typical diets in ascending order of vegetable/animal intake: France plus the Nordic countries, western Europe, south-west Europe, eastern Europe and south-east Europe. Although differences can be observed between the clusters, in general the current diet patterns are rich in red meat and energy and relatively low in vegetables in fruit.

Alternative diets with positive health impacts

The second task was to identify diets with positive health impacts on the basis of generally accepted, authoritative recommendations. Such balanced diet patterns are likely to have positive/preventive effects with regard to health problems like obesity, type II diabetes, cardiovascular diseases and cancer. Two diet scenarios were developed by adapting the diets per country cluster on the basis of such recommendations, as reflected by Table 1. Additionally, a third scenario was developed in which the diets in all country clusters were adapted on the basis of the prevailing diet in southern Europe. In essence this 'Mediterranean diet' is plant-centred; compared with other diets in the northern parts of the United States and Europe, it is composed of relatively frequent consumption of whole grains, fruit and vegetables, fish, olive oil and alcohol combined with low to moderate intakes of dairy products, beef, pork and lamb. Research has shown that the combined nutrients of the Mediterranean diet offer a significant source of disease prevention.

The alternative diets were developed with the restriction not to result in unrealistic nutritional patterns, such as a full vegetarian menu for all Europeans. The main reason for that was the aim to present dietary patterns which can reasonably be disseminated through policy measures and meet, partly at least, acceptance in the European population.

Environmental impacts of existing diets and three alternative scenarios

The environmental impacts of the existing diets and the three alternative scenarios were assessed with a further developed version of the model that was used in the EIPRO study, i.e. the E3IOT model. E3IOT is an environmentally extended input-output model for the EU-27. This model maps the purchases and sales of products between industry sectors. This allows calculating the added value that each individual industry sector contributes to a product that is purchased for final consumption. With the emissions and primary resource use for each industry sector available in the environmental intervention matrix, the total

Table 1. Diet recommendations in relation to Scenarios 1 and 2

Food group or nutrient	Recommendation [1]	Recommendation used in	
		Scenario 1	Scenario 2
Vegetables	At least 200 g/day	Yes	Yes
Fruit	At least 200 g/day	Yes	Yes
Fish	At least 2x/week	Yes	Yes
Fatty fish	At least 1x/week	No	No
Red meat (beef, pork, lamb) [2]	Less than 300 g/week	No	Yes
Processed meat [2]	No consumption	No	Yes
Fat [2]	Less than 30–35 % of energy	No (reduction)	No (reduction)
Saturated fat	Less than 10 % of energy	Yes	Yes
Trans-fatty acids	Less than 1 % of energy	No	No
Sugar (added) [2]	Less than 10 % of energy	Yes	Yes
Fibre	18–35 g/day	No	No
Salt	Less than 5–6 g/day	No	No

NB: Scenario 3 is not based on dietary recommendations, but the factual diets in the Mediterranean countries. For this reason Scenario 3 does not appear in this table.
Sources: Health Council of the Netherlands, 2006; WHO Regional Office for Europe, 2003; World Cancer Research Fund and American Institute for Cancer Research, 2007.
(1) For adults.
(2) Not a universal recommendation.

impacts of a product can be calculated by adding up the emissions and resource use per industry sector according to added value contributed. Emissions and resource use are expressed in the environmental impact categories used in life-cycle assessment (for example, global warming, acidification, etc.). For presentation purposes, all these scores on environmental impact categories were added after weighting to a single environmental indicator ([1]). Results of the scenario calculations are given in Table 2.

Table 2. Aggregated environmental impacts of the final consumption of food product groups and non-food product groups in the EU for Scenarios 0, 1, 2 and 3, and the same scenarios including first- and second-order effects

	Aggregated environmental impacts (%)			
	Scenario 0: Status quo	Scenario 1: Recommendations	Scenario 2: Recommendations including red meat reduction	Scenario 3: Mediterranean
Sub-scenario 'All'				
Food	27	27	25	25
Non-food	73	73	73	73
Total	100	100	98	98
Sub-scenario ' All + first order'				
Food	27	27	25	25
Non-food	73	73	74	73
Total	100	100	99	98
Sub-scenario 'All + first and second orders'	100	100	99	99

1 Where obviously a subjectivity is introduced here, we showed in the main report that the results are robust for changes in impact assessment and weighting methods, and that hence our overall conclusions are independent of the method used.

Scenario 0 reflects the baseline situation, i.e. the impacts of food consumption at the current expenditure levels per food category in the EU-27. In the three scenarios, however, in the EU-27 somewhat different food baskets are bought (2).With the new expenditures per food category in Scenarios 1, 2 and 3, the E3IOT model was run again. The first three rows labelled with sub-scenario 'All' in Table 2 provide the result of this analysis. This sub-scenario does not take into account indirect effects of a change in food consumption, such as, for example, a changed household budget for non-food products or structural changes in the agricultural sector. It hence purely provides the direct change in environmental impacts due to a change in food baskets. The aggregated environmental impact of the sum of final consumption in the European Union for the baseline or status quo situation ('Scenario 0 — All') is by definition 100 %. In the baseline situation, 27 % of these environmental impacts are associated with environmental impacts related to the final consumption of food products.

A change from the baseline scenario to the alternative diets 1, 2 and 3 results in the following outcome.

- Scenario 1 provides no reduction in environmental impacts, since it mainly focuses on enhancing fruit and vegetable intake, and does not reduce in the intake, and consequently the production of, meat.
- In Scenarios 2 and 3, the environmental impacts related to food consumption decrease from 27 % to 25 % out of all impacts related to final consumption in the EU-27. This 2 % reduction corresponds to a reduction of the impacts related to food consumption of around 8 %. It has to be kept in mind that this substantial reduction bases on the change to diets with only moderate changes in the share of meat consumption.
- Various other diet changes like limiting salt intake or limiting trans-fatty acid intake are not likely to have high environmental implications, since it concerns small mass flows (salt), or technical changes in the production chain that do not lead to major changes in primary food production (for example, transforming trans-fatty acids in healthier fat types).

First-order and second-order effects

The sub-scenario 'All' in Table 2 concerns thus the direct (economic and environmental) effects of a change in food expenditure patterns. In a subsequent step, the analysis was enlarged in two ways. The first step was to take into account the changed distribution of the household budget to non-food goods, which were named first-order effects. The second step was to analyse price and substitutional effects and the resulting structural changes in the agricultural sector, together with resulting changes in environmental impacts, which were named second-order effects.

The food basket in Scenarios 1, 2 and 3 will have a slightly different value than the food basket in baseline Scenario 0. This implies that the citizens in the EU-27 have a changed budget to spend on non-food products, if they are under the restriction of a fix household budget. These first-order effects were calculated by proportionally enhancing or diminishing the purchase of non-food products according to their consumption under the original total household budget.

2 Technically, we approached this as follows. A bridge matrix was build to link the FBS classification of food products with the classification of food expenditure categories in E3IOT. The diet recommendations from scenarios 1, 2 and 3 were translated into (relative) changes consumption per FBS category, and E3IOT expenditure per category. At this stage, prices were assumed to be constant and not influenced by change in diet patterns.

If consumers decide to spend differently, this has implications for demand and supply in certain sectors. Resulting price changes usually lead not only to a changed supply quantity, but in the mid- and longer term also to changed production structures. A related effect in open economies is a change in the trade balance, i.e. import and export are affected as well.

These secondary effects have been calculated with the CAPRI model. This partial general equilibrium model for the agro-food sector is able to estimate, for example, what alternative products food and agriculture will produce if the original demand changes due to diet changes. When such economic data are fed back into E3IOT, this gives a tentative insight into the second-order economic and environmental effects of diet changes.

By definition, Scenario 0, being the status quo, has no first or second-order effects. As for Scenarios 1, 2 and 3, the following can be concluded. The first-order effects for Scenarios 1, 2 and 3 proved to be hardly relevant and lead to a very similar outcome without first-order effects (see Table 2). Only in Scenario 2 it appears that the environmental impacts not only decrease due to changed dietary habits, but at the same time slightly increase as a reaction to changed consumption of non-food goods. The net result in this scenario is a 1 % reduction of overall environmental impacts related to final consumption in the EU-27. However, in summary the environmental impacts of diet change with and without first-order effects are basically the same.

The analysis of the second-order effects, which were calculated with the CAPRI model, revealed a somewhat different picture. In response to a changed final consumption of food products, agricultural production switched to increased exports and reduced imports of red meat products. At the same time, production and imports of products with higher demand, such as fish, increased. These changes in production resulted in supply figures which do not correspond to changed European demand, and consequently in different environmental impacts than those calculated with the E3IOT model. The environmental benefits appear to be much smaller, as can be seen in Table 2. In the last row, the environmental benefits are shown with second-order effects, and result in a reduction of 1 % of all environmental impacts related to European final consumption.

This result implies that a change in European diets has only a marginal impact on the environment. However, a shift towards alternative diets in Europe as developed in this study is nevertheless recommendable for two reasons. First, the study results analyse the impact on the European environment caused by changes in European diets. The trade balance of meat products as calculated with CAPRI shows that import of these products decreases while exports increase. That in turn implies that red meat production figures in non-European countries decrease, which might imply reduced environmental pressure in the respective non-European countries. In other words, the CAPRI calculation shows that the environmental benefits from a changed diet in the EU-27 are not occurring exclusively in Europe, but are distributed globally. However, the results from this study are not sufficient to strongly support such a hypothesis without additional research. Second, alternative diets in this study have been developed from the perspective of healthier nutrition. The assumption of increasing health through changed dietary patterns remains valid, independently of the environmental implications as calculated in the E3IOT and CAPRI models. The benefits of a large-scale reduction of obesity, diabetes, cardiovascular diseases or even cancer is sufficient justification in itself. From this perspective, a positive conclusion from this study is therefore that a shift to healthier diets in Europe has no negative environmental impacts, or even marginal improvements.

Potential policies to support implementation of healthier diets

Insights from a broad set of behavioural and systemic theories that were reviewed for this study show that changes in the behaviour of consumers and producers face important constraints. Such constraints consist of 'landscape factors' like the existing physical context (meta-structures), overarching values in society (meta-values), and interdependencies that have been developed in the production–consumption regime itself, such as habits and routines, bounded rationalities, etc. As a result it appears that recourse to awareness-raising policies such as information campaigns and product labelling is not sufficient to change long-established structures and routines in European dietary patterns.

Keeping in mind that the alternative diets developed in this study do not imply radical changes from current diets in the identified five country clusters, our policy review shows that various measures could be an effective means to stimulate such a change. Such suggestions include:

(1) working with retailers and main industry players in the food industry on 'choice editing' for sustainable and healthy food as an enabling factor for consumers to choose more healthy diets in an easy way; stimulating them to practise 'sustainability and health marketing' as a motivational factor;

(2) stimulating proactive businesses to develop healthier food products in response to trends like the need for convenience food and healthy living, and stimulating them to use bargaining power to diffuse sustainability and health standards in the supply and downstream chains;

(3) organising information campaigns, promoting sustainability and health labelling, and stemming the advertising for unhealthy dietary habits;

(4) introducing sustainable public procurement of healthy food, in particular in public institutions and organisations (hospitals, canteens of government organisations); in particular, introducing healthy meals in schools seems to be promising due to the educational effect;

(5) setting indirect incentives via, for example, healthcare systems, like lower insurance fees if a certain physical health is strived for by individuals.

1. Introduction

In June 2006, the European Council adopted its revised sustainable development strategy that included, as a key priority, the topic of sustainable consumption and production (SCP). The Commission was asked to develop an SCP action plan. This plan should build upon and combine existing initiatives like integrated product policy (IPP), the environmental technologies action plan (ETAP), ecolabelling activities, etc.

In order to support an important element of the SCP and IPP, the 'Environmental impacts of products' (EIPRO) study was launched in 2004–05 by IPTS. This study developed an environmentally extended input-output (EEIO) table for the EU-25, called CEDA-EU-25 ([3]), and reviewed a large number of other studies on the impacts of products. It showed that over 70 % of the life-cycle environmental impacts from final consumption expenditures are related to food consumption (particularly meat and dairy), mobility and housing/energy use ([4]).

It is now widely accepted that these three areas should form a priority for the SCP. Indeed, the follow-up of EIPRO, the series of studies on environmental 'Improvement potential of products' (IMPRO), focuses on improvement potentials in exactly these three domains.

The IMPRO study on meat and dairy products presented a systematic overview of the life cycle of meat and dairy products and their environmental impacts, covering the full food chain. It provided a comprehensive analysis of the improvement options that allow reducing the environmental impacts throughout the life cycle, and assessed the different options regarding their feasibility as well as their potential environmental and socioeconomic benefits and costs. The report showed that meat and dairy products contribute on average 24 % to the environmental impacts from the total final consumption in the EU-27, while constituting only 6 % of the economic value. The main improvement options were identified in agricultural production, in food management by households (avoidance of food wastage), and in power savings ([5]).

In the IMPRO study, improvement options were explored along the food supply chain, assuming that dietary habits remain constant. However, the results of EIPRO and IMPRO research indicate that changed dietary habits have the potential for improved environmental impacts as well. IPTS therefore launched this study analysing the environmental impacts of diet changes in the EU-27, addressing the following tasks:

(1) identify currently prevailing diets in the EU-27;
(2) identify alternative diets with positive health impacts;
(3) calculate impacts related to current diets;
(4) compare impacts of different diets on the basis of different diffusion scenarios;
(5) discuss the best suited policy measures for the promotion of healthier diets.

3 Comprehensive environmental database for the EU-25.

4 IPTS/ESTO (2006), Tukker, A., Huppes, G., Heijungs, R., de Koning, A., van Oers, L., Suh., S., Geerken, T., Van Holderbeke, M., Jansen, B., Nielsen, P., Eder, P. and Delgado, L., *Environmental impact of products (EIPRO)*, Technical Report EUR 22284.

5 IPTS/ESTO (2008), Weidema, B. P., Wesnaes, M., Hermansen, J., Kristensen, T., Halberg, N., Eder, P. (ed.) and Delgado, L. (ed.), *Environmental improvement potential of meat and dairy products (IMPRO meat)*, Technical Report EUR 23491 EN.

The study was carried out by a consortium consisting of the Netherlands Organisation for Applied Scientific Research (TNO) and the Institute of Environmental Sciences (CML Netherlands). TNO and CML earlier were responsible for the EIPRO study and the development of the CEDA-EU-25 model. The latter model, further developed into E3IOT [6] in the meantime, forms the backbone for the calculation of environmental impacts related to current and alternative diets in the EU (Chapter 5). Additionally, the CAPRI model was applied by IPTS to assess the indirect economic impacts of diet changes (for example, farmers switching to other production, change of the trade balance of agricultural products, etc.). TNO further drew on its expertise in food diets (Chapters 3 and 4) and its insight into policies with regard to consumer behavioural change to address the other tasks (Chapter 6).

This report discusses the results of the study:

- Chapter 2 discusses the main methodological approach to the project.
- Chapter 3 discusses the prevailing diet in EU Member States.
- Chapter 4 discusses alternative diets.
- Chapter 5 discusses the impacts of the existing and alternative diets.
- Chapter 6 provides suggestions for policies supporting diet change.
- Chapter 7 ends with conclusions.

Two annex reports complete this main report. One report provides annexes to the individual chapters in the main report that contain background information and data that are too large to be put in the main report itself. Each chapter contains references to relevant annexes. It concerns, for example:

- FAO food balance sheets;
- a description of the CAPRI model;
- tables with detailed expenditure data in different scenarios, that were used as input to E3IOT and CAPRI.

Another annex report describes in detail the E3IOT environmental and economic model.

6 Environmentally extended economic input-output tables.

2. Project approach, data sources and data linkages

2.1. Study methodology

The study relied on available data provided by organisations such as FAO or Eurostat. The actual research was carried out in the following steps.

(1) Chapters 3 and 4, dealing with prevailing and alternative diets in the EU-27, required a coherent data set on food consumption in different countries in Europe as a baseline (see Section 2.2.2). Via cluster analysis, European countries were clustered into groups with similar diet patterns, providing a representative overview of current dietary patterns. For the development of alternative diets, diet recommendations from most EU countries and some non-EU countries where gathered and archetypical recommendations derived. These recommendations were superimposed to the baseline diets for the different country clusters, leading to three different diet scenarios per country cluster. Changes in consumption of individual foodstuffs were expressed in relative terms to the baseline diet.

(2) The calculation of environmental impacts in Chapter 5 was performed with the E3IOT model. This model calculates environmental impacts on the basis of consumption expenditure data via environmentally extended input-output analysis (EEIO). The EU-27 baseline diet corresponds to the baseline expenditure on food in E3IOT. By applying the relative changes in diet, first-order changes in life-cycle impacts could be calculated.

(3) An additional analytical step was carried out in Chapter 5 by calculating dynamic changes in production with the CAPRI model. This partial equilibrium model for the agro-food sector is able to estimate, for example, what alternative products will be produced if the original demand changes due to diet changes. The feedback of such economic data in E3IOT gives a tentative insight into the second-order economic and environmental effects of diet changes.

(4) Finally, experiences with consumption policy were reviewed in Chapter 6 to identify to what extent diet change can realistically be stimulated.

The next sections describe in more detail how food data were compiled, and how the E3IOT and CAPRI models are structured. The section after that describes how food data were linked to E3IOT, and how E3IOT data were linked to CAPRI.

2.2. Data sets and classifications to be used

2.2.1. Introduction

The study methodology resulted in a relation between data sources and models that involves dietary data, E3IOT and CAPRI. The following sections discuss what data sets and related classifications were used for:

- the definition of current and simulated healthier diets;
- the calculation of environmental impacts/ E3IOT;
- the calculation of indirect economic effects/ CAPRI.

2.2.2. Dietary data

The selection of data sets for the definition of diets was done according to the following guidelines:

- data should be readily available for all 27 separate EU Member States;
- they should be classified in a way that translation into E3IOT classification is feasible;
- they should be classified in a way that they can be compared with prevailing dietary recommendations.

Roughly, three types of data relevant for representing food consumption in Europe were considered suitable.

(1) Food balance sheets (FBSs), assembled by the Food and Agricultural Organisation of the United Nations (FAO) from national statistics on production and imports and export of ingredients and primary agricultural foods: Such data are available for almost every country worldwide and are intended and mainly used for planning purposes. FBSs estimate per country the amount of food *available* per capita per day and produce derived information, such as energy, fat and protein availability per capita per day (7).

(2) Data from household budget surveys (HBS), based on surveys of households' expenditures, usually conducted with two-week diaries: From such surveys the availability of foods per household can be estimated. The DAFNE network uses HBS data to assemble a food database of such data (Naska et al., 2007; Trichopoulou et al., 2005). However, DAFNE data are not available for all EU countries

(3) Food consumption survey data: Many European countries have commissioned national food consumption surveys, conducted at regular time intervals or as a rolling system. These surveys aim at measuring food intake at the individual level and are mainly used for nutrition policy and food safety issues. In the past, each country used its own methodology and food composition database, making data between countries not completely comparable (Brussaard et al., 2002). Currently, a new effort to harmonise and standardise national food consumption surveys in Europe is under way, using a computerised 24-hour recall method ([8]). In the meantime, the European Food Safety Authority (EFSA) has composed a database with a selection of aggregated data from national food consumption surveys to be used for exposure assessment (to contaminants, etc.) in Europe, i.e. the Concise European Food Consumption Database (CEFCD) ([9]). The database contains data from 15 EU Member States and the aggregation level is more or less comparable to FBSs, although the underlying foods are those at the end of the production chain.

It was decided to use food balance sheets for the reasons below.

- The data were readily available for all 27 EU Member States, except Luxembourg. Luxembourg may have been included in Belgian data. In any case, the country's very small population compared with the EU-27 population implies that this does not form a major problem for data reliability for the countries included.

7 http://faostat.fao.org/site/502/default.aspx

8 http://www.efcoval.eu/index.htm

9 http://www.efsa.europa.eu/EFSA/ScientificPanels/DATEX/efsa_locale-1178620753812_ConciseEuropeanConsumptionDatabase.htm

- The data are designed to be used for planning purposes, i.e. for the available food supplies in countries across the world. Such data have to be available for all countries and at the level of commodities. Thus, this purpose is similar to the purpose of the current report.
- FBSs are collected as availability data, i.e. the data refer to foods as available for consumption. Such data are not equivalent to final food consumption. To calculate the environmental impact, such data are more relevant, as a consumed product has to be produced first, even though part of the product will be wasted at the consumer level.
- The detailed classification of commodities at the level of primary agricultural products could be reasonably translated into E3IOT categories as well as nutritional recommendations, using the CEFCD data for calibration.

A more detailed description of how FBSs are produced and should be interpreted can be found in Annex 1 to Chapter 2. This annex is derived from http://www.fao.org/es/ess/consweb.asp. The most recent available and complete FBS data were used, which pertain to 2003.

The classification of FBS commodities and their contribution to energy intake for the EU can be found in Annex 2 to Chapter 2.

2.2.3. E3IOT and environmental data

Environmental interventions (emissions, resource extraction) due to the production, consumption and waste disposal of food products are calculated with the E3IOT model (the improved version of the CEDA-EU-25 model, which was used in the EIPRO study (Tukker et al., 2006a)).

E3IOT is an environmentally extended input-output model that, in contrast to many other EIOA models, includes environmental interventions during the production, consumption and post-consumer waste management phase of products (Tukker et al., 2006a). The E3IOT model represents the average EU-25 economy for the year 2003. The E3IOT model has been based on harmonised OECD input-output tables for a number of European countries at the level of 35 different sectors. Further disaggregating of these 35 sectors into a total of 500 different sectors has been done on the basis of the CEDA 3.0 EIOA model (Suh, 2004). The environmental satellite has been adapted as to reflect total environmental interventions in the EU-25 in 2003 (Tukker et al., 2006a).

The E3IOT model discerns about 500 different commodities and services, of which about 250 are actually bought by consumers, the other commodities being used as intermediates only. Fifty different food items are distinguished that are bought by consumers. The different food items included in the E3IOT model are given Table 3, column 'E3IOT EU-25 category'. The classification is based on the economic sectors' classification as used by the US Department of Commerce — Bureau of Economic Analysis, which in turn is based on the North American Industry Classification System NAICS 2002.

The food products in Table 3 represent food products bought by consumers only. There are several more food items in the E3IOT model, but these are used as intermediate only (e.g. cattle). It is important to realise that the food products' group as classified in the E3IOT model represents end-products as bought by consumers in stores and not primary agricultural products as specified by the FBSs. Therefore a translation between FBS categories and E3IOT categories has been developed.

2.2.4. CAPRI

The CAPRI model is a partial equilibrium model for the EU-27, focusing on the agricultural and food sectors and making use of non-linear mathematical programming tools to maximise regional agricultural income with explicit consideration of policy instruments of support (i.e. the common agricultural policy) in an open economy where price interactions with other regions of the world are taken into account. It consists of a supply and market module, which interacts iteratively. The supply module follows a 'template approach', where optimisation models can be seen as representative farms maximising their profit by choosing the optimal composition of outputs and inputs at given prices. Major outputs of the supply module are crop acreages and animal numbers at regional level, with their associated revenues, costs and income, as well as information about feeding and nutrient management practices. The market module consists of a constrained equation system with a spatial world trade model. Major outputs of the market module include bilateral trade flows, market balances, and producer and consumer prices per product and trade partner. CAPRI describes in great detail European agriculture, and is capable of estimating how the agricultural and food sectors will respond to disruptive changes in demands, such as the simulation exercise attempted in this report. A more detailed description of CAPRI is given in Annex 5.1.

2.3. Bridges between data sets

2.3.1. From dietary data to E3IOT

The correspondence established by the project group between FBS foods and E3IOT items is presented in Table 3. In the EIPRO study, E3IOT items were grouped into the COICOP classification ('Classification of individual consumption by purpose for households'), and this classification is shown too (Tukker et al., 2006a). The correspondence was only needed and hence established for those E3IOT expenditure categories related to foodstuffs. Furthermore, the correspondence was mostly made at the level of main FBS food groups, as there was no need and/or no possibility from both a nutritional and environmental perspective to make the correspondence at subgroup level. For example, the E3IOT categories such as 'cookies and crackers' and 'cereal breakfast food' all were related to the FBS group 'cereals' with a weight based on the status quo consumption situation (according to the E3IOT data). In other words, the weights of *all* E3IOT categories that contribute to *one* FBS main category (e.g. cereals) amount to 100 %. The only exceptions were meat, which was split into red meat and poultry for nutritional reasons and into bovine meat and pig meat for environmental reasons. Also 'animal fats' were addressed at the subgroup level (i.e. butter), which was separated in whole/skimmed milk and cheese for environmental and nutritional reasons.

For the correspondence of most FBS items, on the one hand, and E3IOT food items, on the other, a satisfactory solution was found. An exception was the FBS item 'animal fats (raw)', a subgroup of the main group 'animal fats', for which no suitable counterpart was found in the E3IOT classification. This item was therefore not included in the translation. For some less important items, no correspondence was established; this was considered acceptable as these items were not the subject of the simulation.

Finally, it was decided that the current dietary situation in Europe in E3IOT would be represented by the existing expenditure on food as incorporated in E3IOT for 2003. Such data are available in the baseline consumer and government expenditure data for the EU-25 in E3IOT, which have been derived from statistical sources like COICOP for the year 2003. There is no added benefit of scaling the existing expenditure on food as incorporated in E3IOT up to 2007 for the EU-27 as the results of the E3IOT model are only used in relative comparison and it creates inconsistencies between the final consumption vector and the emission coefficients and input-output coefficients that are based on the EU-25 for the year 2003. Improved dietary situations, as simulated as several scenarios in Chapter 4, will become available as a change in each item (in g) relative to the status quo based on the FBS (also in g). Assuming the price of each product is constant, a change in weight is similar to a change in expenditure (used in the E3IOT matrix) in terms of percentage. Hence, in the simulations with alternative scenarios, the proportional changes in the FBS food groups were carried through in each corresponding E3IOT item. In this way, the new dietary scenarios are easily transformed into new expenditure scenarios, simply by imposing the same relative changes on the baseline expenditure on food.

The most important argument for this choice was that in this way the errors introduced by the translation of FBS into E3IOT are as small as possible. Also, there is no need for additional assumptions and calculations.

2.3.2. From E3IOT to CAPRI

Also for the link between E3IOT and CAPRI a bridge matrix had to be developed, since both models have different classifications of sectors and products.

The application of the CAPRI model in this study was chosen in order to better understand the potential economic and environmental reactions of the agricultural sector to a change in European diets within an open economy. The CAPRI model is a partial equilibrium model, focusing on the agricultural sector, which looks at supply and demand of primary products in the European agricultural sector, taking into account the impacts of the EU common agricultural policy and the feedback from agricultural trade at a worldwide level. The final demand vector of agricultural commodities in the E3IOT model includes end-user food products as well as non-food products. In this model, a specific shock through a new demand vector for food products would automatically lead to a new supply vector across all sectors, prices remaining as an exogenous variable. With this study, the intention is to analyse, with CAPRI, if different diets in Europe lead to changes in the European agricultural sector that are different from the production changes calculated with E3IOT. In case of significant differences between the two models in the agricultural production vector, the environmental impacts should then be calculated again on the basis of the CAPRI production figures, which are assumed to reflect the specifities of the European agricultural sector more precisely than the E3IOT model and include agricultural prices as endogenous variables.

One challenge to be addressed was the nature of product categories in the two models. Whereas CAPRI includes primary agricultural products such as beef and pork meat, the E3IOT final demand vector, which reflects current and changed diets, contains product categories like, for example, sausages and other prepared meat products. For that reason it was deemed necessary to link the intermediate food products in E3IOT, which do not appear themselves in the final food demand vector, to the respective CAPRI categories. However, as all the final food products in E3IOT are processed from these intermediate products, a bridge matrix ensured that all food-related items in the E3IOT final demand vector were covered. Accordingly it was not the final demand but intermediate demand from E3IOT which was introduced as demand shock in CAPRI. The list of intermediate products can be found in Annex 2 to Chapter 5.

As CAPRI is a model focusing on the agricultural sector, the representation of food products and product categories is more detailed than the intermediate products' disaggregation in E3IOT. The questions arising from this were how to link the differently aggregated product categories between the two models. For the data transfer from CAPRI to E3IOT, this was relatively straightforward, as most of the more detailed CAPRI categories could be included in the respective higher aggregated E3IOT categories. For example, the CAPRI products butter, milk powder, cheese, etc. were transferred to the E3IOT category dairy products. One exception in this process was the distinction between food grains and feed grains in E3IOT, which made it necessary to disaggregate a number of CAPRI categories when being transferred to E3IOT.

The construction of the bridge matrix from E3IOT to CAPRI was more challenging, as here the higher aggregated E3IOT categories had to be disaggregated to the more detailed CAPRI categories. This disaggregation was done on the basis of CAPRI production shares for the year 2002. The bridge matrix E3IOT–CAPRI can be found in Annex 2 to Chapter 5.

Through the disaggregation of categories in both directions, it became necessary to calibrate the bridge matrix from CAPRI to E3IOT for each alternative diet, which in turn led to different bridge matrices for all three diets dealt with in this report. The different bridge matrices CAPRI–E3IOT can be found in Annex 2 to Chapter 5.

2.4. Conclusion

Summarising, the project is based on the following data sets, models and calculation approaches.

(1) For establishing the food supply available to the consumer in each country of Europe, the FAO food balance sheets (FBSs) were used. The FBSs allow clustering of EU countries in groups with similar diets. Prevailing recommendations for a healthy diet provided insight into desired changes in food consumption compared with the current situation, which was formulated as changes in food items relative to the current situation.

(2) A correspondence table between the FBS and E3IOT food categories was made. The monetary expenditure on different food categories in E3IOT, derived from consumer and government expenditure data in the base year 2003, was assumed to correspond with the baseline diet as derived from the FBS.

(3) Based on monetary expenditure on food (and other products) in the base year, the EU-25 environmentally extended input-output model E3IOT provides the life-cycle impacts related to food purchase and consumption in the EU-25. Assuming that the relative changes in diet in the scenarios mentioned under (1) lead to the same relative changes in expenditure on food products, E3IOT is also capable of calculating the first-order changes in environmental impacts.

(4) Another correspondence table between E3IOT and the CAPRI model was developed, to allow the use of CAPRI for calculating second-order economic effects, which in turn could be fed back to E3IOT to calculate second-order environmental effects.

Table 3. Correspondence between COICOP, CEDA (E3IOT) and FBS food groups

COICOP category	COICOP code	E3IOT EU-25 category	E3IOT code	FAO food balance sheets
Bread and cereals	CP0111	Bread, cake and related products	[I78]	Cereals
		Cereal breakfast foods	[I72]	Cereals
		Cookies and crackers	[I79]	Cereals
		Flour and other grain mill products	[I71]	Cereals
		Frozen bakery products, except bread	[I80]	Cereals
		Macaroni, spaghetti, vermicelli and noodles	[I98]	Cereals
		Potato chips and similar snacks	[I99]	Starchy roots
		Prepared flour mixes and doughs	[I73]	Cereals
Meat	CP0112	Beef packing plants	[I53]	Bovine meat
		Pork packing plants	[I55]	Pig meat
		Miscellaneous livestock	[I5]	Mutton and goat/other meat
		Poultry slaughtering and processing	[I57]	Poultry
		Sausages and other prepared beef products	[I54]	Bovine meat
		Sausages and other prepared pork products	[I56]	Pig meat
Fish and seafood	CP0113	Canned and cured fish and seafood	[I63]	Fish and seafood
		Commercial fishing	[I19]	Fish and seafood
		Prepared fresh or frozen fish and seafood	[I68]	Fish and seafood
Milk, cheese and eggs	CP0114	Creamery butter	[I58]	Butter
		Dairy farm products	[I1]	Whole milk/skimmed milk
		Dry, condensed and evaporated dairy products	[I60]	Whole milk/skimmed milk
		Fluid milk	[I62]	Whole milk/skimmed milk
		Natural, processed and imitation cheese	[I59]	Cheese
		Poultry and eggs	[I2]	Eggs
Oils and fats	CP0115	Edible fats and oils, n.e.c.	[I96]	Vegetable oils
		Oil bearing crops	[I16]	Oilcrops
Fruit	CP0116	Dehydrated fruit, vegetables and soups	[I66]	Fruit
		Frozen fruit, fruit juices and vegetables	[I69]	Fruit/vegetables
		Fruit	[I11]	Fruit
		Tree nuts	[I12]	Tree nuts
Vegetables	CP0117	Greenhouse and nursery products	[I17]	Vegetables
		Vegetables	[I13]	Vegetables
Sugar, jam, honey, chocolate and confectionary	CP0118	Candy and other confectionery products	[I84]	Sugar and sweeteners
		Canned fruit, vegetables, preserves, jams and jellies	[I65]	Sugar and sweeteners
		Chocolate and cocoa products	[I82]	Sugar and sweeteners
		Ice cream and frozen desserts	[I61]	Sugar and sweeteners
		Sugar	[I81]	Sugar and sweeteners

COICOP category	COICOP code	E3IOT EU-25 category	E3IOT code	FAO food balance sheets
Food products, n.e.c.	CP0119	Canned specialties	[I64]	
		Food preparations, n.e.c.	[I100]	
		Frozen specialties, n.e.c.	[I70]	
		Manufactured ice	[I97]	Sugar and sweeteners
		Miscellaneous crops	[I15]	Starchy roots/pulses
		Pickles, sauces and salad dressings	[I67]	
		Salted and roasted nuts and seeds	[I83]	Tree nuts/oilcrops
Coffee, tea and cocoa	CP0121	Roasted coffee	[I95]	
Mineral waters, soft drinks, fruit and vegetable juices	CP0122	Bottled and canned soft drinks	[I89]	Sugar and sweeteners
		Flavouring extracts and flavouring syrups, n.e.c.	[I90]	Sugar and sweeteners
Spirits	CP0211	Distilled and blended liquors	[I88]	Alcoholic beverages
Wine	CP0212	Wines, brandy and brandy spirits	[I87]	Wine/alcoholic beverages
Beer	CP0213	Malt beverages	[I85]	Beer
Excluded items ([10])		Cattle	[I3]	
		Pigs	[I4]	
		Food grains	[I7]	
		Sugar crops	[I14]	
		Agricultural, forestry and fishery services	[I20]	
		Rice milling	[I76]	
		Wet corn milling	[I77]	
		Malt	[I86]	
		Cottonseed oil mills	[I91]	
		Soybean oil mills	[I92]	
		Vegetable oil mills, n.e.c.	[I93]	
		Animal and marine fats and oils	[I94]	

[10] *These items were excluded since they do not concern end-consumers*

3. Identification of diets currently prevailing in the EU-27

3.1. Introduction

Nutritionists always formulate diets in relative terms, i.e. independent of energy intake. This is because energy requirements (and therefore energy intakes) depend on variables such as age, sex, body mass and physical activity. Dietary guidelines for, and therefore also descriptions of, macronutrients (fat, protein, carbohydrates and alcohol) are therefore defined as 'energy per cent' (or 'energy %'), i.e. the contribution (in %) of the nutrient to the overall energy intake. Guidelines for other nutrients, such as vitamins and minerals, may be formulated in absolute or relative terms.

As food balance sheets are based on availability of food per capita, such data overestimate the actual per capita intake of food. However, expressed as a percentage of energy contribution, they can be directly compared with consumption data and recommendations in terms of energy percentage.

As foods are always the starting point for nutrient calculation, representative diets will be expressed in terms of foods (absolute weight for a given amount of energy) and, correspondingly, in terms of nutrients (relative to energy where applicable). In this way, we can be assured that the compiled dietary patterns are the ideal starting point for formulating healthier patterns as well as estimating environmental impacts.

3.2. Methods

3.2.1. Processing of food balance sheets

Data available on the website of the FAO for 2003 were downloaded for all EU Member States, except Luxemburg, for which no separate data were available (10). For each food group (main and subgroups; see Annex 2.2 for list of foods), the following variables were used: food/capita/year (kg), recalculated in food/capita/day (g), calories/capita/day, proteins/capita/day (g) and fat/capita/day (g). Also, the total per capita energy intake and intake of fat and protein as well as the total intake (and energy, fat and protein) from vegetable and animal foods were extracted for each Member State. The data set was enriched with data on milk products, teased out for whole milk, skimmed milk and cheese available from the FAO Statistical Yearbook, as these were not available on the Faostat website (11).

For each food item, its contribution of energy intake relative to total energy intake was calculated. Furthermore, the ratio of energy derived from vegetable foods to energy derived from animal foods was calculated for each country.

The population size of each country for 2003 was downloaded from the Eurostat website ([12]).

3.2.2. Clustering of countries according to dietary pattern

For each EU Member State, the 'vegetable energy/animal energy' ratio as well as the energy share of the most important food groups at the aggregate level were used to divide the countries into clusters. Two methods were applied:

10 http://faostat.fao.org/site/502/default.aspx
11 http://www.fao.org/statistics/yearbook/vol_1_1/site_en.asp?page=consumption
12 http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136184,0_45572595&_dad=portal&_schema=PORTAL

(1) sorting the countries by 'vegetable energy/animal energy' ratio and applying logical geographical cut-offs; this ratio was a priori considered to be an important characteristic of (differences and similarities in) dietary patterns in Europe;
(2) formal cluster analysis, using the K-means method and the same variables as above, as a confirmative method; this method is designed to cluster objects in a data set, based on the 'distance' between the objects in terms of one or more of their characteristics (see also Annex 1 to Chapter 3 for an explanation and references).

The complete food data were aggregated over countries in each cluster by calculating the mean of all variables and foods, weighted by the population size of each country in that cluster.

3.2.3. Addition and calculation of additional information

The variables available for each cluster were enriched with saturated fat, as reduction of saturated fat is an important dietary recommendation in Europe. Saturated fat for each food was based on the fat contributed by that food, multiplied by the 'saturated fat/total fat' ratio calculated from data on total fat and saturated fat in the Dutch food composition table ([13]). This was not done for foods contributing negligible amounts of saturated fats, either because the food was hardly eaten or because it contained a very small amount of saturated fat. For main food groups including foods with varying saturated fat content, such as vegetable oils, the calculation was done at the subgroup level. For others, such as milk, the value was established at the main level. A list of the values used is available in Annex 2 to Chapter 2.

In addition, the energy percentages of fat, saturated fat and protein were calculated for each cluster.

3.3. Results

Sorting by 'vegetable energy/animal energy' ratio yielded five logical clusters, divided according to geographical criteria. The results of the formal cluster analysis (Annex 1 to Chapter 3) were virtually the same as those achieved by sorting by 'vegetable energy/animal energy' ratio, if five clusters were fixed. This was because the 'vegetable energy/animal energy' ratio was by far the most important determinant of the variation between countries. Choosing less or more clusters yielded less interpretable results and less recognisable clusters. The cluster analysis revealed that, besides the 'vegetable energy/animal energy' ratio, consumption of cereals, vegetables, meat, animal fats and fish were the dietary characteristics that contributed to the differences between the clusters (see Table A3.3 in Annex 1 to Chapter 3).

A few countries (the Netherlands, Latvia, Malta, Italy) seemed to be placed in the wrong cluster, that is, according to the geographical criterion. As these were minor 'misplacements', we solved these by switching the neighbouring (according to the ratio) countries (Latvia and Malta) or shifting the cut-off one place (the Netherlands, Italy). France seemed to be even more 'geographically' misplaced in the cluster of Nordic countries. However, as most dietary characteristics and in particular the low vegetable/animal ratio (due to the high meat and dairy consumption) of France are much more similar to those of the Nordic countries than those of western Europe (as confirmed by the cluster

13 http://www.voedingswaardetabel.nl

analysis) we decided to leave France in the Nordic cluster. Due to France's large population, it contributes more weight to the cluster than the combined Nordic countries.

The results of the clusters are presented in Table 4. Values for cereals through to fish/seafood are percentages of the total energy intake. They add up to more than 100 % because 'vegetables and fruit' is included together with 'vegetables and fruit' separately.

The five clusters in ascending order of vegetable/animal intake are: Nordic countries plus France, western Europe, south-west Europe, eastern Europe, south-east Europe. Finally, note that the country list only includes 26 countries since there are no FBSs published for Luxembourg, which, given the small population of that country, has little implications for the overall picture.

The clusters Nordic countries + France (NC+F) and western Europe (WE) are both characterised by a low 'vegetable energy/animal energy' ratio, a high intake of animal fats and relatively low in cereals and vegetables consumption. However, NC+F consume more meat and fish than WE. South-east (SEE) and south-west (SWE) Europe are characterised by a relatively high consumption of vegetables and low consumption of animal fats. However, SEE consumes much more cereals (Italian pasta) and less meat, also resulting in a much higher 'vegetable energy/animal energy' ratio than SWE. SWE consumes a lot of fish. The diet in eastern Europe (EE) is characterised by a very high 'vegetable energy/animal energy' ratio, low meat, high cereal consumption and relatively high fish consumption.

Table 4 — Final clustering of European Member States with similar food patterns into five clusters, according to the contribution of each commodity group to the total per capita energy intake, based on FAO food balance sheets for 2003

	CaloriesV/ caloriesA	gProteinV/ gProteinA	gFatV/gFatA	Cereals	Starchy roots	Sugar and sweeteners	Pulses	Tree nuts	Oilcrops	Vegetable oils	Vegetables	Fruit	Alcoholic beverages	Meat	Animal fats	Milk	Eggs	Fish/seafood
Finland	*1.70*	*0.62*	*0.42*	0.275	0.043	0.105	0.004	0.002	0.006	0.081	0.015	0.029	0.058	0.158	0.042	0.140	0.010	0.019
France	*1.72*	*0.54*	*0.58*	0.245	0.032	0.106	0.005	0.007	0.005	0.121	0.029	0.024	0.047	0.146	0.079	0.110	0.016	0.013
Denmark	*1.76*	*0.56*	*0.32*	0.239	0.040	0.147	0.003	0.000	0.003	0.052	0.022	0.040	0.065	0.130	0.119	0.080	0.020	0.015
Sweden	*1.79*	*0.48*	*0.56*	0.246	0.029	0.144	0.005	0.005	0.007	0.102	0.017	0.035	0.043	0.104	0.077	0.140	0.013	0.027
Austria	*2.06*	*0.58*	*0.67*	0.239	0.030	0.117	0.002	0.011	0.011	0.119	0.016	0.045	0.075	0.131	0.086	0.090	0.013	0.006
Hungary	*2.08*	*0.86*	*0.54*	0.267	0.036	0.125	0.008	0.001	0.006	0.109	0.028	0.024	0.061	0.110	0.128	0.060	0.018	0.002
Ireland	*2.15*	*0.59*	*0.63*	0.251	0.054	0.107	0.007	0.002	0.005	0.103	0.019	0.030	0.093	0.121	0.040	0.140	0.007	0.008
Belgium	*2.24*	*0.70*	*0.81*	0.216	0.042	0.144	0.005	0.013	0.007	0.150	0.034	0.020	0.056	0.079	0.111	0.100	0.013	0.000
Slovenia	*2.25*	*0.69*	*0.67*	0.372	0.031	0.047	0.004	0.010	0.005	0.077	0.018	0.062	0.045	0.124	0.054	0.110	0.009	0.005
Germany	*2.26*	*0.69*	*0.70*	0.254	0.038	0.127	0.002	0.010	0.008	0.115	0.019	0.039	0.070	0.103	0.093	0.090	0.013	0.007
United Kingdom	*2.26*	*0.76*	*0.68*	0.259	0.062	0.116	0.012	0.003	0.011	0.111	0.020	0.033	0.056	0.133	0.044	0.100	0.013	0.011
Netherlands	*2.35*	*0.63*	*0.84*	0.229	0.044	0.142	0.005	0.012	0.006	0.119	0.020	0.050	0.050	0.096	0.048	0.120	0.017	0.014
Cyprus	*2.32*	*0.57*	*0.93*	0.238	0.023	0.140	0.012	0.014	0.024	0.109	0.035	0.041	0.040	0.137	0.018	0.110	0.015	0.014
Portugal	*2.47*	*0.70*	*0.81*	0.275	0.060	0.083	0.010	0.009	0.003	0.117	0.030	0.039	0.072	0.104	0.066	0.080	0.010	0.023
Spain	*2.54*	*0.55*	*1.38*	0.215	0.041	0.097	0.015	0.014	0.010	0.199	0.028	0.040	0.052	0.144	0.021	0.080	0.015	0.024
Malta	*2.61*	*0.84*	*0.57*	0.373	0.031	0.131	0.009	0.006	0.015	0.046	0.029	0.037	0.025	0.090	0.049	0.100	0.014	0.023
Latvia	*2.59*	*0.86*	*0.81*	0.296	0.085	0.104	0.000	0.005	0.005	0.108	0.022	0.022	0.053	0.078	0.067	0.110	0.015	0.006
Lithuania	*2.70*	*0.82*	*0.68*	0.353	0.065	0.096	0.013	0.003	0.005	0.083	0.022	0.023	0.058	0.086	0.048	0.080	0.014	0.033
Slovakia	*2.71*	*1.01*	*0.65*	0.335	0.047	0.110	0.012	0.004	0.010	0.101	0.018	0.025	0.064	0.097	0.101	0.050	0.017	0.005
Poland	*2.78*	*0.96*	*0.55*	0.352	0.071	0.132	0.004	0.001	0.004	0.085	0.021	0.018	0.044	0.110	0.066	0.060	0.013	0.012
Estonia	*2.78*	*0.74*	*0.63*	0.271	0.067	0.185	0.003	0.004	0.002	0.059	0.022	0.028	0.064	0.086	0.037	0.110	0.013	0.014
Czech Republic	*3.02*	*0.79*	*0.92*	0.289	0.037	0.146	0.008	0.005	0.013	0.112	0.015	0.027	0.086	0.094	0.052	0.080	0.016	0.006
Italy	*2.88*	*0.85*	*1.19*	0.319	0.020	0.082	0.014	0.010	0.003	0.178	0.029	0.044	0.038	0.110	0.044	0.080	0.012	0.012
Bulgaria	*3.22*	*1.03*	*1.01*	0.388	0.021	0.098	0.014	0.002	0.009	0.120	0.031	0.022	0.051	0.102	0.026	0.090	0.014	0.002
Romania	*3.35*	*1.26*	*0.85*	0.441	0.049	0.072	0.006	0.003	-0.004	0.089	0.032	0.024	0.042	0.075	0.023	0.120	0.014	0.002
Greece	*3.42*	*0.88*	*1.55*	0.296	0.032	0.091	0.012	0.017	0.015	0.165	0.043	0.051	0.037	0.084	0.012	0.110	0.009	0.010

NB: After applying the geographical criterion, countries indicated in purple were manually shifted to the neighbouring cluster

4. Identification of alternative diets with presumed positive health impacts

4.1. Introduction

In this chapter, an alternative, healthier dietary pattern is developed, with several variations, taking into account prevailing dietary recommendations. This chapter will first review how nutrition and food habits affect health and how the scientific evidence has been translated into dietary recommendations. Then, three alternative scenarios with expected positive health effects are chosen. The first two will be based on the same universal dietary recommendations, but differing with respect to red meat consumption; the third scenario took a somewhat more extreme point of departure. It was based on a Mediterranean diet, taking the dietary pattern of the south-eastern and south-western dietary pattern as an example with some modifications. The reason for this was that several studies concluded that a Mediterranean diet is recommended as being healthy (see Section 4.5).

4.2. Nutrition and health

Evidently, regular food intake is required for the basic physiological functions of everyday life, such as blood circulation, respiratory activities and cell turnover. However, making the right healthy choices in terms of nutrition also has other effects. Healthy nutrition has its beneficial effects throughout the life course, starting from foetal development and lasting into old adulthood (WHO/FAO, 2003). Indeed, evidence has shown that healthy nutrition makes people live both longer in total and longer in good health.

Making poor choices — eating too much of the wrong kinds of food and too little of the right kinds, or eating too much food altogether — increases people's risk for chronic conditions such as: heart disease (cardiovascular disease), diabetes, digestive disorders, cancer, and ageing-related loss of vision. Unhealthy diets during pregnancy can also cause serious birth defects (Willett, 2001). Indeed, it is universally recognised that a diet that is high in fat, salt and free sugars, and low in complex carbohydrates, fruit and vegetables is unhealthy (Allender et al., 2008). This paragraph will elaborate briefly on the known effects of (un)healthy food choices on individuals' health and quality of life. Evidently, the focus will be on chronic conditions with a large (public) health impact. A summary of the scientific evidence for (causal) relationships between dietary factors and obesity, type II diabetes mellitus, cardiovascular diseases, cancer, dental disorders and osteoporosis was drawn up after a joint WHO/FAO expert consultation. Part of this summary is provided in Table 5 (WHO/FAO, 2003).

Since cardiovascular diseases (CVD), cancer and diabetes are among the main causes of morbidity and mortality in Europe, and relatively much is known about the dietary factors affecting these conditions, we will elaborate on how much unhealthy diets contribute to morbidity and mortality.

Each year, cardiovascular diseases are responsible for 4.3 million deaths (48 % of mortality) in Europe and 2.0 million deaths in the European Union (42 % of mortality) (Allender et al., 2008). Apart from smoking, the main risk factors for CVD are elevated levels of blood pressure and serum cholesterol. These factors can both be attributed in part to unhealthy food consumption patterns; nutrition thus plays a dominant role in the promotion and prevention of CVD. Lloyd-Williams et al. (2008), for example, calculated that reducing saturated fat

Table 5. Summary of the strength of the evidence for relationships between dietary factors and obesity, type II diabetes mellitus, cardiovascular diseases, cancer, dental disorders and osteoporosis

	Obesity	Type II diabetes	CVD	Cancer	Dental disease	Osteoporosis
Energy and fats						
High intake of energy dense foods	C↑					
Saturated fatty acids		P↑	C↑			
Trans-fatty acids			C↑			
Dietary cholesterol			P↑			
Fish and fish oils			C↓			
Nuts (unsalted)			P↓			
Carbohydrate						
High intake of dietary fibre	C↓	P↓	P↓			
Free sugars					C↑	
Starch					C-NR	
Whole-grain cereals			P↓			
Meat						
Preserved meat				P↑		
Fruit and vegetables						
Fruit and vegetables	C↓	P↓	C↓	P↓		
Whole fresh fruit					P-NR	
Alcoholic beverages						
High alcohol intake			C↑	C↑		C↑ (*)
Low to moderate alcohol intake			C↓			

C↑: convincing evidence: increasing risk; C↓: convincing evidence: decreasing risk; C-NR: convincing evidence for absence of relation;
P↑: probable relation: increasing risk; P↓: probable relation: decreasing risk; P-NR: probable lack of relation.
(*) In populations with a high fracture rate only, i.e. men and women aged 50–60 years and older.

Source: WHO/FAO, 2003.

consumption by 1 % (for example, from 13.1 % of the total energy intake to 12.1 % of the total energy intake) and increasing monounsaturated and polyunsaturated fat by 0.5 % each would lower blood cholesterol levels by approximately 0.063 mmol/l, resulting in approximately 9 800 fewer coronary heart disease (CHD) deaths and 3 000 fewer stroke deaths each year. Furthermore, the World Health report estimates that just under 30 % of CHD and almost 20 % of stroke in developed countries is due to fruit and vegetable consumption levels below the recommended levels (WHO, 2002).

The burden of cancer is also substantial. Each year, millions of new cancers are detected across Europe (Berrino et al., 2007). It is difficult to establish the proportion of cancers directly attributable to diet (World Cancer Research Fund and American Institute for Cancer Research, 2007), although this proportion may be as high as 30 %. The most up-to-date and authoritative publication comprising (meta-analyses and systematic reviews of) all epidemiological research on diet and cancer (World Cancer Research Fund and American Institute for Cancer Research, 2007), gives the following conclusions with respect to the effect of diet on cancer risk.

- Overweight and obesity are convincing risk factors for cancers of the oesophagus (adenocarcinoma), pancreas, large bowel, breast, uterus and kidney.

- Alcohol consumption is a convincing risk factor for cancers of the mouth, pharynx, larynx, oesophagus, liver, large bowel and breast.
- Red meat (if consumed in high quantities) is a convincing risk factor for large bowel cancer.
- Vegetables and fruit are probable protective factors for cancers of the mouth, pharynx, larynx, oesophagus, lung (fruit only) and stomach.
- Growth in childhood (which in turn is influenced by yet unknown nutritional factors during childhood), as represented by attained adult height, is a convincing risk factor for large bowel and breast cancer and probably for a number of other cancers.

Finally, the estimated prevalence of diabetes mellitus in the adult populations worldwide (both in developing and developed countries) is expected to rise by 35 % from 4 % (135 million people) in 1995 to 5.4 % (300 million) in 2025 (Ramachandran and Snehalatha, 2004). Other estimates are slightly more conservative (235 million in 2025; De Beaufort et al., 2003) but the figures are still daunting. Patients with diabetes mellitus present with various symptoms as a result of their diabetes, but they are also at an increased risk of cardiovascular, cerebrovascular and peripheral vascular diseases. Diabetes is a metabolic disorder with a multifactorial aetiology. The consumption of high-energy, high-fat diets, for example, leads to the conservation of excess energy as depot fats and has an association with weight gain and type II diabetes (Ramachandran and Snehalatha, 2004). More specifically, recent research showed that rates of diabetes varied across dietary patterns and were lower among those following a healthy eating pattern in midlife, which was defined as a high consumption of fruit and vegetables, polyunsaturated oils, and high-fibre bread and breakfast cereals, and a low consumption of red meat, saturated fats and refined carbohydrate foods. These effects remained after taking account of exercise and smoking habits and were robust to adjustment for potentially confounding socioeconomic factors (Brunner et al., 2008).

As can be derived from Table 5, similar cases to support the substantial effects of unhealthy diets on the onset and development of chronic conditions can be built for many other chronic conditions than CVD, cancer and diabetes. Suffice to say here that the public health need for healthy diets across Europe is evident.

4.3. Dietary recommendations

Internationally, population nutrition goals are drawn up and presented as the desired levels of intake to maintain health in a population. In this context, health is marked by a low prevalence of diet-related (chronic) diseases in the population. Ideally, these population-based nutrition goals (or nutrition guidelines) are based on a comprehensive appraisal of high-quality scientific evidence derived from well-designed and well-conducted studies. On some topics, however, such evidence is not available and, even in the presence of a high-quality evidence base, different interpretations of the evidence may lead to different EU countries having slightly different population nutrition goals (WHO/FAO, 2003). Recently, EFSA concluded, in an attempt to establish comprehensive uniform food-based dietary guidelines for Europe, that this is not feasible, due to differences between countries and regions in dietary patterns and health problems (EFSA, 2008). In general, however, there is an apparent consensus among (European) countries, especially on the population nutrition goals that should be in place to prevent chronic diseases (WHO/FAO, 2003).

Dietary recommendations are formulated for foods (food-based dietary guidelines) (for example, 'more fruit and vegetables') as well as nutrients (for example, energy per cent of fat intake less than 35 and saturated fat intake less than 10). Such recommendations exist in many EU countries (WHO Regional Office for Europe, 2003) and are usually issued by authoritative national institutes or committees. They are sometimes also issued by international bodies, such as WHO (2002) and the World Cancer Research Fund (World Cancer Research Fund and American Institute for Cancer Research, 2007). Nowadays, these recommendations are based on prevention of nutritional deficiencies on one hand, but also aim at reducing chronic diseases and obesity on the other hand. A summary of the general (international and European) recommendations intended to prevent chronic diseases such as obesity, cardiovascular disease, diabetes, cancer and dental disease is given in Table 6.

As they are based on the same scientific evidence, the recommendations used throughout Europe (and other western societies, such as the United States) are quite similar. For example, virtually all contain the recommendations to eat at least 200 g fruit and 200 g vegetables per day, to eat (fatty) fish at least one to two times per week, to reduce the amount of salt, simple sugars and saturated and trans-fat, and to eat whole-grain rather than refined cereal (WHO Regional Office for Europe, 2003). Recommendations to reduce (saturated) fat intake are mostly implemented by the advice to shift to low-fat types of meat and dairy. Recommendations for meat consumption, if any, mostly limit the total *amount* of meat (for example, in the Netherlands, it is recommended to eat no more than 100–120 g/day (Health Council of the Netherlands., 2006)). The recently published report by the World Cancer Research Fund recommends restricting the intake of *red* meat (i.e. beef, pork and lamb) to 500 g/week (70 g/day, cooked) for an individual and to 300 g/week for a population (i.e. mean consumption of red meat in a population should not exceed 300 g/week) and to avoid processed meat (World Cancer Research Fund and American Institute for Cancer Research, 2007). This recommendation is currently the most extreme

Table 6. General dietary recommendations for Europe

Food group or nutrient	Recommendation [1]	Recommendation used in	
		Scenario 1	Scenario 2
Vegetables	At least 200 g/day	Yes	Yes
Fruit	At least 200 g/day	Yes	Yes
Fish	At least 2x/week	Yes	Yes
Fatty fish	At least 1x/week	No	No
Red meat (beef, pork, lamb)[2]	Less than 300 g/week	No	Yes
Processed meat [2]	No consumption	No	Yes
Fat [2]	Less than 30–35 % of energy	No (reduction)	No (reduction)
Saturated fat	Less than 10 % of energy	Yes	Yes
Trans-fatty acids	Less than 1 % of energy	No	No
Sugar (added) [2]	Less than 10 % of energy	Yes	Yes
Fibre	18–35 g/day	No	No
Salt	Less than 5–6 g/day	No	No

Sources: Health Council of the Netherlands, 2006; WHO Regionl Office for Europe, 2003; World Cancer Research Fund and American Institute for Cancer Research, 2007.
[1] *For adults.*
[2] *Not a universal recommendation.*

(lowest) general recommendation with respect to the consumption of meat. In general, nutritionists think that current meat consumption in many countries can be reduced without jeopardising nutritional status. The recommendations (at the food and macronutrient level) chosen for the first two scenarios are presented in Table 6. Note that (as is common practice) some of these recommendations are given in absolute weight values (for example, for vegetables as grams per day), while others are given in relative values (for example, for fat as a percentage of total energy intake). When addressing the environmental impact of the production and transportation of food items, it should be noted that this impact is a function of the commodities' weight rather than their contribution to total energy intake.

4.4. Scenarios 1 and 2

Based on the recommendations in Table 6, two scenarios with an improved dietary pattern were simulated. Some of the recommendations included in the table were not applied in the scenarios. These are listed below.

- Fatty fish: Too complex to simulate.
- Fat less than 30–35 energy %: This would be difficult to achieve for some clusters without completely changing the dietary pattern. Also, more recent developments in science tend not to support this recommendation, except for overweight people. For this reason, we aimed for a reduction in fat intake only for the clusters with a high-fat intake, without specifying a level.
- Trans-fatty acids: Trans-fatty acids originate from hydrogenation of unsaturated fat (from, for example, vegetable oils). Currently, the European industry is involved in a process to replace trans-fatty acids in products such as cookies, French fries, etc, following the improvements introduced in margarine production around 1995. It is expected that in Europe the trans-fatty acid intake will be very much reduced in a few years' time.
- Fibre: Fibre intake partly depends on the extraction rate of milled grains. Such information is not available in the FBS. Also, substitution of refined grain by whole grain is considered to have no differential environmental impact.
- Salt: No data available and a change in salt intake (of grams per day) is not considered to have an environmental impact.

The improved dietary patterns took the existing diets in the country clusters identified in Chapter 3 as a starting point and may therefore be regarded as the least drastic and most feasible alternatives for existing diets.

The first alternative scenario that was used as a basis for calculations provides insight into the environmental impact of Europe-wide changes in the current food consumption patterns towards those specified by the population nutrition goals/nutrition guidelines. A second (more demanding) scenario is based on these very same changes towards the population nutrition goals/nutrition guidelines, combined with a reduction of the intake of red and processed meat. The following recommendation on animal foods that was put forward by the World Cancer Research Fund and American Institute for Cancer Research (2007) was used as a basis: population average consumption of red meat should be no more than 300 g a week and very little (if any) of this should be processed. The term 'red meat' refers to beef, pork, lamb, and goat from domestic animals. The term 'processed meat' refers to meat preserved by smoking, curing or salting or the addition of chemical preservatives. The decision to include a reduction of red and processed meats is supported by the evidence on the adverse effects of these meats on morbidity (for example, CHD, colorectic cancer, rheumatoid arthritis and osteoporotic fractures) and mortality (see, for example: Kushi et al., 1995b; Fernández et al., 2006; Ocké and Kromhout, 2006; Oliver and Silman, 2006;

World Cancer Research Fund, 2007; Santarelli et al., 2008). A reduction of the intake of these meats is thus expected to contribute substantially to a decline in morbidity and mortality across Europe. The decision to include an alternative scenario involving reduced intakes of red and processed meat in the current study is in line with previous work posing serious questions about the environmental impact of the current consumption patterns in western developed countries, which tend to be high in these products (Nestle, 1999; Rosegrant et al., 1999; McMichael et al., 2007).

4.5. Scenario 3: the Mediterranean diet (with reduced red meat)

The third alternative scenario is based on Europe-wide changes towards the so-called Mediterranean diet. The Mediterranean diet was first named as such and proposed to be a healthy diet based on the results of the 'Seven countries study' (Keys, 1970). Although the term 'Mediterranean diet' may be taken to imply that all Mediterranean people have the same diet, individual countries around the Mediterranean basin have different combinations of diets, religions and cultures (Kafatos et al., 2000; Simopolous, 2001; Karamanos et al., 2002; Contaldo et al., 2003). It is still considered legitimate, however, to consider these individual diets as variants of a single entity: the Mediterranean diet. This diet was originally described as the dietary patterns found in olive-growing areas of the Mediterranean basin, in the late 1950s and early 1960s, when the consequences of World War II were overcome, but the fast-food culture had not yet reached the area (Trichopoulou, 2001). In essence the Mediterranean diet is plant-centred; it differs from other diets in the northern parts of the United States and Europe in that it is much lower in meat and dairy products and much higher in fruit and vegetables (Keys, 1995). It is composed of relatively frequent consumption of whole grains, fruit and vegetables, fish, olive oil and alcohol combined with low to moderate intakes of dairy products, beef, pork and lamb (Kushi et al., 1995a and 1995b). Extensive research has shown that the (combined) nutrients of the Mediterranean diet offer a significant source of primary and secondary disease prevention. There is clear evidence that the life expectancy of populations living in Mediterranean countries is longer than the life expectancy of northern Europeans (see, for example: Keys, 1970; James et al., 1989; Kushi et al., 1995a and 1995b; Trichopoulou and Vasilopoulou, 2000; Trichopoulou, 2001; Trichopoulou and Critselis, 2004; Hardin-Fanning, 2008). The Mediterranean diet thus contributes significantly to relatively low rates of morbidity and mortality. Therefore, the Mediterranean diet was chosen to be included as the third alternative scenario. This decision was supported by previous questions posed regarding the environmental impact of Mediterranean diets (Gussow, 1995).

Since the original definition of the Mediterranean diet, food consumption patterns in the relevant areas have changed (Buzina et al., 1991; Balanza et al., 2007). Furthermore, evidence has also shown that, despite the fact that the advantages of the Mediterranean diet are transferable to other populations (Kouris-Blazos et al., 1999), even temporary translocation from a Mediterranean to a northern European environment diet leads to substantial undesirable changes towards unhealthier diets (Papadaki and Scott, 2002). This poses serious concerns for the feasibility of a Europe-wide shift to the Mediterranean diet that was common approximately five decades ago. We therefore chose to define Mediterranean diet as the food consumption pattern currently observed in the Mediterranean countries (as opposed to the more traditional definition based on the diets in the 1950s and 1960s). For the same reasons as discussed for the second scenario, a reduction of red and processed meat was also included in the third scenario. This decision was supported by recent data on the 'plant and animal sources' ratio in the intakes of protein and fat, which showed remarkable differences

Table 7. Contribution of commodities to energy intake chosen for Scenario 3: the Mediterranean diet

Commodity	Energy %
Cereals (excluding beer)	31.9
Starchy roots	4.0
Sugar and sweeteners	8.5
Pulses	1.4
Tree nuts	1.3
Oilcrops	0.9
Vegetable oils	16.5
Soyabean oil	2.4
Groundnut oil	0.2
Sunflowerseed oil	5.6
Rape and mustard oil	0.3
Cottonseed oil	0.2
Palmkernel oil	0.0
Palm oil	0.3
Coconut oil	0.2 (1)
Sesameseed oil	0.0
Olive oil	6.7
Maize germ oil	0.4
Oilcrops oil, other	0.1
Vegetables	3.0
Fruit (excluding wine)	4.0
Alcoholic beverages	5.0
Red meat	4.2 (2)
Poultry meat	2.8
Animal fats (including butter)	3.2
Milk (excluding butter)	8.3
Eggs	1.3
Fish, seafood	2.3
Cocoa beans	0.3
Total	98.9

(1) *Simulated coconut oil (in %) lower than current consumption in SE and SW Europe.*
(2) *Simulated red meat (in %) lower than current consumption in SE and SW Europe.*

between the contemporary dietary patterns in the Mediterranean countries and the traditional Mediterranean diet (Karamanos et al., 2002).

The 2003 food balance sheets for south-east and south-west Europe (largely consisting of Mediterranean countries; see Table 4) largely confirm the Mediterranean food pattern and are further distinguished from the rest of Europe with respect to the low sugar intake, a higher intake of pulses and a low intake of animal fat (including butter). Contrary to what is often thought, the contemporary meat intake is quite high, particularly in south-west Europe (Spain). Only south-west, but not south-east, Europe eats a lot of fish and seafood.

Scenario 3 (Table 7) is composed of a mixture of the dietary patterns of south-east and south-west Europe, as described by their respective FBSs. However, we used the higher fish, tree nut and vegetable oil consumption of south-west Europe and the lower sugar consumption of south-east Europe. We also used the specific vegetable oils used in both clusters, with a reduced percentage of coconut oil (very high in saturated fat). Furthermore, we substantially reduced the red meat consumption in such a way that altogether 9.3 energy % is contributed by poultry, fish and red meat (instead of 15.8 % in the status quo situation of south-west Europe). After division of the weight by 1.8 (to translate availability into consumption, see Section 4.6), these amounts approximate an average daily consumption of 48, 46 and 74 g of raw red meat, poultry and fish respectively.

4.6. Calculation and simulation

Recommendations for foods are formulated at the level of individual intake, whereas FBSs represent per capita availability of foods. We calculated the factor required to make both data sources comparable by comparing the energy availability (FBS) with the energy intake of adults according to the Concise European Food Consumption Database published by EFSA. For most countries, the conversion factor for total energy was around 1.8. For two randomly chosen countries, i.e. Belgium and Italy, it was also checked whether the factor was similar for the energy contribution of the food groups:

vegetables/tree nuts/pulses, fruit, meat and fish. Altogether the factor varied between 1.7 and 2.1 between food groups and between countries. We decided to use the factor 1.8 for all conversions of recommendations expressed as absolute amount of food, i.e. vegetables, fruit, fish and meat.

The simulation was performed for each cluster and each defined scenario using a spreadsheet. The principle was to change the share of food groups in the recommended direction (see Table 6 for Scenarios 1 and 2 and Table 7 for Scenario 3), without changing the overall energy intake. Care was also taken that protein intake was maintained between 11 and 12 energy %. To achieve this, substitutions were made with favourable foods, such as cereals (to compensate for energy and protein), pulses (to compensate for protein), tree nuts and vegetable oils (to compensate, if necessary, for meat and animal fat). Substitutions were mostly made at the level of main food groups (for example, cereals), unless there was a reason to do this at a subgroup level (for example, types of meat and vegetable oils in Scenario 3).

Dairy products, although very variable between the clusters, were not reduced (except for slight changes in the Mediterranean scenario), as their consumption is very culturally determined and therefore difficult to change. They are also important for providing calcium and other nutrients. Instead, in Scenarios 1 and 2 a shift was simulated in the dairy group towards a larger share of low-fat dairy products, such as milk and cheese. Such a shift has no consequences for the environmental impact.

For each scenario, the five simulated clusters were subsequently aggregated for total Europe by weighting their results (i.e. change in specific food groups) according to their population size.

4.7. Results, discussion and conclusion

Tables 8 to 12 present the results of the simulations for each of the five country clusters identified in Chapter 3. The overall summary of results in terms of nutrient composition of the simulated diets, aggregated for the 26 Member States, is shown in Table 13. It shows that all scenarios achieved a more favourable dietary pattern in terms of reduction of fat intake, reduction of saturated fat and sugar intake to below 10 % of energy intake. Table 14 gives the integrated change for the food groups per scenario for the five country clusters combined, and translates the composition of diets per scenario in E3IOT items, making use of the FBS-E3IOT correspondence table presented before.

In general, it appeared to be very feasible to design more healthy food patterns for European regions, without introducing very unrealistic changes. The energy percentage of fat could be reduced where necessary and saturated fat could be reduced in all cases to below 10 % of energy intake by a shift from full fat to less fat types of milk and cheese, a reduction in animal fat consumption, including butter, and a minor reduction in meat consumption in high meat regions (as in Scenario 1). The only commodities with a considerable relative change on some of the country clusters are pulses and tree nuts (up to a threefold increase). However, since the absolute intake levels are very low, the proposed changes are feasible in terms of the total grams of food intake required. Some of the proposed changes, although realistic in terms of food intake, may not easily be implemented in parts of Europe other than the Mediterranean regions, since they require a shift in consumer behaviour.

The results of the simulations should not be seen as exact goals to be pursued to improve European diets. A much more in-depth investigation, including nutritional, cultural, behavioural and other aspects would be needed. Together, the simulations do give, however, a realistic perspective of the direction and approximate size of the environmental and nutritional gains that can be achieved if dietary habits across Europe changed in the desired direction.

Table 8. Nordic countries + France: Food and macronutrient availability/capita/day and relative changes according to simulated scenarios [1]

	Status quo		Scenario 1	Scenario 2	Scenario 3
Energy (kcal)	3 537		idem	idem	idem
	energy %		%	%	%
Animal products (energy %)	36.7		[2]	[2]	[2]
Total fat (energy %)	40.3		37.6	37.0	35.6
Saturated fat (energy %)	13.3		9.9	9.6	8.6
Protein (energy %)	12.4		12.5	11.9	11.6
Commodities [3]	energy %	g	**Change relative to status quo** (% of weight)		
Cereals	24.6	319	16	16	30
Starchy roots	3.3	178			21
Sugar and sweeteners	11.3	115	– 11	– 11	– 25
Pulses	0.5	5		302	178
Tree nuts	0.6	9		293	105
Oilcrops	0.5	7			65
Vegetable oils	11.2	45	40	40	48
Vegetables	2.6	352	2	2	15
Fruit	2.7	276	30	30	49
Alcoholic beverages	4.8	260			4
Meat	14.1	260			
Poultry	2.6	61			10
Red meat [4]	11.5	199			– 52
Bovine meat	2.4	71	– 20	– 61	– 52
Pig meat	8.3	108	– 20	– 61	– 52
Animal fats	2.7	13	– 65	– 65	– 59
Butter	3.8	19	– 65	– 65	– 59
Milk (excluding butter)	11.0	791			– 25
Whole milk	3.2	n.a.			
Skimmed milk	1.2	n.a.	Shift to low-fat milk and cheese		
Cheese	6.6	n.a.			
Eggs	1.6	40			– 18
Fish/seafood	1.5	85			54

[1] *Data for clusters were calculated as weighted (according to population size) means of the respective individual countries.*
[2] *Not available for alternative scenarios.*
[3] *Some food groups that contribute very little to total energy intake and not subjected to simulation are excluded from the table (e.g. sugar crops, offal, stimulants). As a result, the total energy intake does not add up to 100 %.*
[4] *Sum of bovine, mutton and goat, pig, and other meat.*

Table 9. Western Europe: Food availability/capita/day and relative changes according to simulated scenarios [(1)]

	Status quo		Scenario 1	Scenario 2	Scenario 3
Energy (kcal)	3 596		idem	idem	idem
	energy %	g	%	%	%
Animal products (energy %)	30.8		(2)	(2)	(2)
Total fat (energy %)	36.3		34.8	33.0	34.2
Saturated fat (energy %)	12.6		10.0	8.9	8.3
Protein (energy %)	11.4		12.0	11.6	11.9
Commodities [(3)]	energy %	g	**Change relative to status quo** (% of weight)		
Cereals	25.2	312	11	16	27
Starchy roots	4.6	244			– 13
Sugar and sweeteners	12.4	123	– 19	– 19	– 31
Pulses	0.6	6		261	142
Tree nuts	0.8	11		241	65
Oilcrops	0.9	9			6
Vegetable oils	11.5	45	34	34	45
Vegetables	2.0	254	42	42	47
Fruit	3.6	321	12	12	10
Alcoholic beverages	6.3	360			– 21
Meat	11.2	231			
Poultry	2.1	56			31
Red meat [(4)]	8.9	170		– 56	– 44
Bovine meat	21.5	44	– 5	– 56	– 44
Pig meat	6.9	119	– 5	– 56	– 44
Animal fats (raw)	4.1	19	– 70	– 70	– 57
Butter	2.7	13	– 50	– 50	– 57
Milk (excluding butter)	9.6	702			– 14
Whole milk	4.8	n.a.	Shift to low-fat milk and cheese		
Skimmed milk	1.1	n.a.			
Cheese	3.7	n.a.			
Eggs	1.4	34			– 5
Fish/seafood	0.9	49	33	33	169

(1) Data for clusters were calculated as weighted (according to population size) means of the respective individual countries.
(2) Not available for alternative scenarios.
(3) Some food groups that contribute very little to total energy intake and not subjected to simulation are excluded from the table (e.g. sugar crops, offal, stimulants). As a result, the total energy intake does not add up to 100 %.
(4) Sum of bovine, mutton and goat, pig, and other meat.

Table 10. South-western Europe: Food availability/capita/day and relative changes according to simulated scenarios [(1)]

	Status quo		Scenario 1	Scenario 2	Scenario 3
Energy (kcal)	3 483				
	energy %	g	%	%	%
Animal products (energy %)	28.4		(2)	(2)	(2)
Total fat (energy %)	39.4		39.0	36.0	34.3
Saturated fat (energy %)	9.9		9.8	8.5	8.2
Protein (energy %)	12.4		12.3	12.0	11.4
Commodities [(3)]	energy %	g	**Change relative to status quo** (% of weight)		
Cereals	22.9	291		16	39
Starchy roots	4.5	239			– 11
Sugar and sweeteners	9.5	94			– 10
Pulses	1.4	15		29	– 1
Tree nuts	1.3	22		33	1
Oilcrops	0.9	14			6
Vegetable oils	17.9	71			– 8
Vegetables	2.8	414			4
Fruit	4.0	310	16	16	1
Alcoholic beverages	5.6	298			– 11
Meat	13.5	314			
Poultry	2.9	79		75	– 2
Red meat ([4])	10.5	227		– 67	– 48
Bovine meat	1.7	44	– 6	– 67	– 48
Pig meat	7.8	168	– 6	– 67	– 48
Animal fats (raw)	2.1	10			4
Butter	0.6	3			4
Milk (excluding butter)	7.7	499			8
Whole milk	5.1	n.a.			
Skimmed milk	0.5	n.a.	Shift to low-fat milk and cheese		
Cheese	2.0	n.a.			
Eggs	1.4	34			– 6
Fish/seafood	2.3	136			– 2

[(1)] Data for clusters were calculated as weighted (according to population size) means of the respective individual countries.
[(2)] Not available for alternative scenarios.
[(3)] Some food groups that contribute very little to total energy intake and not subjected to simulation are excluded from the table (e.g. sugar crops, offal, stimulants). As a result, the total energy intake does not add up to 100 %.
[(4)] Sum of bovine, mutton and goat, pig, and other meat.

Table 11. Eastern Europe: Food availability/capita/day and relative changes according to simulated scenarios [(1)]

	Status quo		Scenario 1	Scenario 2	Scenario 3
Energy (kcal)	3288				
	energy %	g	%	%	%
Animal products (energy %)	26.3		(2)	(2)	(2)
Total fat (energy %)	30.1		30.5	30.3	34.4
Saturated fat (energy %)	9.9		9.9	9.3	8.5
Protein (energy %)	11.5		12.0	11.5	11.9
Commodities (3)	energy %	g	**Change relative to status quo** (% of weight)		
Cereals	33.7	369	– 6		– 5
Starchy roots	6.4	296		– 32	– 37
Sugar and sweeteners	13.0	116	– 23	– 23	– 35
Pulses	0.6	5		233	146
Tree nuts	0.2	2			433
Oilcrops	0.6	6			43
Vegetable oils	9.1	31		25	72
Vegetables	2.0	238	52	52	53
Fruit	2.1	139	159	159	93
Alcoholic beverages	5.4	260			– 8
Meat	10.3	186			
Poultry	2.2	49			30
Red meat (4)	8.1	135		– 44	– 39
Bovine meat	0.9	19		– 44	– 39
Pig meat	7.2	116		– 44	– 39
Animal fats (raw)	3.3	13			– 51
Butter	2.5	11			– 51
Milk (excluding butter)	6.7	453			24
Whole milk	2.3	n.a.	Shift to low-fat milk and cheese		
Skimmed milk	0.8	n.a.			
Cheese	3.7	n.a.			
Eggs	1.4	30			– 8
Fish/seafood	1.1	41	60	60	105

(1) Data for clusters were calculated as weighted (according to population size) means of the respective individual countries.
(2) Not available for alternative scenarios.
(3) Some food groups that contribute very little to total energy intake and not subjected to simulation are excluded from the table (e.g. sugar crops, offal, stimulants). As a result, the total energy intake does not add up to 100 %.
(4) Sum of bovine, mutton and goat, pig, and other meat.

Table 12. South-eastern Europe: Food availability/capita/day and relative changes according to simulated scenarios [1]

	Status quo		Scenario 1	Scenario 2	Scenario 3
Energy (kcal)	3 590				
	energy %	g	%	%	%
Animal products (energy %)	24.6		(2)	(2)	(2)
Total fat (energy %)	34.6		34.3	32.5	34.3
Saturated fat (energy %)	9.4		9.3	8.4	8.4
Protein (energy %)	12.1		12.1	11.9	12.1
Commodities [3]	energy %	g	**Change relative to status quo** (% of weight)		
Cereals	34.8	466	– 1	4	– 8
Starchy roots	2.8	152		7	43
Sugar and sweeteners	8.2	84			4
Pulses	1.2	13		32	17
Tree nuts	0.9	15		54	46
Oilcrops	0.5	11			79
Vegetable oils	15.3	62			8
Vegetables	3.2	512			
Fruit	3.9	305	18	18	3
Alcoholic beverages	4.0	210			26
Meat	9.9	222			
Poultry	1.6	47		75	72
Red meat [4]	8.0	165		– 56	– 41
Bovine meat	2.7	53	– 7	– 56	– 41
Pig meat	4.7	103	– 7	– 56	– 41
Animal fats (raw)	2.1	11			– 8
Butter	1.1	5			– 8
Milk (excluding butter)	8.8	654			5
Whole milk	4.3	n.a.	Shift to low-fat milk and cheese		
Skimmed milk	0.6	n.a.			
Cheese	3.8	n.a.			
Eggs	1.2	31			5
Fish/seafood	0.9	52	25	25	150

(1) Data for clusters were calculated as weighted (according to population size) means of the respective individual countries.
(2) Not available for alternative scenarios.
(3) Some food groups that contribute very little to total energy intake and not subjected to simulation are excluded from the table (e.g. sugar crops, offal, stimulants). As a result, the total energy intake does not add up to 100 %.
(4) Sum of bovine, mutton and goat, pig, and other meat.

Table 13. Summary of nutrient composition (energy %) of the average European diet (2003) and of simulated dietary scenarios

Scenario	Type	Fat (%)	Protein (%)	Saturated fat (%)
Status quo	2003	36.2	11.8	11.4
Scenario 1	Dietary recommendations	35.1	12.1	9.8
Scenario 2	Dietary recommendations + low red meat	33.6	11.7	8.9
Scenario 3	Mediterranean + reduced red meat	34.5	11.8	8.4

Table 14. Changes in food use relative to status quo (%) in the three dietary scenarios aggregated over five regional clusters presented in Table 4 and linked to CEDA (E3IOT) items

E3IOT category	E3IOT code	Items food balance sheets	Relative change (%)		
			Scenario 1	Scenario 2	Scenario 3
Bread, cake and related products	[I78]	Cereals	5.2	10.6	14.6
Cereal breakfast foods	[I72]	Cereals	5.2	10.6	14.6
Cookies and crackers	[I79]	Cereals	0.0	0.0	14.6
Flour and other grain mill products	[I71]	Cereals	5.2	10.6	14.6
Frozen bakery products, except bread	[I80]	Cereals	5.2	10.6	14.6
Macaroni, spaghetti, vermicelli and noodles	[I98]	Cereals	5.2	10.6	14.6
Potato chips and similar snacks	[I99]	Starchy roots			– 4.3
Prepared flour mixes and doughs	[I73]	Cereals	5.2	10.6	14.6
Beef packing plants	[I53]	Beef	– 9.1	– 40.3	– 58.8
Pork packing plants	[I55]	Pork	– 7.2	– 39.2	– 58.8
Miscellaneous livestock	[I5]	Mutton and goat/other meat		– 58.0	– 58.8
Poultry slaughtering and processing	[I57]	Poultry		24.0	28.9
Sausages and other prepared beef products	[I54]	Beef	– 9.1	– 100	– 58.8
Sausages and other prepared pork products	[I56]	Pork	– 7.2	– 100	– 58.8
Canned and cured fish and seafood	[I63]	Fish and seafood	18.9	18.9	95.4
Commercial fishing	[I19]	Fish and seafood	18.9	18.9	95.4
Prepared fresh or frozen fish and seafood	[I68]	Fish and seafood	18.9	18.9	95.4
Creamery butter	[I58]	Butter	– 41.9	– 41.9	– 47.6
Dairy farm products	[I1]	Whole milk/skimmed milk			– 9.3
Dry, condensed and evaporated dairy products	[I60]	Whole milk/skimmed milk			– 9.3
Fluid milk	[I62]	Whole milk/skimmed milk			– 9.3
Natural, processed and imitation cheese	[I59]	Cheese			– 9.3
Poultry and eggs	[I2]	Eggs			– 6.0
Edible fats and oils, n.e.c.	[I96]	Vegetable oils	18.3	20.2	40.6
Oil bearing crops	[I16]	Oilcrops			33.1
Dehydrated fruit, vegetables and soups	[I66]	Fruit	25.8	25.8	18.6
Frozen fruit, fruit juices and vegetables	[I69]	Fruit/vegetables	22.1	22.1	18.6
Fruit	[I11]	Fruit	25.8	25.8	18.6
Tree nuts	[I12]	Tree nuts		151.5	62.2
Greenhouse and nursery products	[I17]	Vegetables	17.4	17.4	22.0

E3IOT category	E3IOT code	Items food balance sheets	Relative change (%)		
			Scenario 1	Scenario 2	Scenario 3
Vegetables	[I13]	Vegetables	17.4	17.4	22.0
Candy and other confectionery products	[I84]	Sugar and sweeteners	– 13.7	– 13.7	– 23.3
Canned fruit, vegetables, preserves, jams and jellies	[I65]	Sugar and sweeteners	– 13.7	– 13.7	– 23.3
Chocolate and cocoa products	[I82]	Sugar and sweeteners	– 13.7	– 13.7	– 23.3
Ice cream and frozen desserts	[I61]	Sugar and sweeteners	– 13.7	– 13.7	– 23.3
Sugar	[I81]	Sugar and sweeteners	– 13.7	– 13.7	– 23.3
Canned specialties	[I64]				
Food preparations, n.e.c.	[I100]				
Frozen specialties, n.e.c.	[I70]				
Manufactured ice	[I97]	Sugar and sweeteners	– 13.7	– 13.7	– 23.3
Miscellaneous crops	[I15]	Starchy roots/pulses		5.1	– 1.4
Pickles, sauces and salad dressings	[I67]				
Salted and roasted nuts and seeds	[I83]	Tree nuts/oilcrops		119.0	55.0
Roasted coffee	[I95]				
Bottled and canned soft drinks	[I89]	Sugar and sweeteners	– 13.7	– 13.7	– 23.3
Flavouring extracts and flavouring syrups, n.e.c.	[I90]	Sugar and sweeteners	– 13.7	– 13.7	– 23.3
Distilled and blended liquors	[I88]	Alcoholic beverages			– 7.9
Wines, brandy and brandy spirits	[I87]	Alcoholic beverages			– 7.9
Malt beverages	[I85]	Alcoholic beverages			– 7.9

5. Environmental impacts related to current and alternative diets

5.1. Introduction

Environmental interventions (emissions and resource extraction) due to the production, consumption and waste disposal of food products are calculated with the E3IOT model (European environmentally extended input-output table).

E3IOT is an environmentally extended input-output model that, in contrast to many other EIOA models, includes environmental interventions during the production, consumption and waste management phase of products. The E3IOT model represents the average EU-25 economy for the year 2003. It is described in detail in a specific annex to this report.

E3IOT is the updated version of the CEDA-EU-25 model which was used in the EIPRO study ([14]). In this model, the environmental emissions for all food products have been estimated within the same consistent framework so that there is no methodological bias in the assessment of the food products. About 1 200 different environmental interventions are characterised in the E3IOT model, including fossil energy use, emissions to air, water and soil, etc., which allows for an unbiased assessment of the environmental impacts of the consumer products. For instance, there is no particular emphasis on processes with a high emission of major air pollutants. The E3IOT model not only allows for the assessment of the environmental interventions of food products, but for all products consumed by final consumers. This makes it possible to place the environmental interventions of the food products in perspective with other (non-food) products and total economy-wide environmental interventions or in terms of eco-efficiency.

The E3IOT model basically contains two improvements over the CEDA-EU-25 model.

(1) Some of the environmental interventions, specifically metal compounds, have been aggregated, which makes the calculation of the environmental impacts of these substances more easy. Like CEDA-EU-25, the E3IOT model is able to provide data on individual emissions and other primary interventions.
(2) Aggregating individual environmental interventions to scores on environmental impact categories with CEDA-EU-25 was quite cumbersome because it required the manual operation of several Matlab scripts. E3IOT has been incorporated in the CMLCA life-cycle software tools, which allows for the automatic calculation of the environmental impacts associated with the consumption of food products and other consumer products.

CMLCA is the software tool used for calculations with the E3IOT model. CMLCA can be used for life-cycle assessment, environmentally extended input-output analysis and hybrid analysis ([15]).

To be able to reach a high level of detail in the E3IOT model, US data have been used

14 Tukker et al., 2006a, 2006b; Huppes et al., 2006; Heijungs et al., 2006.

15 CMLCA was developed in house by CML and is likely one of the most advanced life-cycle analysis tools available. The mathematical basis for the calculations was described in Heijungs and Suh (2002) and Heijungs et al. (2006). The program concentrates on the computational aspects of life-cycle analysis. It is based on matrix algorithms and contains a large number of possibilities for numerical analysis. It is available free of charge for educational and research purpose from CML.

to subdivide the more aggregated EU-25 input-output data into 500 different sectors (see the E3IOT annex report). At the aggregated level of about 35 sectors, the E3IOT model conforms to an aggregation of the OECD input-output tables of some of the most important European countries; the total environmental interventions are in conformity with total European emission data. This means that, at the highest level of detail, process information assumes similarity in production processes in the United States and Europe for most products. For several key sectors in the economy (agriculture, energy mix for electricity generation), the technical coefficients have been changed to European standards. The industry sectors given in Table 3 do not contain implicit information on US diets. It is only the final consumption expenditure on these products that constitutes the diet.

The starting point for the calculation of the environmental impacts due to the final consumption of products with environmentally extended input-output analysis is the Leontief inverse, $(\mathbf{I}-\mathbf{A})^{-1}$, in which $\mathbf{A}$ is the technology matrix (Leontief, 1970). The technology matrix specifies for one monetary unit of output of a sector how much in the way of inputs from other sectors is required for producing it and also how the production of one unit is distributed over all users of the product involved. Next, a matrix $\mathbf{B}$ is specified representing the direct environmental interventions for each sector. The total direct and indirect environmental interventions induced to deliver a certain amount of each input can be calculated by:

$$\mathbf{m}=\mathbf{B}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{k} \qquad (1)$$

where $\mathbf{m}$ = the total direct and indirect interventions vector and $\mathbf{k}$ is the final demand vector, specifying the expenditure for each product. The total of direct plus indirect demand for each sector which represents the total supply of each industry can be calculated from:

$$\mathbf{x}=(\mathbf{I}-\mathbf{A})^{-1}\mathbf{k} \qquad (2)$$

where $\mathbf{x}$ = the total supply vector. Having a known total supply vector, emissions associated with this total supply are calculated accordingly:

$$\mathbf{m} = \mathbf{Bx} \qquad (3)$$

E3IOT, in contrast to many other EIOA models, takes into account environmental interventions during the production, consumption and waste management phase of products. Therefore the technology matrix of the E3IOT model also contains matrices for consumption activities ($\mathbf{A}_{22}$) and post-consumer waste management ($\mathbf{A}_{33}$). To systematically record the relations between these three activities, six linking matrices are specified ($\mathbf{A}_{12}$, $\mathbf{A}_{13}$, $\mathbf{A}_{21}$, $\mathbf{A}_{23}$, $\mathbf{A}_{31}$, $\mathbf{A}_{32}$; see equation 4). For each of the three activity groups a corresponding $\mathbf{B}$ matrix has been developed which makes the total E3IOT model:

$$\mathbf{m}=(\mathbf{B}_1\,\mathbf{B}_2\,\mathbf{B}_3)\times\left(\mathbf{I}-\begin{pmatrix}\mathbf{A}_{11} & \mathbf{A}_{12} & \mathbf{A}_{13}\\ \mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{A}_{23}\\ \mathbf{A}_{31} & \mathbf{A}_{32} & \mathbf{A}_{33}\end{pmatrix}\right)^{-1}\mathbf{k} \qquad (4)$$

The E3IOT model discerns about 500 different commodities and services, of which about 250 are actually bought by consumers, the other commodities being used as intermediates only. About 50 different food items are distinguished that are bought by consumers. The different food items included in the E3IOT model plus the food items that will be added to the E3IOT model for this specific project (see Section 5.2, 'Specific adaptations of the E3IOT model') are presented in Table 3. The food products in Table 3 represent food products bought by final consumers only. There are several more food items in the E3IOT model, but these are used as intermediate only (e.g. cattle).

Of particular importance for the analysis of the environmental impacts of dietary changes is the distinction that can be made between different animal products in the adapted E3IOT food model. The meat products that can be distinguished are:

- poultry products from the industry sector 'poultry slaughtering and processing';
- pork products from the two industry sectors 'pork packing plants' and 'sausages and other prepared pork products';
- beef products from the two industry sectors 'beef packing plants' and 'sausages and other prepared beef products';
- miscellaneous meat products (goats, sheep, etc.) from the industry sector 'miscellaneous livestock'.

The 'miscellaneous livestock' industry sector also includes items such as pet animals.

Because the E3IOT model takes into account the complete life cycle of all consumed products and no cut-offs have to be made in the life-cycle chains, it is well suited for analysing the environmental impacts due to the consumption of all product groups or particular product groups. However, the application of EIOA for product comparisons is often hampered by the very high level of aggregation in the product groups. E3IOT overcomes this challenge due to its high level of product disaggregation.

5.2. Specific adaptations of the E3IOT model

The most import adaptation to the existing E3IOT model for this project is the subdivision of the default meat sectors into a pork and beef sector variant. The default meat sectors are raising of meat animals ('meat animals') and two sectors that process meat ('meat packing plants' and 'sausages and other prepared meat products'). Consumers buy only at the meat processing sectors while the sector 'meat animals' supplies meat as an intermediate product to the meat processing sectors. All these three sectors will be split into a beef and pig variant.

The meat animals sector has been subdivided on the basis of LCA (life-cycle assessment) data available from the Danish food LCA database (Nielsen et al., 2003). These LCA data have not been used directly but as proxy for the coefficients that describe the subdivision of the emission coefficients and technical coefficients of the original meat animals sector. There are three reasons why we did not use the LCA data directly but have used them as proxy.

- The number of emissions and economic flows in the LCA data are only a fraction of the number of emissions and economic in- and outputs recorded in the input-output tables of the E3IOT model. If we had used the LCA directly, a discrepancy would have been created between the number of emissions recorded for the pig and cattle sector and the rest of the sectors in the E3IOT model, creating an imbalance in the environmental analysis.
- We would like to split the meat animals sector into a pig and cattle sector in such a way that the aggregation of the pig and cattle sector equals the original meat sector.
- The LCA data available for the cattle sector in fact represent cattle for meat coming from a dairy farm. This is a less ideal situation because cattle for meat are also raised on farms that raise cattle for meat exclusively. This ranges from extensive cattle farming where the cattle graze on grasslands to intensive cattle farming where the cattle is kept in cowsheds. Environmental emissions associated with the different practices of cattle raising will likely differ. As dairy farm practice is in between very intensive and extensive cattle raising practice it seems reasonable to use this as the average. Using the LCA data as proxy for the coefficients

that are used to subdivide the technical and environmental emission coefficients guards against a too large influence of this data availability problem.

As will be shown in Section 5.5.3, the result of our 'split procedure' places the environmental impact associated with the final consumption of beef in between those of pork and poultry which seems reasonable. Finally how the environmental interventions of the original meat animals sector have been attributed to the new pigs and cattle sector is not of much relevance for the analysis of the environmental impact assessment of changes in the European diet because the relative changes of beef and beef products and pork and pork products are almost the same (see Table 24).

Data describing the physical inputs and outputs and emissions of a pig farm and a mixed dairy–cattle farm have been converted into monetary in- and outputs using price data available from the Agricultural Economic Institute in Wageningen for 2003 [16]. The physical in- and outputs are subsequently expressed per euro output of the sector. The physical in- and outputs of the pig farms and mixed dairy–cattle farm and subsequent conversion in monetary in- and outputs are presented in detail in Chapter 5, Annexes 13 and 14 of the annex report. Emissions associated with the sector are also expressed per euro output of the sector. These economic in- and outputs and emission coefficients based on the LCA data can subsequently be compared for the pig and cattle sector and expressed in a coefficient. The pig/cattle coefficient expresses the factor difference in economic inputs of the pig sector compared with the cattle sector per euro output of the sector. These coefficients are shown in Table 15 for specific economic and environmental flows. Aggregates are also calculated for 'feed grains', 'pesticides and agricultural chemicals, n.e.c.' and 'general economic inputs' and 'environmental interventions' based on the geometric mean of relevant specific flows.

The pig/cattle coefficients from Table 15 are subsequently used to subdivide the meat sector coefficients. If available, a specific pig/cattle flow coefficient was used directly; in all other cases the general economic inflow was used for economic inputs and the general environmental intervention coefficient for environmental interventions. The subdivision was made in such a manner that the aggregate of the pig and cattle sector results in the original meat sector. To be able to do so, pig and cattle and price data for the European Union in 2003 were needed. These data have been taken from Eurostat. The resulting technical coefficients and emission coefficient have subsequently been inserted in the E3IOT model.

Processing of pigs and cattle has been assumed to be of a similar structure. Therefore the pig and cattle processing sectors ('beef packing plants', 'pork packing plants', 'sausages and other prepared beef products', 'sausages and other prepared pork products') are a copy of each other except that the pig processing sectors buy their meat from the 'pig animal' sector and the cattle processing sector from the 'cattle' sector. With the previously described plan, the three general meat sectors in E3IOT are replaced by six sectors which differentiate between meat from pigs and meat from cattle.

In addition, every sector that previously used inputs from the sectors 'meat animals', 'meat packing plants' and 'sausages and other prepared meat products' had to be adapted so that it takes inputs from the now six different meat sectors. By assuming that the same amount of meat and the same amount of money is spent on meat, a subdivision can be made of the input coefficients. The resulting adapted E3IOT model has been tested by comparing calculated inventory results of the original model with the new model, which resulted in differences of maximum 0.1 % on several individual environmental interventions.

16 http://www.lei.wur.nl/UK/

Table 15. Coefficients calculated on the basis of LCA process data used as proxy for the subdivision of the technical coefficients and emission coefficients of the meat sector in the E3IOT model

Pig/cattle coefficient				
Group	**Commodity/environmental intervention**	**Coefficient**	**Aggregated**	**Coefficient**
Economic inflows	Spring barley	0.70	Feed grains	3.97
	Soy meal	1.66	Pesticides and agricultural chemicals, n.e.c.	1.41
	Fertiliser, calcium ammonium nitrate	0.72	Economic inflows	1.32
	Fertiliser P	0.69		
	Fertiliser K	0.60		
	P, mineral feed	13.09		
	Electricity Denmark	1.51		
Environmental interventions	Methane [air]	0.23	Environmental interventions	0.67
	Ammonia [air]	1.13		
	N2O [air]	0.51		
	Nitrate [water]	0.70		
	Phosphate [water]	1.27		
	Arable land use [resource]	0.79		

NB: On the left, coefficients for specific economic inputs and environmental interventions; on the right, coefficients calculated for aggregate economic inputs and environmental interventions in general based on the geometric mean of hte pig/cattle coefficient of relevant specific flows.

5.3. Scenarios in environmental impact analysis

In Chapter 4, three alternative diets were presented. Scenario 1 represented a diet which integrated general dietary recommendations, Scenario 2 was based on general dietary recommendations plus a low red meat intake, and Scenario 3 represented a Mediterranean diet + reduced red meat intake. The current diet in the European Union, also called the status quo diet, is called Scenario 0.

For Scenario 0, the status quo environmental impacts of food products bought by private consumers is analysed in two different ways (or sub-scenarios):

- 'Scenario 0 — Food': focusing on the environmental impacts in chain of production and consumption of the consumer food products only;
- 'Scenario 0 — All': analysing the environmental impacts in the chain of production and consumption of all consumer products including food products.

We distinguish between these two sub-scenarios because it allows for the analysis of the environmental impacts of food consumption within the context of the impacts of total consumption.

For dietary Scenarios 1, 2 and 3, the environmental impacts are calculated for the consumption of all consumer products in the same way as for Scenario 0:

- 'Scenario x — Food': focusing on the environmental impacts in the chain of production and consumption of consumer food products only;
- 'Scenario x — All': analysing the environmental impacts in the chain of

production and consumption of all consumer products including food products.

As will be discussed in more detail in Section 5.4, introducing the three alternative scenarios leads to changes in final consumer demand for food products. Assuming that total expenditure of consumers cannot change, the final demand for non-food products will also change. This consumer expenditure redistribution effect may be seen as a first-order economic effect of the introduction of alternative diets. The environmental impacts associated with the changed dietary patterns plus the consumer expenditure redistribution effect is addressed in:

- 'Scenario x — All + first order': analysing the environmental impacts in the chain of production and consumption of all consumer products including the consumer expenditure redistribution effect.

But economic side effects of the introduction of alternative diets might go further than consumer expenditure redistributions only. In Section 2.2 it was discussed that changed final demand for agricultural products may lead to a different structure of the primary agricultural sectors. These structural changes have been modelled with CAPRI and may be called secondary effects. The scenarios where environmental impacts associated with the changed diets, including the

Table 16. Description of the scenarios used in the environmental impact analysis

Scenario	Sub-scenario	Description
Scenario 0	Food	Status quo diet; environmental impacts of the consumption of food products
	All	Status quo diet; environmental impacts of the consumption of all consumer products
Scenario 1	Food	Dietary recommendations; environmental impacts of the consumption of food products only
	All	Dietary recommendations; environmental impacts of the consumption of all consumer products
	All + first order	Dietary recommendations; environmental impacts of the consumption of all consumer products including first-order expenditure redistribution effects
	All + second order	Dietary recommendations; environmental impacts of the consumption of all consumer products including expenditure redistribution effects and agricultural sector restructuring effects
Scenario 2	Food	Dietary recommendations + low red meat; environmental impacts of the consumption of food products only
	All	Dietary recommendations + low red meat; environmental impacts of the consumption of all consumer products
	All + first order	Dietary recommendations + low red meat; environmental impacts of the consumption of all consumer products including first-order expenditure redistribution effects
	All + second order	Dietary recommendations + low red meat; environmental impacts of the consumption of all consumer products including first-order redistribution expenditure effects and agricultural sector restructuring effects
Scenario 3	Food	Mediterranean + reduced red meat; environmental impacts of the consumption of food products only
	All	Mediterranean + reduced red meat; environmental impacts of the consumption of all consumer products
	All + first order	Mediterranean + reduced red meat; environmental impacts of the consumption of all consumer products including first-order expenditure redistribution effects
	All + second order	Mediterranean + reduced red meat; environmental impacts of the consumption of all consumer products including first-order expenditure redistribution effects and agricultural sector restructuring effects

first-order effects and structural changes in the primary agricultural effects, are named:

- 'Scenario x — All + second order': analysing the environmental impacts in the chain of production and consumption of all consumer products including the consumer expenditure redistribution effect and structural changes in primary agricultural sectors.

An overview of all these scenarios in the environmental impact analysis is given in Table 16. In the following text all scenarios will be referred to using the scenario names in this table.

5.4. Final consumer demand and total industry supply

5.4.1. Introduction

In the E3IOT input-output model, the final consumer demand for products is the driver for the model and hence the calculation of the environmental impacts associated with the consumption of products is:

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

where **B** represents the direct environmental interventions for each sector and **A** the technology matrix (see also equation 1). Between sub-scenarios 'Food', 'All' and 'All + first order' the final demand vector (**k**) is changed.

In the sub-scenarios 'Food' the final consumer demand vector ($\mathbf{k}_{food}$) comprises the food products only, as dictated by the three diet change scenarios and the status quo scenario. These final demand vectors are examined in further detail in Section 5.4.2.

In the sub-scenarios 'All' the final consumer demand vector comprises the food products as dictated by the diet change scenarios plus final demand for non-food products ($\mathbf{k}_{all}$). These final demand vectors are examined in further detail in Section 5.4.3.

Total expenditure on food products changes between the different diets. This changed total expenditure can lead to changes in expenditures on non-food products. This changed expenditure on food products is redistributed over the non-food products. The resulting final consumer demand vector ($\mathbf{k}_{all+first\ order}$) is used for the calculation of the environmental impacts (see further details in Section 5.4.4).

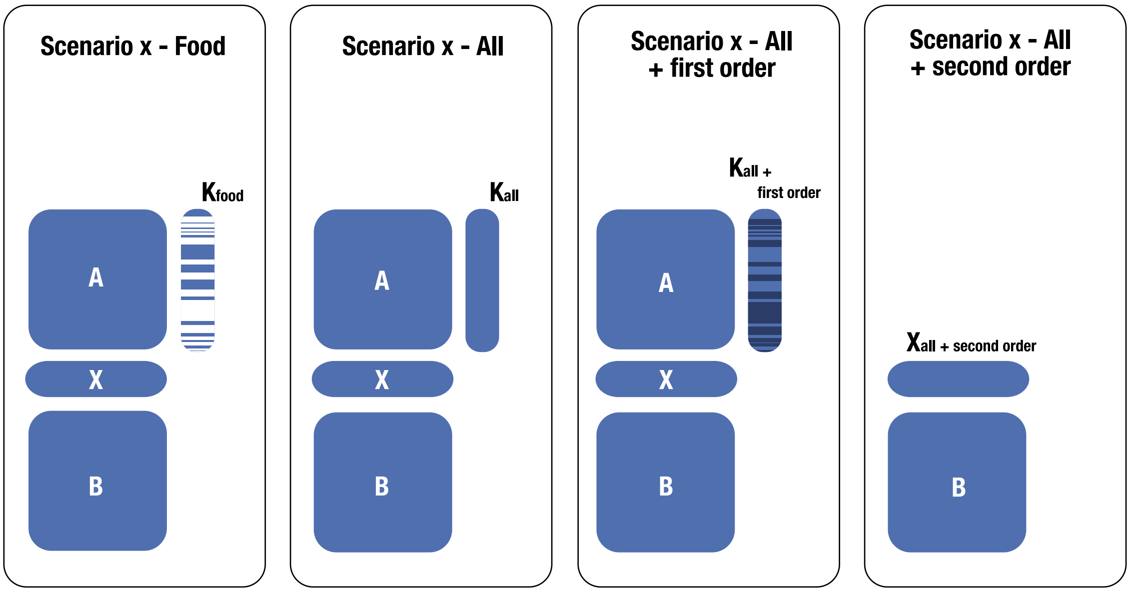
For the sub-scenarios that take into account possible structural changes in the primary agricultural sector as a result of changed demand for primary agricultural products, the calculation of the environmental impacts is carried out differently. As discussed in Section 2.2, the CAPRI model is used to assess changes in the primary agricultural sector. Input into the CAPRI model is the total supply from primary agricultural sectors as calculated in the sub-scenarios that take into account first-order effects ($\mathbf{x}_{all+first\ order}$). The structural changes in the primary agricultural sectors as calculated by CAPRI result in a changed total supply from these sectors. The changed total supply for the primary is combined with the total supply of the other (non-primary agricultural sectors) resulting in a new total supply vector ($\mathbf{x}_{all+second\ order}$). The total supply vector can be used directly for the environmental impacts:

$$\mathbf{m} = \mathbf{Bx}$$

where **x** represents the total supply vector and **B** the direct environmental interventions for each sector (see also equation 3). The procedure is discussed further in Section 5.4.5.

Incorporating structural changes in the primary agricultural sectors using the above described procedure into our environmental impact analysis has limitations. It is important to realise that the final consumption vector ($\mathbf{k}_{all+first\ order}$) and

Figure 1 — Schematic figure of the system used for the calculation of the environmental impacts for the different scenarios



technology coefficient matrix (**A**) are inconsistent with the total supply vector that takes into account secondary effects ($\mathbf{x}_{all+second\ order}$). For instance, the total supply of the cattle sector is adjusted while the total supply of industry sectors that have inputs into the cattle sector and have inputs from the cattle sector (e.g. beef packing plants) are not adjusted. This means that the analysis of secondary effects is limited to primary agricultural sectors. It also means that a dissection of the contribution of individual product groups to the total environmental impacts of final consumption is not possible because we do not have the **A** matrix ([17]) that makes such an operation possible.

The only result that can be obtained from the analysis that takes into account secondary effects is total environmental emissions associated with final consumption. Even a breakdown of the contribution of the final consumption of food products versus non-food products is not possible any more. Notice that between the sub-scenarios 'Food', 'All', 'All + first order' and 'All + second order' the final consumer expenditure on food products is not changed and thus the diet is not changed.

A schematic picture of the system that is used for the calculation of the environmental impacts related to diet changes is given in Figure 1.

5.4.2. Food scenarios

As explained in Chapter 4, weight percentage changes with regard to the current prevailing average European diet have been calculated, to obtain the diets as specified in 'Scenarios 1 — Food', '2 — Food' and '3 — Food' (see Tables 8 to 12 and Table 14). These percentage changes have been calculated for the food items as classified in the food balance sheets.

In E3IOT the current prevailing average European diet is reflected in final consumer expenditures on food products in 2003 in Europe. These final consumer expenditures encompass

17 In theory it is possible to take the final demand vector $\mathbf{k}_{all+first\ order}$ and total supply vector $\mathbf{x}_{all+second\ order}$ and by way of a RAS procedure adjust the coefficients of the technology matrix **A** to obtain a consistent system again. Applying the RAS procedure was beyond the scope of this report and not strictly necessary for this research.

private final consumption as well as public final consumption (e.g. government expenditure). Values for average European consumer expenditure for food products (and also non-food products) were derived from COICOP data as provided by Eurostat (see Section 3.12 in the annex on E3IOT). Having the expenditures for private plus public consumption is in accordance with the specification of the food balance sheets, which considers food quantities reaching the consumer in private households, as well as in the non-household sector.

The weight percentage changes are equal to the percentage changes in final demand for food products expressed in euro. The only obstacle to direct use of weight percentage changes are differences in classification of food products in the food balance sheets and E3IOT model. Following the correspondence table between E3IOT and food balance sheets (Table 3), the weight percentage changes have been translated to changes in final consumption expenditure of food products as specified in the E3IOT model.

In Table 17 the final consumption expenditures for 'Scenarios 0 — Food', '1 — Food', '2 — Food' and '3 — Food' are given. In these scenarios the final demand vector consists only of the food products purchased by consumers. As noted previously, the consumption expenditures on food products for 'Scenarios 1 — Food', '2 — Food' and '3 — Food' have been derived from '0 — Food'. The changes needed to obtain the desired diets from the status quo diet have also been used to obtain the expenditure on food products in 'Scenarios 1 — Food', '2 — Food' and '3 — Food'.

It can be seen in Table 17 that final consumption expenditure on food products in 'Scenario 1 — Food' is 1.8 % higher compared with expenditures in 'Scenario 0 — Food'. Final consumption expenditures on food products in 'Scenario 2 — Food' and 'Scenario 3 — Food' are 3.1 and 0.7 % lower respectively.

5.4.3. All products' sub-scenarios

To be able to put the changed consumer expenditures on food products in perspective of the overall consumer expenditures for each scenario (and hence total environmental impacts of consumption), a final demand vector has also been set up that includes all products (food + non-food) that are purchased by consumers. Between Scenarios 0, 1, 2 and 3 the purchase of food products changes as specified in Table 17, while the purchase of non-food products remains the same as in the status quo scenario. Again the values for average European consumer expenditure for non-food products were derived from COICOP data as provided by Eurostat (see Section 3.12 in the E3IOT description).

The resulting full final demand vectors for every scenario (i.e. 'Scenario 0 — All', 'Scenario 1 — All', 'Scenario 2 — All' and 'Scenario 3 — All') are not shown here because of the large size of the resulting table but are given in Chapter 5, Annex 3 of the annex report. The sums of expenditures on food and non-food products in these scenarios are given in Table 18.

As can be seen in Table 18 the sum of consumer expenditures on food products in 'Scenarios 0, 1, 2 and 3 — All' is exactly the same as in 'Scenarios 0, 1, 2 and 3 — Food' (see Table 17). The sum expenditures on non-food products in 'Scenarios 0, 1, 2 and 3 — All' is the same. Resulting changes in overall expenditures due to changes in the diet are less than 1 %, as can be seen in Table 18.

5.4.4. Taking into account consumer expenditure redistribution effects

If consumers in the European Union have to spend more on food products, it is likely that they can spend less on non-food products and services, and vice versa. This shift between expenditures on food products and non-food products may be regarded as a first-

Table 17. Final consumption expenditures on food products for `Scenarios 0 – Food´, `1 – Food´, `2 – Food´, and `3 – Food´ for 2003

E3IOT categories	'Scenario 0 — Food'	'Scenario 1 — Food'	'Scenario 2 — Food'	'Scenario 3 — Food'
	Final consumer expenditure			
Dairy farm products	0.29	0.29	0.29	0.26
Poultry and eggs	6.87	6.87	6.87	6.46
Miscellaneous livestock	3.79	3.79	1.59	1.56
Feed grains	0.43	0.43	0.43	0.43
Fruit	9.96	12.53	12.53	11.82
Tree nuts	0.95	0.95	2.39	1.54
Vegetables	18.00	21.14	21.14	21.97
Miscellaneous crops	0.002	0.002	0.002	0.002
Oil bearing crops	0.17	0.17	0.17	0.22
Greenhouse and nursery products	12.30	14.44	14.44	15.01
Commercial fishing	5.90	7.01	7.01	11.53
Beef packing plants	24.30	22.09	14.51	10.02
Sausages and other prepared beef products	10.20	9.27	0.00 (*)	4.20
Pork packing plants	25.60	23.76	15.56	10.55
Sausages and other prepared pork products	10.70	9.93	0.00 (*)	4.41
Poultry slaughtering and processing	41.00	41.00	50.84	52.84
Creamery butter	2.06	1.20	1.20	1.08
Natural, processed and imitation cheese	21.80	21.80	21.80	19.78
Dry, condensed and evaporated dairy products	8.27	8.27	8.27	7.50
Ice cream and frozen desserts	2.11	1.82	1.82	1.62
Fluid milk	27.40	27.40	27.40	24.86
Canned and cured fish and seafood	6.85	8.14	8.14	13.39
Canned specialties	1.89	1.89	1.89	1.89
Canned fruit, vegetables, preserves, jams and jellies	7.61	6.57	6.57	5.84
Dehydrated fruit, vegetables and soups	2.45	3.08	3.08	2.91
Pickles, sauces and salad dressings	1.84	1.84	1.84	1.84
Prepared fresh or frozen fish and seafood	9.22	10.96	10.96	18.02
Frozen fruit, fruit juices and vegetables	12.00	14.65	14.65	14.24
Frozen specialties, n.e.c.	3.70	3.70	3.70	3.70
Flour and other grain mill products	1.23	1.29	1.36	1.41
Cereal breakfast foods	9.21	9.69	10.19	10.55
Prepared flour mixes and doughs	6.12	6.44	6.77	7.01
Bread, cake and related products	27.40	28.82	30.31	31.39
Cookies and crackers	10.70	10.70	10.70	12.26
Frozen bakery products, except bread	3.61	3.80	3.99	4.14
Sugar	1.65	1.42	1.42	1.27
Chocolate and cocoa products	0.54	0.47	0.47	0.42
Salted and roasted nuts and seeds	0.78	0.78	1.71	1.21
Candy and other confectionery products	10.50	9.06	9.06	8.05

E3IOT categories	'Scenario 0 — Food'	'Scenario 1 — Food'	'Scenario 2 — Food'	'Scenario 3 — Food'
	Final consumer expenditure			
Malt beverages	9.99	9.99	9.99	9.20
Wines, brandy and brandy spirits	15.60	15.60	15.60	14.37
Distilled and blended liquors	3.93	3.93	3.93	3.62
Bottled and canned soft drinks	18.40	15.88	15.88	14.11
Flavouring extracts and flavouring syrups, n.e.c.	3.03	2.62	2.62	2.32
Roasted coffee	11.20	11.20	11.20	11.20
Edible fats and oils, n.e.c.	16.30	19.27	19.59	22.92
Manufactured ice	0.19	0.16	0.16	0.14
Macaroni, spaghetti, vermicelli and noodles	1.30	1.37	1.44	1.49
Potato chips and similar snacks	12.70	12.70	12.70	12.16
Food preparations, n.e.c.	5.27	5.27	5.27	5.27
Sum food products	447	455	433	444

(*) In Scenario 2, no consumption of processed pork or beef products takes place (see Table 6). Hence there are no final consumption expenditures on the product categories `sausages and other prepared pork products´ and `sausages and other prepared beef products´.

Table 18. Sum of final consumption expenditures on food products and non-food products for `Scenario 0 – All´ `Scenario 1 – All´, `Scenario 2 – All´ and `Scenario 3 – All´

Group	'Scenario 0 — All'	'Scenario 1 — All'	'Scenario 2 — All'	'Scenario 3 — All'
	Sum final consumer expenditure			
Sum food products	447 (100)	455 (101.8)	433 (96.9)	444 (99.3)
Sum non-food	2 069 (100)	2 069 (100.0)	2 069 (100.0)	2 069 (100.0)
Sum all	2 516 (100)	2 524 (100.3)	2 502 (99.4)	2 513 (99.9)

NB: Between parentheses relative figures compared with Scenario 0.

order side effect of changes in European diets. As a first approximation of the environmental consequences of this first-order side effect, the changed expenditures on food items will result in changed expenditures on the non-food products, keeping total final expenditure constant. The changes in expenditures are distributed over the non-food products relatively to the consumption expenditures on the non-food product. In other words, if the total final consumption expenditures of the non-food products has to be increased 20 %, final consumption expenditures for each non-food product is increased 20 %. This is option 'All + first order' within each scenario.

The resulting final consumption expenditures for food products are given in Table 17. The total final expenditures on food and non-food products with the first-order effects are given in Table 19. The full vectors describing the final consumption expenditures for 'Scenarios 1, 2, 3 — All + first order' are given in Chapter 5, Annex 3 of the annex report.

As shown in Table 19 for 'Scenarios 1, 2 and 3 — All + first order' the sum of final consumer expenditures remains the same. The changes in final consumer expenditures on food products are compensated for by changes in expenditures on

Table 19. Sum of final consumption expenditures on food products and non-food products

Group	'Scenario 0 — All'	'Scenario 1 — All + first order'	'Scenario 2 — All + first order'	'Scenario 3 — All + first order'
	Sum final consumer expenditure			
Sum food products	447 (100)	455 (101.8)	433 (96.9)	444 (99.3)
Sum non-food	2 069 (100)	2 061 (99.6)	2 083 (100.7)	2 072 (100.2)
Sum all	2 516 (100)	2 516 (100.0)	2 516 (100.0)	2 516 (100.0)

NB: Between parentheses relative figures compared with Scenario 0. The change in expenditures on food products has beenredistributed over the expenditures on non-food products as a first approximation of the consequences of a first-order side effect of changing European diets.

non-food products. The results in Table 19 suggest that the dietary changes do not result overall in very large differences in the final expenditures on non-food products.

5.4.5. Taking into account structural industry changes

The changed demand for food products in the three diet change scenarios may result in structural changes in the primary agricultural sectors. The E3IOT model as an input-output model with fixed technical coefficients cannot address such dynamic aspects of the economy. The dynamic CAPRI model can make an assessment of these structural changes.

The final consumption vectors for 'Scenario 0 — All' ($\mathbf{k}_{all}$) and 'Scenarios 1, 2 and 3 — All + first order' ($\mathbf{k}_{all + first\ order}$) form the basis for CAPRI to estimate secondary effects of diet changes in the European Union. As input, the CAPRI model needs total supply for the primary agricultural sectors. These total supply vectors for 'Scenario 0 — All' and 'Scenarios 1, 2 and 3 — All + first order' are calculated with the E3IOT model according to:

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

where $\mathbf{x}$ represents the total supply vector, $(\mathbf{I} - \mathbf{A})^{-1}$ the Leontief inverse and $\mathbf{k}$ the final consumption vector(see also equation 2).

The structural changes in the primary agricultural sectors as calculated by CAPRI result in a changed total supply for these sectors. The changed total supply for the primary agricultural sectors is combined with the total supply of the other sectors (non-primary agricultural sectors which did not change) resulting in a new total supply vector ($\mathbf{x}_{all+second\ order}$). The $\mathbf{x}_{all+second\ order}$ vectors are then used to calculate the environmental interventions using:

$$\mathbf{m} = \mathbf{B}\mathbf{x}$$

where $\mathbf{x}$ represents the total supply vector and $\mathbf{B}$ the direct environmental interventions for each sector (see also equation 3).

A complicating factor when linking the total supply vectors of CAPRI and E3IOT is the difference in classification of the primary agricultural sectors in CAPRI and E3IOT. Therefore transformation matrices have been made that transform the E3IOT sector classification into CAPRI and vice versa. These tables are reproduced in Annex 5.

The total supply of the primary agricultural sector in 'Scenarios 1, 2 and 3 — All + first order' and total supply of the primary agricultural sector in 'Scenarios 1, 2 and 3 — All + second order' classified in terms of E3IOT categories are shown in the tables below compared with 'Scenario 0

Table 20. Influence of structural industry changes on total supply of the primary agricultural sectors as a result of the changed final demand for food products as estimated by CAPRI

E3IOT primary agricultural sectors	Total supply		
	'Scenario 0 — All'	'Scenario 1 — All + first order'	'Scenario 1 — All + second order'
Dairy farm products	61.70 (100 %)	61.00 (99 %)	61.16 (99 %)
Poultry and eggs	54.10 (100 %)	53.90 (100 %)	53.88 (100 %)
Cattle	54.60 (100 %)	50.90 (93 %)	52.58 (96 %)
Pigs	55.30 (100 %)	52.20 (94 %)	52.89 (96 %)
Miscellaneous livestock	9.07 (100 %)	9.41 (104 %)	9.27 (102 %)
Food grains	11.40 (100 %)	11.70 (103 %)	11.81 (104 %)
Feed grains	77.00 (100 %)	74.90 (97 %)	75.97 (99 %)
Fruit	27.20 (100 %)	29.90 (110 %)	29.33 (108 %)
Tree nuts	2.06 (100 %)	2.03 (96 %)	2.04 (99 %)
Vegetables	28.40 (100 %)	32.10 (113 %)	30.28 (107 %)
Sugar crops	4.67 (100 %)	4.49 (96 %)	4.59 (98 %)
Miscellaneous crops	1.46 (100 %)	1.46 (100 %)	1.47 (101 %)
Oil bearing crops	33.50 (100 %)	34.80 (104 %)	34.09 (102 %)
Wines, brandy and brandy spirits	19.00 (100 %)	19.00 (100 %)	18.87 (99 %)
Soybean oil mills	26.20 (100 %)	26.90 (103 %)	25.68 (98 %)
Vegetable oil mills, n.e.c.	2.58 (100 %)	2.71 (105 %)	2.66 (103 %)
Edible fats and oils, n.e.c.	24.30 (100 %)	27.80(114 %)	25.76 (106 %)
Prepared feeds, n.e.c.	43.10 (100 %)	42.30 (98 %)	42.52 (99 %)
Sum	535.64 (100 %)	537.50 (100.3 %)	534.85 (99.8 %)

NB: The total supply for `Scenario 1 – All + first order´ and `Scenario 1 – All + second order´ is compared with `Scenario 0 – All´ Between parentheses relative figures compared with `Scenario 0 – All´.

— All'. The results in terms of CAPRI categories are given in Chapter 5, Annex 12 of the annex report.

For Scenarios 1, 2 and 3, the effects of structural changes result in a total supply of the primary agricultural sectors that rebounds close to the original total supply of the agricultural sectors before the new diets were introduced. For individual primary agricultural sectors, the effect of structural changes is rather diverse. As a rule it can be said that, for those products where the demand decreases due to changed dietary habits, the production in the EU-27 is reduced to a lesser extent, while at the same time exports to non-EU countries increase and imports decrease. This is in particular the case for red meat products in Scenarios 2 and 3. For products with increased demand the opposite is the case, i.e. production increases, while exports decrease and imports increase. This is true, for example, for poultry products. As a result, most often the changes induced due to the introduction of the diets are substantially reduced, i.e. total supply hardly changes due to the introduction of the alternative diets when taking into account structural effects.

5.5. Analysis of environmental impacts

5.5.1. Introduction

As explained earlier in this chapter, about 1 200 different environmental interventions have been taken into the E3IOT model. This makes

Table 21. Influence of structural industry changes on total supply of the primary agricultural sectors as a result of the changed final demand for food products as estimated by CAPRI

E3IOT primary agricultural sectors	Total supply		
	'Scenario 0 — All'	'Scenario 2 — All + first order'	'Scenario 2 — All + second order'
Dairy farm products	61.70 (100 %)	60.90 (99 %)	61.54 (100 %)
Poultry and eggs	54.10 (100 %)	61.40 (113 %)	60.15 (111 %)
Cattle	54.60 (100 %)	31.70 (58 %)	50.30 (92 %)
Pigs	55.30 (100 %)	31.50 (57 %)	41.91 (76 %)
Miscellaneous livestock	9.07 (100 %)	6.65 (73 %)	7.70 (85 %)
Food grains	11.40 (100 %)	11.90 (104 %)	14.10 (124 %)
Feed grains	77.00 (100 %)	63.70 (83 %)	75.94 (99 %)
Fruit	27.20 (100 %)	29.90 (110 %)	29.52 (109 %)
Tree nuts	2.06 (100 %)	3.78 (183 %)	4.38 (213 %)
Vegetables	28.40 (100 %)	32.00 (113 %)	31.38 (110 %)
Sugar crops	4.67 (100 %)	4.49 (96 %)	4.87 (104 %)
Miscellaneous crops	1.46 (100 %)	1.42 (97 %)	1.53 (105 %)
Oil bearing crops	33.50 (100 %)	34.40 (103 %)	34.21 (102 %)
Wines, brandy and brandy spirits	19.00 (100 %)	19.00 (100 %)	19.69 (104 %)
Soybean oil mills	26.20 (100 %)	26.20 (100 %)	24.55 (94 %)
Vegetable oil mills, n.e.c.	2.58 (100 %)	2.71 (105 %)	2.67 (104 %)
Edible fats and oils, n.e.c.	24.30 (100 %)	28.20 (116 %)	26.12 (108 %)
Prepared feeds, n.e.c.	43.10 (100 %)	40.70 (94 %)	43.32 (101 %)
Sum	535.64 (100 %)	490.55 (91.6 %)	533.89 (99.7 %)

NB: The total supply for `Scenario 2 – All + first order´ and `Scenario 2 – All + second order´ is compared with `Scenario 0 – All´ Between parentheses relative figures compared with `Scenario 0 – All´.

it possible to examine the influence of dietary changes at the level of individual emissions (for example, CO_2 emissions). However, in order to represent the overall environmental impacts of dietary changes, the environmental interventions are interpreted in terms of environmental impacts and societal preferences. This environmental impact assessment will be carried out with so-called mid-point and end-point indicators.

For the calculation of the mid-point indicators, the CML2002 baseline impact assessment method will be used (Guinée et al., 2002). The end-point indicators will be based on the Eco-indicator 99 (Goedkoop and Spriensma, 2001). By default the CML2002 methodology is used in this study and the Eco-indicator 99 method is used to assess the influence of the choice for a certain impact assessment method on the results of the environmental impact assessment analysis. The results obtained with the Eco-indicator 99 method and assessment of the influence of the chosen impact assessment method is further discussed in Section 5.5.8. The CML2002 method is further described in the following section.

5.5.2. CML2002 impact assessment method

The results of the inventory analysis, which gives the sum of environmental interventions over the whole chain of production, consumption and post-consumer waste management as a result of the final demand for a product, involves over a thousand different environmental interventions

Table 22. Influence of structural industry changes on total supply of the primary agricultural sectors as a result of the changed final demand for food products as estimated by CAPRI

E3IOT primary agricultural sectors	Total supply		
	'Scenario 0 — All'	'Scenario 3 — All + first order'	'Scenario 3 — All + second order'
Dairy farm products	61.70 (100 %)	56.60 (92 %)	58.85 (95 %)
Poultry and eggs	54.10 (100 %)	63.30 (117 %)	61.42 (114 %)
Cattle	54.60 (100 %)	30.40 (56 %)	49.95 (91 %)
Pigs	55.30 (100 %)	29.90 (54 %)	41.09 (74 %)
Miscellaneous livestock	9.07 (100 %)	8.00 (88 %)	8.44 (93 %)
Food grains	11.40 (100 %)	12.10 (106 %)	14.64 (128 %)
Feed grains	77.00 (100 %)	61.30 (80 %)	74.98 (97 %)
Fruit	27.20 (100 %)	28.80 (106 %)	28.61 (105 %)
Tree nuts	2.06 (100 %)	2.76 (134 %)	2.72 (132 %)
Vegetables	28.40 (100 %)	32.70 (115 %)	31.63 (111 %)
Sugar crops	4.67 (100 %)	4.39 (94 %)	4.84 (104 %)
Miscellaneous crops	1.46 (100 %)	1.43 (98 %)	1.54 (105 %)
Oil bearing crops	33.50 (100 %)	36.20 (108 %)	34.96 (104 %)
Wines, brandy and brandy spirits	19.00 (100 %)	17.60 (93 %)	19.05 (100 %)
Soybean oil mills	26.20 (100 %)	27.40 (105 %)	24.32 (93 %)
Vegetable oil mills, n.e.c.	2.58 (100 %)	2.82 (109 %)	2.77 (108 %)
Edible fats and oils, n.e.c.	24.30 (100 %)	32.20 (133 %)	27.91 (115 %)
Prepared feeds, n.e.c.	43.10 (100 %)	40.90 (95 %)	43.27 (100 %)
Sum	535.64 (100 %)	488.80 (91.3 %)	531.01 (99.1 %)

NB: The total supply for `Scenario 3 – All + first order´ and `Scenario 3 – All + second order´ is compared with `Scenario 0 – All´ Between parentheses relative figures compared with `Scenario 0 – All´.

per product. For the interpretation of these outcomes, the impact analysis step has been added as it is common in the environmental life-cycle assessment of products. This considers a set of environmental impact assessment indicators, transforming environmental interventions, as resource extractions and emissions into more aggregated environmental impacts, like resource depletion and global warming. This so-called impact assessment step has been based on the CML2002 impact assessment methodology which considers the following impact categories:

- climate change,
- ozone depletion,
- terrestrial acidification,
- freshwater eutrophication,
- human toxicity,
- photochemical oxidant formation,
- ecotoxicity,
- abiotic resource depletion.

The resulting scores on impact categories are presented in normalised and weighted form. Note that biotic resource depletion, relevant for, amongst other things, fish consumption, is outside the scope of inventory in the E3IOT model, and hence cannot be included in the impact assessment step.

In the normalisation step, the scores for each impact category for a specific product are expressed as a share of the total European score on the impact category. The total European score on an impact category is calculated from the total emission inventory for the EU-25 in 2003, which is equivalent to the total emissions resulting from EU-25 final demand. Thus, for each product, eight normalised scores result, one for each impact category.

For aggregation of the scores per impact category into an overall score, as used for ordering products in graphical surveys, the weights as used in Dutch environmental policy for the oil and gas producing industry (Nogepa) have been used (see reference below). For impact categories not present there, an average over all impact categories has been used. See Table 23 for the weights actually used (Huppes et al., 2007).

Because the E3IOT model is incorporated in CMLCA, all the tools available in CMLCA for the interpretation of the results can be used, like contribution analysis and perturbation analysis at the level of emissions, category indicator results and weighted environmental impact. Contribution analysis calculates the overall contribution to the results of the various factors. Contribution analysis answers questions about the contribution of specific environmental flows, processes or impacts to a given environmental score. Perturbation analysis involves the study of the effects of small changes within the system on the results of an LCA. The combination of these two tools indicates which processes could be targeted for improvement.

It is important to note that the environmental impact assessment used in this study relates to general environmental problems in the chain of production and consumption of products and does not take into account specific and or local environmental problems. Specific and or local environmental problems of agriculture not taken into account are among other things: workplace exposure to agro-chemicals, effects on farm-land birds, effects on erosion, water use, land use and biotic resource depletion. A particularly important example of a specific environmental impact that is not accounted for is the direct effect of fishing on fish stocks. Separate studies are needed to assess the effects of such local and or specific environmental impacts.

5.5.3. Environmental impacts expressed per euro expenditure

Before presenting the total environmental impacts related to the consumption of food products in the European Union, the environmental impacts per euro expenditure on food product will be presented. It is important as a quality check and provides information on the environmental impacts of the food products in itself.

Calculated environmental impacts per euro are shown in **Figure 2** for the different food

Table 23. Weighting factors for aggregate environmental score (percentages)

Impact category	Weighting factors (%)	Reference
Abiotic resource depletion	5	Guinée et al., 2002
Climate change	35	Houghton et al., 2001
Ozone depletion	5	WMO, 1992, 1995 and 1999
Human toxicity	17	Huijbregts, 1999a and 2000
Ecotoxicity	7	Huijbregts, 1999b
Photochemical oxidant formation	9	Jenkin and Hayman, 1999; Derwentet al., 1998
Terrestrial acidification	7	Huijbregts, 1999c
Freshwater eutrophication	15	Heijungset al., 1992

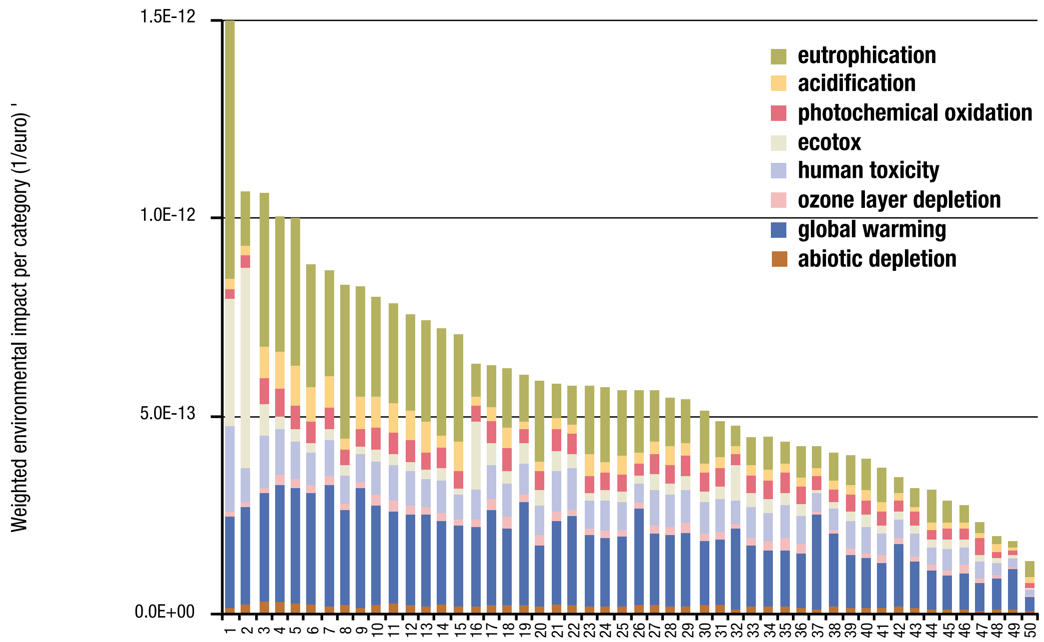
product groups. Only the food product groups as purchased by final consumers are shown. The contribution of the different impact categories to the total aggregated environmental impacts per euro are indicated by the colours in each bar. The aggregated environmental impact of product group 'miscellaneous crops', totalling 4.47E-12 per euro, has been topped.

The units of the weighted environmental impact indicator have been chosen in such a way that the weighted environmental impact of all final consumption of products in the European Union has an impact score of 1. This has the advantage that the y axis can be read as the fraction contribution of a product group to the total environmental impact in the European Union; for example, the final consumption of 'sugar' worth 1 euro contributes 1.06E-12 part to the total environmental impact in the European Union.

The product group 'miscellaneous crops' has the highest environmental impact of all food product groups standing at 4.47E-12, which is about four times higher than the next product group with the highest aggregated environmental impact. 'Miscellaneous crops' has such a high aggregated environmental impact due to the high emissions of eutrophying substances (phosphorous to freshwater) per euro spent on the product, which is clearly visible in **Figure 2**. We may doubt the validity of the emission of phosphorous emissions to freshwater associated with the 'miscellaneous crops' product group. However, it represents the best assessment of this product group in relation to the environmental impacts of the other product groups. In subsequent analysis of the environmental impacts of dietary changes, the perhaps spurious phosphate emission to freshwater for this product group is not relevant because final consumer expenditure on this group is very small in each scenario compared with the expenditure on other food product groups (see Tables 20 to 22).

High aggregated environmental impacts are associated with all meat and meat products

Figure 2 — Environmental impacts per euro for food product groups for all environmental impact categories



NB: Normalised and weighted environmental impacts. The food item number refers to the numbers as given in Table 24.

Table 24. Label numbering as used in Figure 2

No	Name	No	Name
1	Miscellaneous crops	26	Feed grains
2	Tree nuts	27	Chocolate and cocoa products
3	Sugar	28	Frozen specialties, n.e.c.
4	Sausages and other prepared pork products	29	Frozen bakery products, except bread
5	Pork packing plants	30	Macaroni, spaghetti, vermicelli and noodles
6	Miscellaneous livestock	31	Dehydrated fruit, vegetables and soups
7	Sausages and other prepared beef products	32	Vegetables
8	Flour and other grain mill products	33	Canned fruit, vegetables, preserves, jams and jellies
9	Beef packing plants	34	Candy and other confectionery products
10	Poultry slaughtering and processing	35	Bottled and canned soft drinks
11	Natural, processed and imitation cheese	36	Potato chips and similar snacks
12	Fluid milk	37	Oil bearing crops
13	Poultry and eggs	38	Prepared fresh or frozen fish and seafood
14	Prepared flour mixes and doughs	39	Canned specialties
15	Dairy farm products	40	Pickles, sauces and salad dressings
16	Salted and roasted nuts and seeds	41	Cookies and crackers
17	Edible fats and oils, n.e.c.	42	Canned and cured fish and seafood
18	Ice cream and frozen desserts	43	Wines, brandy and brandy spirits
19	Fruit	44	Bread, cake and related products
20	Food preparations, n.e.c.	45	Malt beverages
21	Frozen fruit, fruit juices and vegetables	46	Flavouring extracts and flavouring syrups, n.e.c.
22	Roasted coffee	47	Distilled and blended liquors
23	Creamery butter	48	Manufactured ice
24	Cereal breakfast foods	49	Commercial fishing
25	Dry, condensed and evaporated dairy products	50	Greenhouse and nursery products

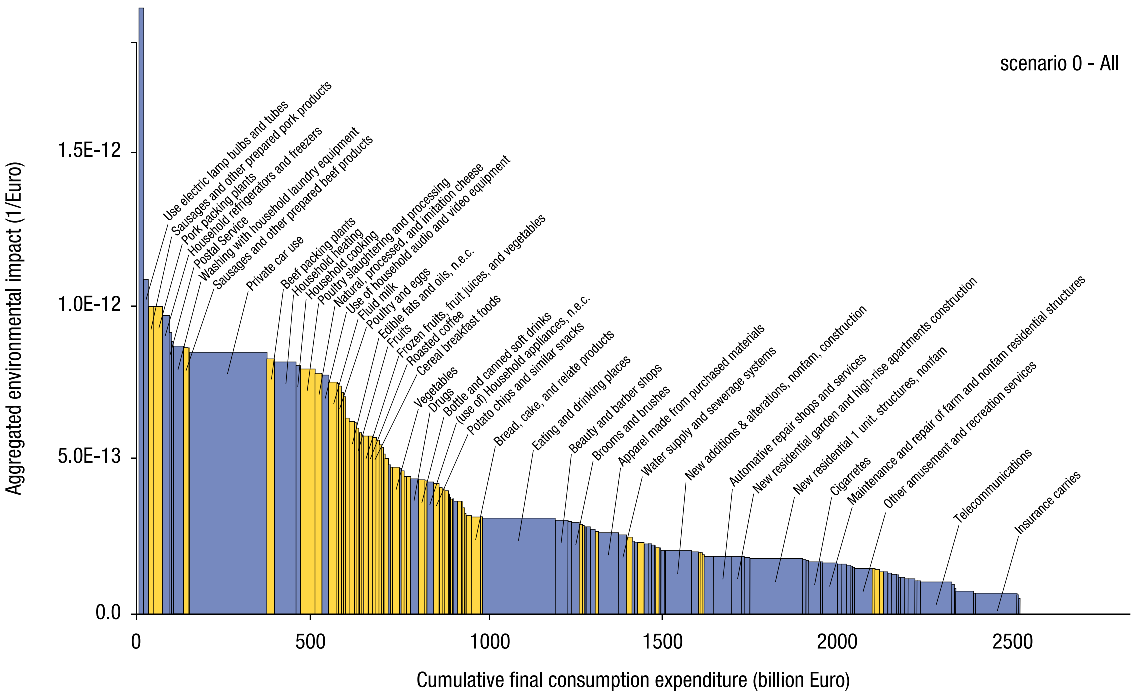
and milk and milk derived products, but also the product groups ‘tree nuts’, ‘sugar’ and ‘flour’. Relatively low aggregated environmental impacts are associated with ‘greenhouse and nursery products’, ‘fishing’, ‘manufactured ice’ and beverages. The aggregated environmental impact per euro for the high impact groups is about a factor 3 higher than that for the low impact product groups ([18]).

18 Based on the difference between the 90 % percentile and the 10 % percentile for the aggregated environmental impacts.

5.5.4. Environmental impacts of food products in sub-scenarios ‘All’

To be able to put the aggregated environmental impacts associated with the final consumption of food products in perspective, the aggregated environmental impacts of the final consumption of all non-food and food products have been plotted in Figure 3 for the status quo situation (‘Scenario 0 — All’). It shows how the impacts per euro and the expenditure on the products together make up the total impact of a product grouping. In this figure, expenditure is shown on the x axis, ordered as to decreasing environmental impact per euro,

Figure 3 — Environmental impact of final consumption, in descending order of impact per euro for 'Scenario 0 — All'



NB: Products indicated in yellow are food products. All non-food products are in blue. Products that contribute more than 0.5 % to total aggregated environmental impacts in the European union have a label attached. Sometimes a bar seems to be black but that is the result of having several product categories side by side with very small consumption expenditure so that the black border of the bar is only shown.

and the aggregated environmental score per euro on the y axis ([19]). The aggregated environmental impacts per euro of three product groups with very high aggregated environmental impact have been topped, i.e. 'miscellaneous crops' 'non-woven fabrics' and 'household use of pesticides and agricultural chemicals'. The food products in Figure 3 have been indicated in dark grey and the non-food products in light grey. The area of each bar (euro final consumption × impact per euro) represents the aggregated environmental impact due to the consumption of this product group in Europe. The total area is equivalent to the aggregated environmental impact of final consumption in Europe and equals 1. Product groups that have been labelled contribute more than 0.5 % to total aggregated environmental impacts in the European union. Notice that many products do not show up in the figure because the final consumer expenditures on the product are relatively small, making the width of the bar in Figure 3 so small that it is invisible. The values underlying Figure 3 for all product groups for 'Scenario 0 — All', 'Scenario 1 — All' 'Scenario 2 — All' and 'Scenario 3 — All' can be found in Chapter 5, Annexes 6, 7, 8 and 9 of the annex report.

What is clearly visible in Figure 3 is that the aggregated environmental impacts of the food products are relatively high for meat and meat products but that we do not spend so much on these products compared with other relatively high impact product groups such as private car use or household heating. The aggregated environmental impact of most of the food

19 A similar figure is presented in the EIPRO report (Figure 5.4.4, p. 90; Tukker et al., 2006a). The figures are not exactly the same because in this report a distinction is made between pork and beef and the environmental interventions matrix of the E3IOT model is slightly different from the CEDA-EU-25 model. See also the E3IOT description in the annex report.

Table 25. Aggregated environmental impacts of the final consumption of food product groups and non-food product groups in the EU for `Scenarios 0, 1, 2 and 3 – All´

Category	Aggregated environmental impact			
	'Scenario 0 — All'	'Scenario 1 — All'	'Scenario 2 — All'	'Scenario 3 — All'
Food	27	27	25	25
Non-food	73	73	73	73
Total	100	100	98	98

products is around 5.0E-13 per euro (see also **Figure 2**).

Using the final consumption expenditures for 'Scenarios 0, 1, 2 and 3 — All', aggregated environmental impacts for the food products and non-food products have been calculated and numerical results are shown in Table 24.

The aggregated environmental impact of the sum of final consumption in the European Union for the status quo situation ('Scenario 0 — All') is by definition 1. Twenty seven per cent of these environmental impacts are associated with environmental impacts related to the final consumption of food products.

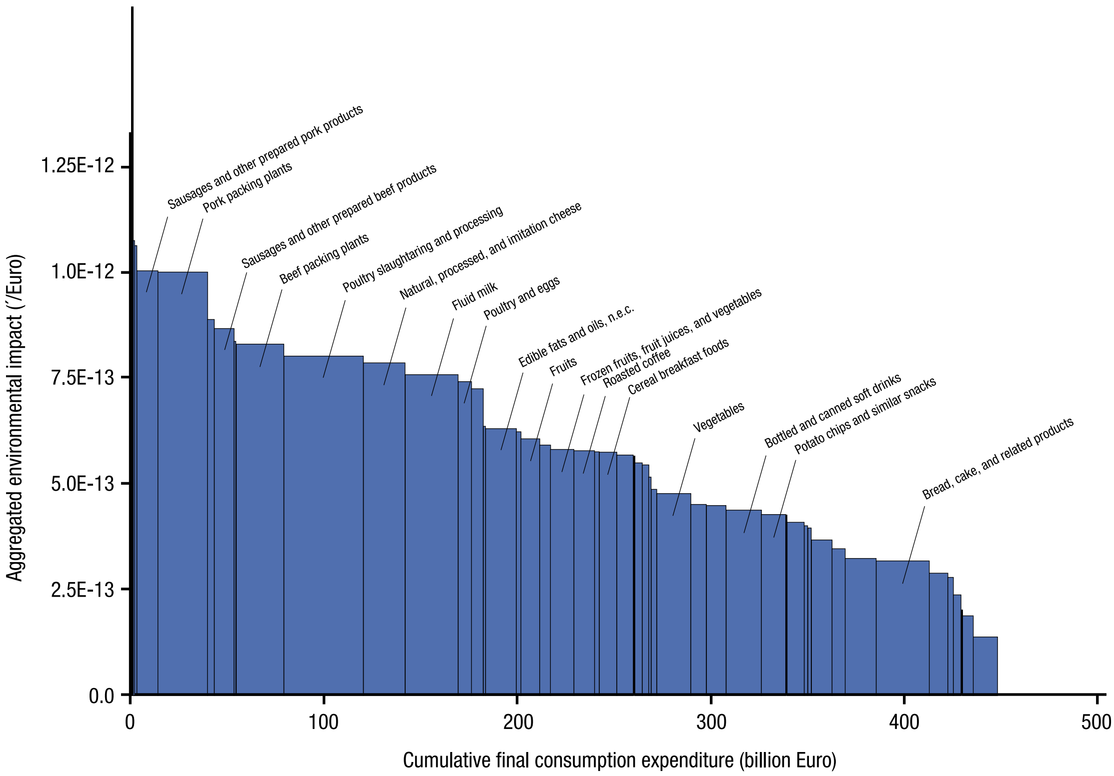
At this very high level of aggregation, changing the diet as specified in Scenarios 1, 2 and 3 leads to a decrease of up to 2 % in environmental impacts, taking into account final consumption of all consumer products. The aggregated environmental impact related to the final consumption of food products decreases about 8 % in Scenarios 2 and 3.

Compared with the changes applied in the alternative diets, the change in overall environmental impacts appears to be relatively moderate. The diets specified in Scenarios 2 and 3 imply a large reduction in the final consumption of beef and pork, which are associated with a relatively large environmental impact per euro. However, the reduction in the final consumption in beef and pork is accompanied by a large increase in the final consumption of a number of other product groups such as poultry, fruit and tree nuts. These product groups are also associated with relatively high aggregated environmental impacts per euro (see Figures 2 and 3).

5.5.5. Environmental impacts of food products in sub-scenarios 'Food'

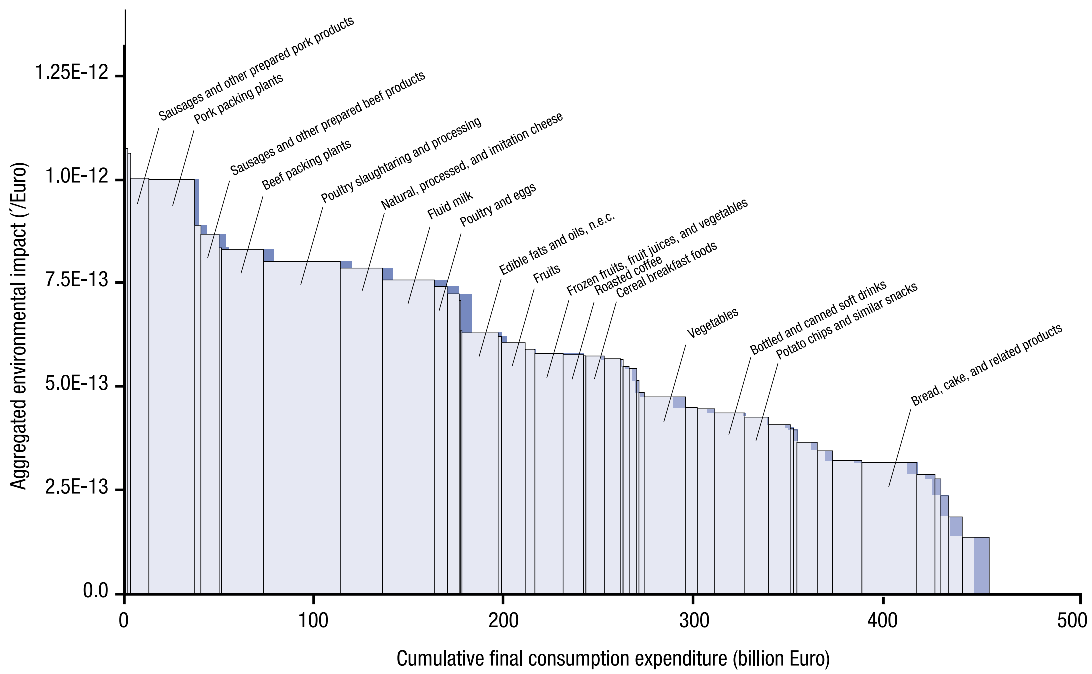
In this section, the focus of the analysis is on the environmental impacts of the final consumption of food products only. The aggregated environmental effects of the changes in final consumption of food products are illustrated in Figures 4 to 7. Values underlying Figures 4 to 7 for all product groups can be found in Chapter 5, Annexes 6, 7, 8 and 9 of the annex report. In Figure 4, the status quo situation ('Scenario 0 — Food') is shown; it is similar to Figure 3 except that it shows the impacts per euro and the expenditure on food products only. In Figures 5, 6 and 7, the effect of changing the current European diet to 'Scenarios 1, 2 and 3 — Food' are shown. Product groups with a label contribute more than 0.5 % to total aggregated environmental impacts in the European Union. The dark grey area in the background represents the impacts per euro and the expenditures in the status quo situation ('Scenario 0 — Food'). The light grey area in the foreground which overlays the dark grey area shows the impacts per euro and the expenditures after the expenditures on food products have changed. Any change in aggregated environmental impact shows up as a difference between the figures. Visible dark grey indicates environmental improvement and, where light grey does not overlay the dark grey, it indicates environmental deterioration.

Figure 4 — Environmental impacts of final consumption of food products in 'Scenario 0 — Food', in descending order of impact per euro



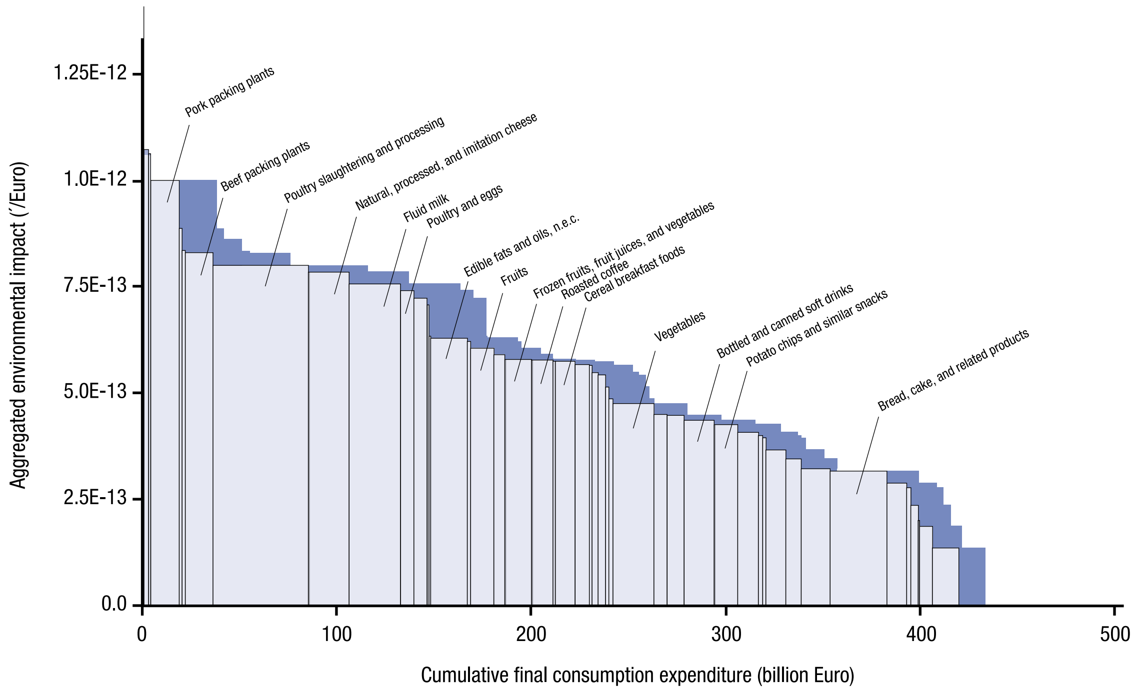
NB: Products that contribute more than 0.5 % to total aggregated environmental impacts in the European union are labelled.

Figure 5 — Comparing the environmental impacts of final consumption of food products in 'Scenario 0 — Food' (dark blue background) and 'Scenario 1 — Food' (light blue foreground), in descending order of impact per euro



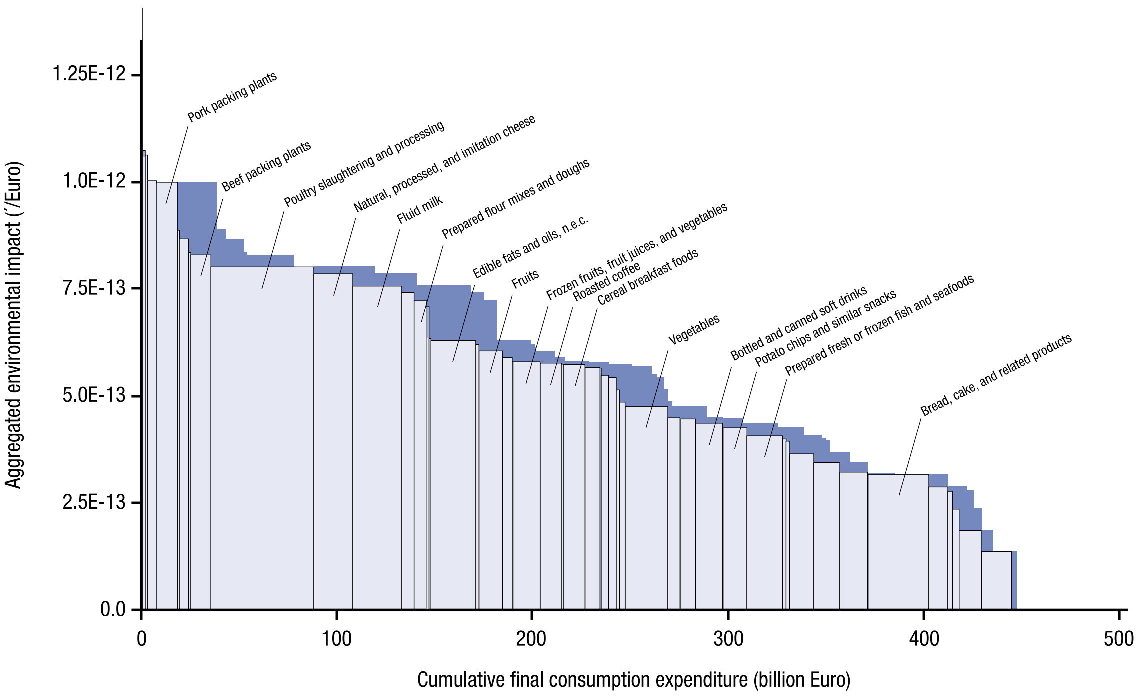
NB: Products that contribute more than 0.5 % to total aggregated environmental impacts in the European union are labelled. The aggregated environmental impacts of 'Scenario 0 — Food' very much look like those of 'Scenario 1 — Food'.

Figure 6 — Comparing the environmental impacts of final consumption of food products in 'Scenario 0 — Food' (dark blue background) and 'Scenario 2 — Food' (light blue foreground), in descending order of impact per euro



NB: Products that contribute more than 0.5 % to total aggregated environmental impacts in the European union are labelled. The aggregated environmental impact of 'Scenario 0 — Food' is somewhat larger than 'Scenario 2 — Food'.

Figure 7 — Comparing the environmental impacts of final consumption of food products in Scenario 0 (dark blue background) and Scenario 3 (light blue foreground), in descending order of impact per euro



NB: Products that contribute more than 0.5 % to total aggregated environmental impacts in the European union are labelled. The aggregated environmental impact of 'Scenario 0 — Food' is somewhat larger than 'Scenario 3 — Food'.

It is quite clear from Figures 5 to 7 that the large differences in expenditures on food products do not lead to large differences in aggregated environmental impacts. The light grey area is similar or slightly smaller than the dark grey area in the background. However, changes in specific environmental impact categories or specific emissions may be large.

5.5.6. Environmental impacts of food products inclusive of first-order effects

In the same way as the aggregated environmental impacts have been calculated for 'Scenarios 0, 1, 2 and 3 — All' (Table 25), also the aggregated environmental impacts of the diet change scenarios including possible consumer expenditure redistribution effects have been calculated. These are shown in Table 26.

Comparing Tables 25 and 26, it can be seen that at this very high level of aggregation the possible consumer expenditure redistribution effect influences the estimated aggregated environmental impacts. In 'Scenarios 2 and 3 — All + first order' the aggregated environmental impacts of non- food products increases 0.6 % and 0.1 % with respect to Scenario 0 because more of these products are purchased by consumers offsetting the decreased aggregated environmental impacts of the food products category.

The analysis of environmental effects of the income expenditure redistribution effect is of course highly dependent on the chosen redistribution key. If the changed expenditure on food products is not redistributed proportionally over all non-food product groups but allocated to a specific non- food product group the results may be different.

Changes in environmental impacts due to changes in the European diet may become more profound at a lower level of aggregation of the environmental impacts. This has been analysed by plotting the calculated environmental impact for 'Scenario 0 — All' and 'Scenarios 1, 2 and 3 — All + first order' per impact category (see Figure 8). Values underlying Figure 8 can be found in Chapter 5, Annex 10 of the annex report.

The scores for the impact categories abiotic deletion, global warming, ozone layer depletion, human toxicity and photochemical oxidant formation do not differ much between the different scenarios. The score for the impact category ecotoxicity increases slightly, about 2 % for Scenario 2. The score for the impact category acidification decreases about 4 % for Scenarios 2 and 3. For eutrophication, the score decreases about 6 % for Scenario 2 and about 7 % for Scenario 3.

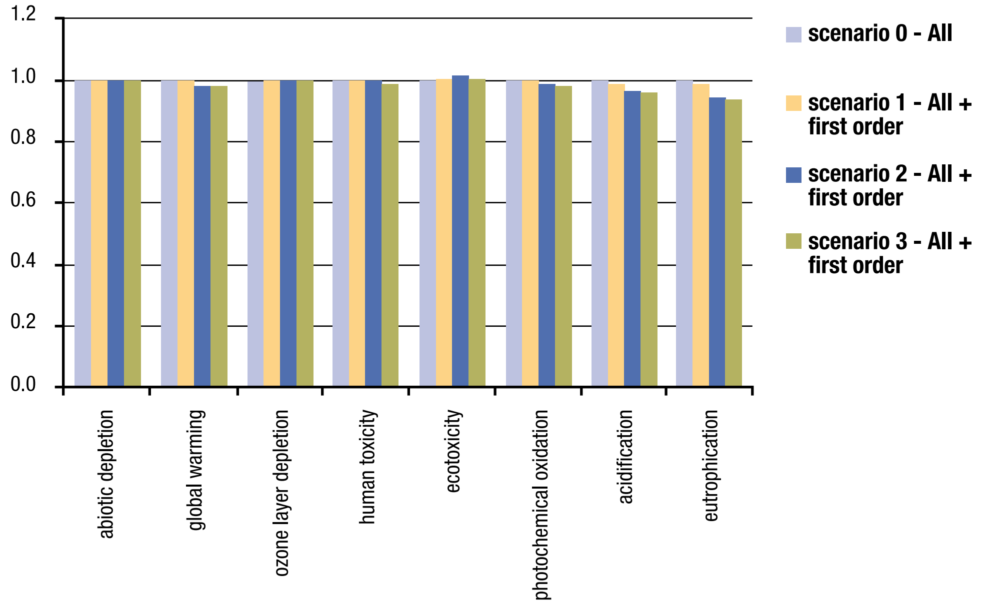
Looking in more detail at the emissions which contribute to the impact category ecotoxicity, the increase is caused by emission of several pesticides to freshwater used in the cultivation of 'tree nuts', and 'fruit' and 'vegetables'. It is the combination of a sizeable contribution of the use of pesticides in these cultures to the ecotoxicity impact indicator and

Table 26. Aggregated environmental impacts of the final consumption of food product groups and non-food product groups in the EU for `Scenarios 0, 1, 2 and 3 – All + first order´

Category	Aggregated environmental impact			
	'Scenario 0 All + first order'	'Scenario 1 All + first order'	'Scenario 2 All + first order'	'Scenario 3 All + first order'
Food	27	27	25	25
Non-food	73	73	74	73
Total	100	100	98	98

NB: The total result in Scenario 2 (98 %) is rounded and therefore lower than the sum of food and non-food impacts.

Figure 8 — Environmental impact scores as a result of the final consumption of all products in the EU for the different impact categories for 'Scenarios 1, 2 and 3 — All + first order' compared with 'Scenario 0 — All'



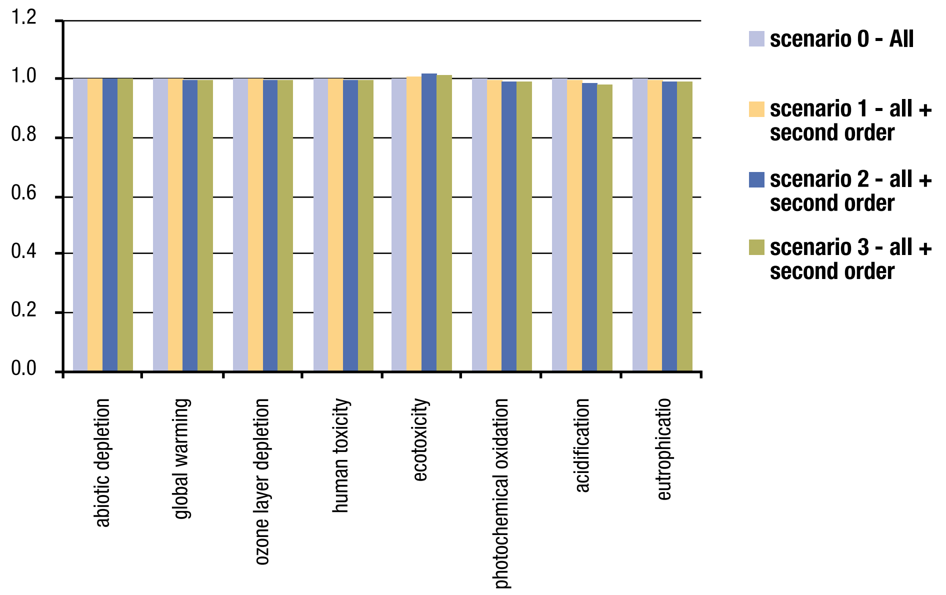
a large increase in the final consumption of these three food product groups in 'Scenarios 1, 2 and 3 — All + first order' which increases the score for this impact category. Notice that the impacts of final European consumption on ecotoxicity are dominated by industrial emissions of hydrogen fluoride [20] to air, metal emissions from industrial processes to soil and household use of pesticides, and not by emissions of pesticides from agricultural practice.

The score on the impact category acidification decreases in 'Scenarios 1, 2 and 3 — All + first order'. Sizeable contributions of direct emissions from agricultural sectors to this impact category are made by 'dairy farm products', 'pigs', 'poultry and eggs' and 'cattle' due to their ammonia emissions to air. In 'Scenarios 1, 2 and 3 — All + first order', the contributions of the cattle and pig sector decrease. The contribution of the 'dairy farm products' sector remains constant in 'Scenarios 1, 2 and 3 — All + first order'. In 'Scenarios 2 and 3 — All + first order', the contribution of the 'poultry and eggs' sector increases but this increase is offset by the decreasing contributions of the cattle and pig sector.

The score on the impact category eutrophication decreases in Scenarios 1, 2 and 3. Eutrophication is the only impact category where the impact score as calculated for the final consumption in the European Union is dominated by direct emissions from the agricultural sectors. Sizeable contributions of agricultural sectors to this impact category are made by: dairy farm products, pigs, poultry and eggs, cattle, food grains, feed grains, miscellaneous crops, sugar crops, feed grains, fruit and miscellaneous livestock as a result of ammonia emissions to air and phosphorous emissions to freshwater. The complex changes in the ammonia and phosphorous emissions in the above sectors result in a lower impact score for eutrophication.

20 For instance, from coal burning power plants, and blast furnace works.

Figure 9 — Environmental impact scores as a result of the final consumption of all products in the EU for the different impact categories for 'Scenarios 1, 2 and 3 — All + second order' compared with 'Scenario 0 — All'



5.5.7. Environmental impacts of food products inclusive of secondary effects

In Section 5.4.5 it was explained that the total supply of primary agricultural sectors rebounded towards the original total supply of these sectors when structural changes are taken into account.

Accordingly the environmental impacts of the supply vector taking into account second-order effects also approximates towards the baseline ('Scenario 0 — All'). In Figure 9 we have, similarly to Figure 8, plotted the calculated environmental impact for 'Scenario 0 — All' and 'Scenarios 1, 2 and 3 — All + second order' per impact category. Values underlying Figure 9 are given in Chapter 5, Annex 11 of the annex to this report.

Comparing Figures 8 and 9 we see that the environmental impacts of the introduction of the alternative diets, taking into account secondary effects, is reduced compared with the scenarios which only included first-order effects.

As explained in Section 5.4.1, a dissection of the contribution of individual product groups to the total environmental impacts of final consumption is not possible for the scenarios that take into account the secondary (non-linear) economic effects. As far as the total impact for the second-order scenarios concerns food and non-food together, the relative impacts are:

Category	Aggregated environmental impact 'Scenario 0 All + first order + second order'	'Scenario 1 All + first order + second order'	'Scenario 2 All + first order + second order'	'Scenario 3 All + first order + second order'
Total	100	100	99	99

5.5.8. Influence of chosen impact assessment method on results

The CML2002 impact assessment method, as used above, is one of several impact assessment methods available. Impact assessment methods contain many subjective choices and model choices. Different choices lead to different impact assessment methods which in turn may affect the assessment of the environmental impacts associated with the change in diets.

To make an assessment of the influence of the chosen impact assessment method on the result as described in Sections 5.5.3 to 5.5.7, a complete different impact assessment method was also used to calculate the aggregated environmental impact of products. This alternative impact assessment is the Eco-indicator 99 method which provides so-called end-point environmental performance indicators.

These end-point impact categories are:

- damage to human health;
- damage to ecosystem diversity;
- damage to resource availability.

To be able to present an overall aggregated environmental impact score the scores for the three impact categories can also be normalised and weighted. The Eco-indicator 99 methodology has built in normalisation data and several sets of weighting factors. The different sets of weighting factors represent different attitudes of society towards environmental problems. The set of weighting factors representing the hierarchist perspective has been used, which is recommended practice ([21]).

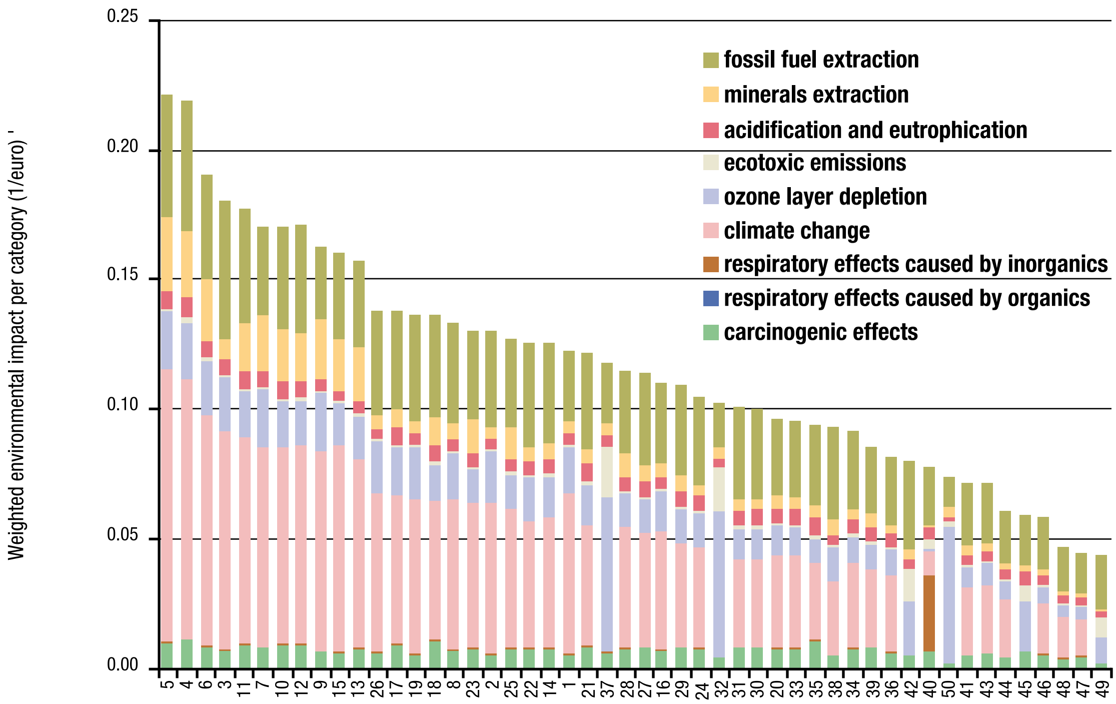
The calculated environmental impacts per euro for the food products using the Eco-indicator 99 method are shown in Figure 10 in descending order of weighted environmental impact per euro. The food item number refers to the number as given in Table 24 and reflects the ranking of the environmental impact per euro for the food products when using the CML characterisation method. In other words, if the ranking of the environmental impact per euro of the food products using the CML and Eco-indicator 99 methodology had been the same, the food item numbers in Figure 10 would also be in ascending order.

Comparing the ordering of the food products in Figures 2 and 10, it can be seen that the ordering is similar (Spearman correlation coefficient = 0.91 ([22])). There is one notable exception: 'miscellaneous crops', which had by far the highest aggregated environmental impacts per euro according to the CML2002 method; it is ranked 22nd according to the Eco-indicator 99 method. The reason for this is that the Eco-indicator 99 method does not take into account emissions of phosphorous in the assessment of damage to ecosystems caused by the combined effect of acidification and eutrophication while the emission of phosphorous dominates the aggregated environmental impact of 'miscellaneous crops' in the CML2002 method. For the general analysis of the environmental impact of diet changes, this is not a problem because the product group 'miscellaneous crops' is the only product group whose environmental

21 Weighting is always subjective and different societal actor groups may have different weighting preferences. Cultural theory as developed by Thompson et al. (1990) claims that there are in any society and any time frame just three manifest perspectives/biases, which are called the hierarchist, egalitarian and individualist perspective. The Eco-indicator 99 project has developed weighting sets reflecting all these perspectives, and recommends using the hierarchist weighting set as default.

22 The Spearman correlation coefficient, also called Spearman rank correlation coefficient, is the correlation coefficient between two data sets after the data have been rank transformed. It measures if an increase in variable x is associated with an increase in variable y. In this case it shows that the ordering of the environmental impacts of the product groups according to the CML impact assessment method is very similar to the ordering of the environmental impacts of the Eco-indicator 99 impact assessment method. If the ordering was the same in both impact assessment methods, the Spearman correlation coefficient would be 1. If the ordering had been exactly opposite the Spearman correlation coefficient would have been 0.

Figure 10 — Environmental impacts per euro for food product groups for all environmental impact categories according to the Eco-indicator 99 method (hierarchist perspective)



NB: The food item number refers to the numbers as given in Table 24.

impact is dominated by eutrophying emissions (Figure 2) and final consumer expenditure on this group is negligible (see Table 17).

Another exception — but much less extreme — of a food product group that is ranked differently is the group 'tree nuts'. It was ranked second by the CML2002 method, having an aggregated environmental impact similar to product groups such as sugar and pork products. According to the Eco-indicator 99 method, it is ranked 18th. In the CML2002 method, the aggregated environmental impact is, for 48 %, determined by emissions having contributions to the impact category ecotoxicity (see **Figure 2**). The contribution of ecotoxic emissions to the aggregated environmental impact in the Eco-indicator 99 method is reduced to 3 %. For all food product groups the contribution of ecotoxic emissions is reduced in the Eco-indicator 99 method but for the food product group 'tree nuts', the reduction is exceptional. Two pesticides (aldicarb, cypermethrin) determine for a large part the ecotoxicity score for the product group 'tree nuts'. The Eco-indicator 99 method does not take into account the emissions of these substances. Aldicarb and cypermethrin are also emitted from other agricultural sectors but their contribution to overall ecotoxic impacts is less dominant. The only exception is the agricultural product group 'miscellaneous crops' contributing to the different ranking of this product group.

Not only the ranking of the food product groups according to environmental impact per euro is rather similar; the relative size of the environmental impact per euro is also very similar. Comparing the aggregated environmental impacts as calculated by the CML2002 and Eco-indicator 99 methods it can be shown that their relative size for the different food products is very similar. The Pearson correlation coefficient between the aggregated environmental impact indicators of CML2002 and Eco-indicator 99

Table 27. Aggregated environmental impacts of the final consumption of food product groups and non-food product groups in the EU for Scenarios 0, 1, 2 and 3, sub-scenarios 'All' and 'All + first order' as calculated with the Eco-indicator 99 method (%)

	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Sub-scenario 'All'				
Food	24	25	22	23
Non-food	76	76	76	73
Total	100	100	98	98
Sub-scenario 'All + first order'				
Food	24	25	22	23
Non-food	76	75	76	76
Total	100	100	99	98

NB: Aggregated environmental impacts for 'Scenario 0 – All' for the sum of all products have been used as reference.

is very high (Pearson correlation coefficient = 0.91 ([23])) if we exclude 'miscellaneous crops' from the analysis. This also means that the aggregated environmental impact per euro for the high impact groups is about a factor 3 higher than that for the low impact food product groups ([24]), similar to the CML2002 method results.

On the basis of the quite similar assessment of the environmental impacts of the Eco-indicator 99 method, the assessment of the environmental effect of dietary changes using the Eco-indicator 99 method does not differ much from the CML2002 results as shown in Table 27.

The contribution of the final consumption of food products to the total environmental impacts due to the final consumption of all products in the European Union is estimated to be 24 % in Scenario 0. It is a little bit less than estimated with the CML2002 method.

Changes in the aggregated environmental impact due to changes in European diets are a little bit more pronounced as estimated with the Eco-indicator 99 method. However, the similarity in quantity and distribution of environmental impacts resulting from both the Eco-indicator 99 and the CML2002 methods allow one to conclude that the choice of the impact assessment method does not have a decisive effect on the assessment of the environmental impacts of current and alternative diets.

5.6. Conclusions

Section 5.5 shows that the change in environmental impacts in the different scenarios appears to be limited. Scenario 1 has virtually no change in environmental impacts. Reductions caused by, for example, reduced beef and pork consumption is offset by consumption and related impacts of other food products, such as fish and fruit. Scenarios 2 and 3 see a further reduction of beef and pork consumption, which is largely replaced by poultry. The net reduction of impacts is less than 10 % related to food consumption, and,

23 The Pearson correlation coefficient, also called the Pearson product moment correlation coefficient, is a measure of the linear association of variable x and y. In this case it shows how far the environmental impacts of the impact assessments, as calculated with CML, are linearly associated with the environmental impacts, as calculated with the Eco-indicator 99 impact assessment method. Perfect linear association would give a Pearson correlation coefficient of 1. No linear association at all would give a Pearson correlation coefficient of 0.

24 Based on the difference between the 90 % percentile and the 10 % percentile for the aggregated environmental impacts.

with food accounting for around 25 % of the total impacts of final consumption, the considerable diet changes in Scenarios 2 and 3 would lead to around 2 % less impacts due to final consumption in the EU-27. Section 5.5 shows that a structural change in the primary agricultural sectors as a result of the introduction of the alternative diets further reduces the environmental effects. It has to be noted that E3IOT is not capable of assessing the impacts on biotic depletion. Negative impacts on natural fish stocks of the highly enhanced fish consumption in Scenario 3 is hence not taken into account.

6. Policy options for dissemination of healthy diets

6.1. Introduction

A change towards healthy diets with less environmental impacts is a representative example of a change towards sustainable consumption and production patterns (SCP). In such a process of change, producers, market-based instruments and consumers all play a different role. In this section, theories on the change to the SCP in general will be reviewed, and the roles therein of markets, producers, consumers and other elements (Section 2). Then instruments that can foster change to the SCP in general will be presented (Section 3). Finally, the results will be specified for the case of a change to healthier diets with lower environmental impacts (Section 4).

6.2. Concept: changes in consumption and production patterns

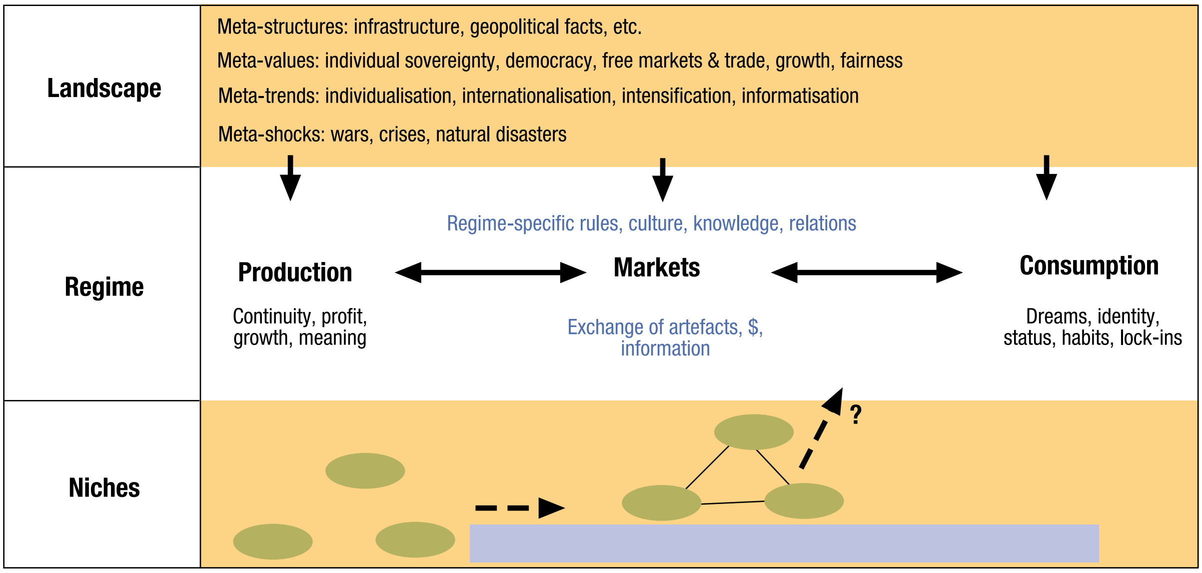
6.2.1. A systemic view of consumption and production practices

A useful model to understand changes in the production–market production chain is given in Figure 11. It describes a production–market–consumption regime in a landscape context consisting of meta-trends, meta-values and meta-structures, and meta-shocks. Within or below the production–market–consumption regime, niche developments with alternative producer–consumer relations, which have not reached a high level of diffusion, are described. This multi-level theory of systems of production and consumption has been developed by innovation specialists like Kemp, Rip, Rotmans and Geels (2005), but also has many parallels with the idea of 'social practices' that has been embraced firmly by consumer scientists (cf. Shove, 2004; Spaargaren, 1997). It explains why an intentional radical change in practices in domains like food, mobility and housing is often difficult (for example, Tukker et al., 2008).

First, the meta-factors in the landscape pose clear boundaries for regime development and hence enforce stability. Meta-structures include existing infrastructures, geopolitical realities and other 'hard facts'. Meta-trends include internationalisation/globalisation, individualisation, informatisation and intensification [25]. Meta-values are widely-held beliefs and cultural values such as personal freedom, democracy, equal rights, pursuit of growth, free markets, (unlimited) private ownership and a high level of personal responsibility for personal well-being (Mandelbaum, 2002). The former meta-factors usually represent a set of fixed variables, which cannot be modified by actors in the regime in the short term, and tend to change only slowly. Meta-shocks are sudden disruptive events like wars, economic crises, etc. and, unlike the other meta-factors, a source of instability. These meta-factors give a first explanation why change often is incremental (except if meta-shocks cause crises forcing quick changes). For instance, we cannot expect policymakers to embark on policies that would radically cut meat consumption. This would go against the prevailing paradigm of free consumer choice. We can expect, however,

25 Intensification reflects, on the one hand, the high interest in change and variation of experiences, but also the fact that time pressure on private and professional life is rising, since more is being done in the same time. All these trends in themselves can have important consequences for (unsustainable) consumption patterns: smaller households and choices for individualised rather than communal services (individualisation), more use of energy-using ICT products (informatisation) and the creation of global relation networks leading to higher transport needs (internationalisation), and more use of convenience products and services and time-saving appliances like dish washers (intensification).

Figure 11 — The production–consumption regime embedded in a landscape context and with competing (niche) practices



Source: Tukker et al., 2008.

some support for animal rights, since that finds resonance with the rise of moral standards that have developed over the last centuries in most European countries.

Second, also the regime itself is usually a source of stability. It forms an interdependent and co-evolving set of technologies, symbolic meanings, services, consumer practices, habits, rules, financial relations and expectations. A change in one of these elements influences the others as well. This dynamic equilibrium changes usually only incrementally. In a technological analogy, it would not be possible to introduce hydrogen vehicles in the passenger car fleet without hydrogen gas stations, new safety rules, maybe even new driving licence standards, etc. Similarly, plant-based meat replacements require a different infrastructure to be produced, which might conflict with the existing meat processing industry. These products at the same time do not reach broad consumer acceptance, which is the reason why they are still confined to niche markets. This in turns implies that it is expensive for supermarkets to give them ample shelf space. The list of affected elements in this system can be continued ad infinitum.

The limits of change to sustainability can be exemplified by a generic description of the role that businesses play in this. Business is well placed to respond positively to sustainability challenges via radical innovative products and services and related new business models. Businesses' drive for efficiency gives them a natural role in making production and products more resource efficient. Businesses are also sensitive to emerging sustainability norms and values, such as the call for socially and environmentally responsible production and trade. The history of, for example, the Marine Stewardship Council, Responsible Care, and similar schemes shows that business is well capable of promoting sustainability values in their supply and downstream chains. Yet, the competitive market system also rewards companies that make people dependent via the promotion of greed, fear and addictions, that externalise costs, and that draw hitherto freely available non-market goods into a market context (Charter et al., 2008; Tukker, 2008). Finally, few businesses are flexible enough to respond to sustainability challenges that require a radical change in existing production structures, and the build-up of new ones. In such cases businesses often take up a role of lobbying for a slowdown of change [26].

For this reason, many radical alternative practices for the mainstream regime take place in niches (the bottom level in Figure 11): small, alternative markets where a different value proposition is asked than in mainstream markets. Examples are car-sharing systems in the field of mobility (typically less than 1 % of the market), the dedicated organic food shops of the 1970s and 1980s in several western European countries, etc.

6.2.2. Implications for the role of consumers in the change to the SCP

This overview shows that consumers and producers usually face important limitations to embark on radical change. These theories point to the importance of physical context (meta-structures), overarching values in society (meta-values), habits and routines, bounded rationalities, etc. as factors that limit consumer behaviour and choice *de facto*. In this section, the factors that promote and hinder a change in practices of consumers in particular will be analysed, since they play a key role in the acceptance of diet changes.

Consumers in theory are free to exercise sustainable choice. This can be stimulated via informative instruments and campaigns. However, consumers are for a large part 'locked in' in infrastructures, social norms and habits that limit consumer choice in practice severely. Consumer behaviour change is only likely if three components are addressed simultaneously: motivation/intent, ability and opportunity (Sto et al., 2008). The alternative opportunity should have a mix of features that is at least as attractive as the existing way of doing things — in terms of functionality and immaterial features such as symbolic meaning, identity creation, and expression of dreams, hopes and expectations (Scholl, 2008). Relying on, for example, informative instruments only is hence insufficient (Tukker et al., 2008). At an individual level, consumer behaviour change tends to be easier when 'windows of opportunity' are created by life-changing events or transitional life stages such as moving, starting to live together, getting a new job, or the arrival of children, or when external crises occur.

In the development of alternative diets in the context of this study, the first and second alternative scenarios were both based on current nutrition recommendations across Europe. The first scenario looked at changes towards these nutrition recommendations only; the second also took a reduction of red and processed meat intake into account. The third alternative was based on the Mediterranean diet. All three alternatives require changes in terms of grocery shopping, food preparation and meal planning; all are elements of individual European consumer behaviour. Additionally, European consumers' food choice should be considered from the perspective of individual health behaviour and health behaviour change. The tools and actions that are required to make consumers more willing and thus likely to make behaviour changes and to adopt the scenarios can be explained using social marketing theories (Figure 12). This figure shows that, depending on individual consumers' motivational readiness, different strategies may be most suitable. Marketing and/or nutrition and health education may be used as strategies to promote healthy and sustainable diets in

26 Examples in, for example, the automotive industry include the lobby against CO_2 emission targets in the EU, and the development of SUVs that were not subject to the fuel efficiency standards adopted in the United States for normal cars. Few policymakers are prepared to make life more difficult for an industry that is already struggling with staying profitable, and that at the same time forms in many countries a high part of jobs and turnover in industrial production.

populations that are relatively prone to the desired behaviour, while law may be a better tool in populations relatively resistant to the desired behaviour.

Several theoretical constructs can be used to explain where individuals or groups are located in the above described continuum and how their behaviour can be influenced. Many key theories of individual health behaviour change, for example, postulate that behaviour change is predicted by intention to change. Intention in its turn is thought to be the outcome of reasoned decision-making based on several socio-cognitive constructs, such as: attitudes, self-efficacy, social norms and perceived health threat (Janz et al., 2002; Montaño and Kasprzyk, 2002). The relative importance of these constructs varies across specific behaviours and (sub)groups of the population. For example, a major self-efficacy barrier towards increasing fish consumption for full-time employed men may be their low perceived ability to influence the content of family meals. For women with a low socioeconomic status, however, low self-efficacy in terms of increasing fish consumption may be the result of a perceived lack of cooking skills.

In addition to arguments for reasoned action, it has been argued that human nutrition behaviour may not be reasoned (in part or at all). Instead, human risk or health behaviour in the area of nutrition may be the result of unconscious processes such as habits and stereotypes (Triandis, 1977; Gibbons et al., 1998; Verheijden et al., 2003). The debate about if and how reasoned and habitual processes act and interact in the explanation and prediction of human health behaviour is likely to continue over the next decades. For now, however, it is safe to assume that neither conscious nor unconscious processes alone can fully explain the complex nature of human nutrition and health behaviour.

Theories on the diffusion of innovations also provide insight into the dynamics of individual consumers adopting new food consumption patterns (Oldenburg and Parcel, 2002). Rogers (1995), for example, describes the process of adoption as a normal distribution with five adopter categories: innovators, early adopters, early majority adopters, late majority adopters and laggards. The identification of such categories provides a basis for intervention work. For example, cognitive approaches may be most appropriate for early adopters while a motivational approach may be most effective for early/late majority adopters.

A recent publication (RIVM, 2006) supported the notion that eating behaviour is complex behaviour which is very difficult to change for the better (either in terms of health or in terms of sustainability). A combination of interventions aimed at changing individuals' readiness to change as well as making healthy choices the easy choices by modifying the environment (for example, changing the food supply and thus changing availability and accessibility) is considered to be most effective. In doing so, it has been advocated to design and implement

Figure 12. Continuum of marketing, education and law in achieving individuals' desired behaviour change and behaviour maintenance

Willingness and flexibility of behaviour	Prone to behave as desired		Resistant to behave as desired
Alignment with self-interest	Easy to see or convey self-interest	Need to manage and show benefits	Can't see and can't convey self-interest or benefits
Intervention	Education	Marketing	Law
	Continue behaviour		Change behaviour

Source: Maibach et al., 2002.

behaviour change interventions that are tailored to the characteristics and needs of relevant individuals or subgroups and to include the target group as early as possible in this process (Carlson Gielen and McDonald, 2002; Tyus et al., 2006).

6.2.3. Implications for a change in consumption and production practices

On the basis of the analysis in the former sections, some general insights can be provided into how change to sustainable consumption and production can be fostered.

First, systems are not only prone to inertia. A systemic view of change can also help to find tensions or 'cracks' in the system that facilitate the stimulation of changes. Such cracks can be internal tensions in the production–consumption regime, or a misfit between regime and landscape, and can have a normative and operational dimension. Examples include a production structure evidently based on labour exploitations in poor countries (misfit with ethical meta-values), or a sector practising agriculture in greenhouses, that due to rising energy prices becomes too expensive (operational misfit). Second, when niches with alternative producer–consumer relations exist that have matured and got connected, they may start to form a challenge to the existing regime.

When such niches are existent and at the same time tensions in the producer–consumer regime occur or meta-values change, pressure on the regime may become so high that rapid change may become possible (niches 'scaling up'). The regime breaks down, and niches plus the remnants of the existing regime will develop new structures, which eventually will stabilise and form a new regime (cf. Geels, 2005; Kemp and van den Bosch, 2006).

An *intentional* (as opposed to the above described autonomous) regime change usually is only possible if actors align to create a critical mass for change. This implies that a gatekeeper in the production–market–consumption chain, or a critical mass in this chain, must be convinced of the need for change and act upon it. Usually, one sees a group of actors in favour of change struggling with a group of actors opposing it. The power, interest/desires/beliefs and the legitimacy of the position then determine the position of an actor coalition and its success in defending it (cf. Sabatier, 1987). Typically, the situations below may occur (Hisschemöller, 1993; Guba and Lincoln, 1989 Schön and Rein, 1994).

- Level 1: Take targeted action. There is agreement on (problem) perception, and knowledge of how to solve the problem is rather certain. Taking action fits with mainstream beliefs and paradigms. Here, governments could make operational agreements on implementation of instruments like green public procurement, stimulating ecodesign, etc.
- Level 2: Embark on learning processes. There is agreement on (problem) perception, but the situation is too complex to develop a commonly agreed strategy. Here, governments could foster visioning, experimentation and support, for example, international collaboration in leap-frogging programmes.
- Level 3: Develop strategies to overcome opposing paradigms. There is no agreement on (problem) perception, and knowledge is uncertain — the problem is complicated and intransparent. Potential solutions would outright clash with mainstream beliefs and paradigms. Here, governments could foster informed deliberation on the more fundamental issues related to markets, governance and growth.

In the first two situations, the operational or normative tensions and misfits in the system are so obvious that a usually sufficient sense of urgency and therewith legitimacy is created for action. This is, for instance, currently, after 30 years of discussion and struggle, the case with policies with regard to smoking. The belief that smoking is undesirable is now so widespread in most countries in Europe that governments are legitimised to take drastic measures such as banning advertisements for smoking, and banning smoking in public buildings and pubs. The strong power of the argument that this is a drastic intervention in free markets and contradicts the principle of free consumer choice has clearly been overcome.

Usually, however, the situation is not that clear. With a high level of complexity in many of the systems of consumption and production involved, quite some of these problems will be complicated and intransparent. The perspective on the problem can differ, and/or knowledge about how to reach goals is not certain. A favourite tactic of potential losers is to articulate such uncertainties and ambiguities in an attempt to de-legitimise intervention. Interests and interpretative frames are hopelessly mixed up, and calls upon science to arbitrate usually fail due to the 'trans-scientific' nature of the problem (cf. Weinberg, 1971). Prolonged discursive struggles usually then determine the outcome.

6.3. Instruments and approaches to foster change

Based on the analysis above, a mix of instruments and approaches that fosters change in consumption and production patters can be developed via two axes:

(1) the point in the production–market–consumption chain that they influence;
(2) the level complexity of and controversy with regard to change, as indicated in Section 6.2.

Real active policies seem only possible at a level 1 complexity (in those situations where there is not too much controversy over meta-values, or collision with other meta-factors, and where it is clear how goals can be reached). It is a situation where all actors agree that change in production and consumption systems are needed. Here, instruments can be used directly to influence consumption, production or markets. We then usually see 'regime compliant' measures that may create momentum for further change, but usually have some limitations in impact. Per step in the production–consumption chain and per actor at stake one can discern, for example, the approaches below.

Production side

- Businesses can apply cleaner production; embark on greening supply and downstream chains, design of sustainable products, etc.
- Government can provide legislation and other incentives that provide a level playing field with regard to sustainability demands.

Markets

Here government is the only factor that is capable of setting the rules of the game. Strategies include 'getting the prices right' (abolishing perverse subsidies and taxes where externalities have to be internalised), promoting transparency about sustainability issues, and setting limits to advertising where relevant [27].

Consumption side

- Consumers can within limits exercise sustainable choice, and use their action power as citizens and voters to call for sustainable behaviour of other actors in the production–consumption chain.
- Businesses can help consumers to choose responsible products, for example by making available more sustainable products, choice editing, sustainability marketing, and help consumers to behave sustainably with, for example, informative instruments.

27 Examples include, for example, limiting advertising that could lead to unhealthy habits, like smoking.

Governments

Governments can create sustainable markets by sustainable public procurement, make consumers aware via information campaigns, and enable consumers to behave sustainably by providing infrastructures that encourage sustainable choice.

Policies addressing the other levels of complexity require a different approach. At level 2, there is broad agreement on the direction of change, but the means for change are unclear. Here, government should promote, with business and other players, the creation of new niche practices, and stimulate innovation in the desired direction (compare: Hekkert et al., 2007; Kemp and van den Bosch, 2006). At level 3, it is hardly possible to develop any direct policy intervention at all: both goals and means are contested. Here, the main strategies are embarking on deliberative processes that may lead to more consensus on goals, stimulating research that may lead to a kind of proof that certain goals are more important than others, and stimulating niche experiments that may prove the value of hitherto not accepted practices ([28]).

6.4. Stimulating healthy diets

6.4.1. Introduction

In this section, the concept presented before will be specified for the purpose of changing diets. It will be first discussed what landscape or meta-factors may hinder or re-enforce and enable change, and provide some examples of niche developments. After that, measures at mainstream regime level will be discussed that could be suggested to support healthier diets.

6.4.2. Some relevant landscape/meta-factors and niche developments

In various contexts, including the SCORE! project, analyses have been done regarding important trends in the food sector (for example, Tischner and Sto, 2009) ([29]). Such trends and developments are listed below.

(1) Globalisation/delocalisation, industrialisation and power concentrations in the food chains: In most chains of food products, a limited number of retailers and producers of intermediate or finished food products form powerful nodes that control the main part of the market. Due to this power concentration, these are the actors that tend to be able to capture most of the added value in the food chain (cf. Porter, 1985). Primary producers (farmers, the fishing sector, etc.) tend to have much less influence, although in the EU this is partially compensated by the fact that such groups have organised strong lobbies by their representative organisations. Industrialised and globalised production further implies that food components are split off from their original chains and used in other chains, and combined with ingredients from different parts of the world.

(2) New technologies in food production: Developments in ICT and GPS allow for easier tracking and tracing, even in the more

28 Here are some examples. Research into health effects of smoking slowly but steadily lead to legitimacy for government to intervene in smoking habits, advertising, etc. The pioneering efforts of 'Third World shops' and labels like Max Havelaar in the 1970s and 1980s, that articulated the problems around fair trade, slowly lead to a change in expectations, norms and values of the general public about how firms should deal with social and environmental problems in their production chains (Tukker, 2008). While issues like 'fair trade' may have been contested 20 years ago, the question now for businesses, consumers, NGOs and policymakers seems no longer to be whether the issue is relevant, but how the problem can be tackled. This issue hence has been transformed from a level 3 to a level 2 problem.

29 The 'Sustainable consumption research exchange' (SCORE!) project is an EU sixth framework programme funded network project, engaging a few hundred scientists that deal with the issue of change to SCP. The main conclusions of the project are reflected in four books, of which the book on general change to SCP (Tukker et al., 2008) and the book dedicated to the food area (Tischner and Sto, 2008) are the most relevant ones for this chapter.

complex food webs that are developing. Biotechnology and genetic engineering are playing a more important role too in food production.

(3) Convenience, fast and finger food: Time-efficient life styles that consumers in developed countries follow imply that the time for preparing meals has been reduced considerably over time. Consequently, there is a growing demand for convenience and fast food.

(4) Moral and health standards: Societal concerns, critical consumerism and demands for transparency, fair trade, compliance with basic social norms and standards in production are factors which influence consumer decision-making (30). In the last decades, crises like food-and-mouth disease, BSE, bird flu, etc. have lessened the public's trust in food safety, although at the same time food safety issues are strongly controlled and regulated in the EU. Transparency in the food chain is likely to stay an issue in the period to come. Other societal concerns include the health aspects of food (obesity, cardiovascular diseases, etc.).

(5) Consumer sovereignty and free trade/free markets: The paradigms of consumer sovereignty, free trade and free markets are basic concepts in the EU-27. For instance, it is well known that when societies become richer meat consumption usually becomes relatively more important. Interventions in such consumer choices are currently only acceptable if they are mainly addressed via soft measures like education and awareness-raising, but not via price mechanisms or bans [31].

The above can provide both support measures as well as hindrances to influencing food consumption patterns. Directly posing limits on consumer choice, trade and markets (point 5) is usually not acceptable, unless such limits are meant to restrict practices that do not comply with basic standards with regard to working conditions (point 4). The development towards more convenience food (point 3) implies that retailers and fast food outlets become ever more important, which further supports globalised and industrialised as opposed to localised food chains and systems (point 1). The power concentration in the food market (point 1) implies that policies that directly oppose the interests of such players are unlikely to be feasible, but at the same time such powerful players may be compelled to support developments in the food chain that result in the desired high moral and health standards (point 4). New technologies may help cleaner production of food, but also may make the food production system more global and complex, leading to more transport, etc. (point 2).

There are various small-scale developments that can be regarded as niche practices providing alternatives for the mainstream way of food consumption. Such niches include (Jégou, 2008) [32]:

- the growing popularity of the 'slow food' movement: restaurants sourcing their food locally, providing healthy meals, in a context that deliberately stimulates taking meals slowly so that social cohesion between dinner participants is fostered;
- the 'organic bag' business model fostered by organic farmers in various countries;

30 For instance, provisions that inhibit the use of child labour, ensure payment of minimum wages, and ensure that workers have reasonable working weeks of, for example, 48 hours at most.

31 The exception is smoking. Over the last decades, enough evidence has been gathered to change the societal perception of this habit. Now it is possible for governments to embark on radical measures like smoking bans in buildings and bans on all advertising.

32 The niche examples discussed here focus to a large extent on organic food. As will be explained later, one of the problems in the food area is that what is sustainable and what is non-sustainable food is not always uncontested. Organic food uses less or no pesticides and fertilisers in production, but may have disadvantages like less (area) intensive production, with a higher surface and energy use in production as a consequence. Similar discussions are at stake with regard to the relevance of local production, etc. (Tischner and Sto, 2008).

households can subscribe to an 'organic bag' system, and are provided with a weekly supply of local, organic food of the season, including recipes for cooking;

- food clubs: groups of citizens organising their own food supply chain, collaborating with local and/or organic farmers.

Such approaches, even a rather large one like the slow food movement, currently only cover a limited part of the food market in the EU. Yet, like the 'Third World shops' and fair trade movement in the 1970s and 1980s, such niches may develop — in adapted form — to mainstream concepts in the future.

6.4.3. Changing consumption

In this section, we want to discuss how business, government and consumers can contribute to a change in food consumption patterns.

Business

Although the main driver of business is making profit, there are reasons why business can play a role in changing food consumption patterns. The main reason is that society tends to become more and more aware of and opposed to unsustainable and unhealthy patterns in the food system, and that companies in the food chain are more and more expected to behave responsibly. Businesses hence have an interest in making their food chains transparent and show that they comply with basic environmental and social standards. While in the 1970s and 1980s fair trade labels like Max Havelaar were mainly niche markets sold via specific channels and outlets, today major retailers and producers embark on labelling systems that support transparency and overall compliance with basic environmental and social standards, also in the part of the food chain that is outside Europe. Some retailers set themselves targets with regard to sales of biological and organic food, and put massive amounts of financial resources into analyses of how to reduce their carbon footprint, how to contribute to sustainable consumption, etc. ([33]). Measures that business can take to change food consumption patterns that result in healthier diets include:

(1) choice editing: offering only or mainly high-quality and healthy food products, and, by this, deleting the less sustainable and unhealthy competition; as food shopping today is largely routine behaviour, this can have a large impact on the buying behaviour of consumers; examples are promoting certified/labelled food, providing healthy convenience food, etc.;

(2) sustainability and health marketing: promoting healthy food consumption patterns via advertising and raising awareness.

Government

Government can have an influence on food consumption patterns in a variety of ways.

(1) Traditional awareness and stimulation campaigns: Promoting healthy food consumption patterns, either directly by advertising, television or Internet campaigns, or via the schooling systems, and providing an infrastructure that supports individual behaviour change towards healthier food consumption, etc.

(2) Providing structures for direct feedback: Some interesting experiments have been done that, on a small scale, used an approach combining direct feedback on health status and a positive form of peer group pressure. They showed a general change towards more healthy life styles and food consumption patterns. In the north of Sweden various small villages were provided with a programme that would measure basic parameters in the blood of citizens, such

33 See, for instance, the investment of GBP 25 million made by TESCO in the Manchester University Sustainable Consumption Institute.

as cholesterol, etc. Results were published publicly on a regular basis, and a kind of competition developed between the villages regarding who had on average the healthiest body parameters. Citizens started to change their diet and living habits to score better in this competition, and the result after a decade or two was an improved life span of several years.

(3) Sustainable public procurement: In the EU, around 16 % of final expenditure in societies is done by government. In the food area, governments and the semi-public sector determine what catering contracts are in place for their offices, and in several countries also in schools. They can use such contracts to influence the type of food on offer. Via such channels, the lunch habits of a large amount of the population can be influenced. The exemplifying value may further motivate consumers to develop food consumption patterns in line with what they are offered at their work or educational place, and such measures hence may have a high indirect impact.

(4) Indirect stimuli: In most EU countries, governments also have a large influence on the health systems and their financial structures. Some countries are currently considering introducing a system in which individual health insurance fees are linked to personal risk-taking behaviour. People with unhealthy life styles would, under such a regime, be charged more for their healthcare insurance. Such measures may stimulate individuals to embark on healthier food consumption patterns.

(5) Direct restrictions on sales based on the premise of consumer protection: In a system that is based on free markets and free trade, such measures are not easily feasible, but in some cases enough legitimisation may exist for governments to apply them. Regulating outlets and setting minimum ages for purchasing tobacco and alcoholic drinks is one example. In the same line, future regulations that limit the sales of fast food, candy, etc. could be considered in places where vulnerable groups are present (for example, schools, to avoid fast food chains providing subsidies to a school in return for the possibility to locate their restaurant in that school).

Consumers

Consumers themselves, also in their role as citizens, have responsibility in changing consumption patterns. However, the suggestion that consumers themselves have full control to change consumption patterns largely is flawed. As discussed in Sections 6.2 and 6.3, consumers live in a context that often leaves them with a limited choice; the amount of choices to be made and the parameters that play a role in it are so large that no one can be expected to make them 100 % consciously, resulting in a main role for habits, etc. The options that consumers do have to change to healthier and more sustainable food consumption patterns are:

(1) exercising more sustainable and healthier choices, where possible endorsed by consumer organisations;
(2) organising local 'healthy food clubs', which organise their own sources of local, healthy food;
(3) articulating sustainability and health values, and putting pressure on industry to implement them (for example, via consumer organisations and environmental NGOs).

6.4.4. Changing markets

Changing markets is mainly an issue for governments. In this area, governments can consider the following measures that can stimulate healthier food consumption patterns:

(1) promoting transparency on the environmental, social and health aspects of

specific food products (mainly via voluntary or obligatory labelling rules);

(2) setting basic advertising norms, for instance restrictions on advertising of less healthy food, particularly if directed at vulnerable groups;

(3) limiting mono- and oligopolies, particularly if such cartels block a diffusion of healthier food consumption patterns;

(4) internalising external costs, and abolishing perverse subsidies, so that healthy food does not come at an unnecessary premium.

The last of the above listed measures is probably most difficult to realise. Particularly in the food area, regarding some important issues no objective opinion is available about what is a sound standard for social, environmental and health aspects. The use of genetically modified organisms (GMOs) is controversial, although proponents argue that no health or environmental problems have been encountered yet. Organic/biological food is seen by some as healthier and more environmentally benign as regular food, but this statement is not unchallenged. Organic food may have disadvantages such as lower productivity rates per unit of surface, and the environmental advantages of using no or less fertiliser and pesticides may be offset by a higher land use and energy use per kg of crop produced. More generally, calculating externalities is not easy.

6.4.5. Changing production and products

Changing production and products can be an important approach to make diets healthier and more sustainable. The advantage of this approach is that consumers do not need to change behaviour, which is usually complicated. Consumer behaviour remains unchanged; however, the expected benefits emerge from a product that has been made with less damage to the environment.

Business

As already indicated in Section 6.4.3, businesses have important incentives to embark on sustainability and health strategies. Actions they can undertake include:

(1) using bargaining power in the supply and downstream chain to promote social, environmental and health issues, usually by setting minimum standards in combination with voluntary certification and labelling; important examples are the Marine Stewardship Council (MSC; sustainable fishing), the 'Sustainable agricultural initiative' (SAI), and various voluntary food labelling programmes;

(2) using social, environmental and health issues and societal expectations as inspiration to develop novel products, business models and other strategic innovations; an example is the low-calorie fast food meals offered by some fast food chains; another good example is the limitation of trans-fatty acids from food in the EU, mainly since producers started to transform such fats into their non-hydrogenated counterparts.

Government

Government can support solving sustainability and health issues in the production and product phase via the following measures:

(1) providing a level playing field with regard to production processes and production in order to comply with social, environmental and health standards by regulation, norms, standards or covenants;

(2) fostering innovation policies that support the development of food products that are inherently healthy and sustainable.

Consumers and civil society

Consumers and civil society have no direct role in production, but can indirectly be an important driver for change. It appears that tacit or explicit expectations, norms and values provide important stimuli for business. Without activities like 'Third World shops' and 'Fair trade shops' in the 1970s and 1980s, the current mainstreaming of sustainability labels by major firms cannot be understood properly. Civil society hence has an important role in articulating social norms, and, by this, in providing in due time legitimacy for broader action. In the food area, civil society can play this role with regard to health and sustainability standards.

6.5. Conclusion

Table 28 summarises the potential measures and actions of the different actors in the food area that can contribute to a broader dissemination of healthier and more sustainable diets. The potential measures that seem most viable in the short term are shown in bold: awareness-raising and information campaigns directed towards consumers; choice editing by retailers, using sustainable public procurement to promote healthier catering in (semi-) public offices and institutions like schools and hospitals; promoting sustainability and health labelling and countering advertising for unhealthy food consumption patterns; and actions by proactive businesses, such as developing healthier food products in response to trends like the need for convenience food and healthy living, and using bargaining power to diffuse sustainability and health standards in the supply and downstream chains. With regard to the latter, government can obviously support such developments with regulation and voluntary agreements.

Table 28. Food specific leverage points for change

Landscape	Meta-structures: globalised and industrialised food production Meta-values: individual sovereignty, democracy, free markets and trade, fairness and health values Meta-trends: individualisation, internationalisation, intensification, informatisation Meta-shocks: oil price hikes, food price hikes			
Regime	**Production** ↔	**Markets** ↔	**Consumption**	
Time horizon of impact	Actions and leading actor			Dominant leverage point
Short-term impact Goals and direction: agreement Means: fairly clear Main problem: overcoming opposition of 'laggards'	*Business* • Develop healthier food products • Manage supply and downstream chains; see the examples of MSC, SAI, etc. *Government* • Provide level playing field supporting the above (covenants, regulations, standards) • Foster innovation systems that develop healthy food	*Government* • Promote transparency on the environmental, social and health aspects of specific food products (mainly via voluntary or obligatory labelling rules) • Set basic advertising norms, for instance restrictions on advertising of less healthy food, particularly if directed at vulnerable groups • Limit mono- and oligopolies, particularly if such cartels block a diffusion of healthier food habits • Internalise external costs, and abolish perverse subsidies, so that healthy food does not come at an unnecessary premium	*Consumers/citizens/NGOs* • Exercise sustainable choice • As citizens and workers: organise 'healthy food clubs' and/or alternative channels *Government (combine the below for effect!)* • GPP (focus on visible examples with ripple effects; for example, providing high-quality school meals) • Awareness-raising and information campaigns • Motivate via repetitive feedback (for example, health competitions) *Business* • Choice editing • Apply sustainability and health marketing of food	Technical and incentive change

NB: In bold: the measures that seem most feasible and effective.

7. Conclusions

In June 2006, the European Council adopted its revised sustainable development strategy. Key priorities included the topic of sustainable consumption and production (SCP) and the related environmental product policy. In 2004, the Institute for Prospective Technical Studies (IPTS) launched the 'Environmental impacts of products' (EIPRO) study. This study was published in 2006 and showed that food (particularly meat and dairy), mobility and housing, including energy-using products, cause the majority of environmental impacts related to final consumption expenditure.

This study analysed the causal relation between alternative dietary consumption patterns in the EU-27 and the environmental impacts generated through the production of the respective food products. The analysis was carried out in four steps:

(1) identification of currently prevailing diets in the EU-27;
(2) identification of alternative diets;
(3) calculation of impacts related to current diets and alternative diets;
(4) discussion of the best suited policy measures for the promotion of healthier diets.

Identification of currently prevailing diets in the EU-27

In order to analyse environmental impacts of food consumption and production quantitatively, consolidated figures on actual food consumption in the EU-27 were gathered on the basis of FAO data (year 2003), which provide empirical data on food consumption per capita. These data were combined with 2003 demographic figures from Eurostat.

As dietary habits vary between different countries in the EU, it was not convenient to define one single European diet. Instead the FAO data were clustered in five groups of countries with respective average dietary habits, which were in ascending order of vegetable/animal food intake: Nordic countries + France, western Europe, south-west Europe, eastern Europe and south-east Europe.

Identification of alternative diets

Once having established the empirical overview of dietary patterns in the EU-27, alternative diets were constructed in order to be able to analyse potential changes of environmental impacts. Two diets were developed based on the nutritional recommendations of the WHO, the European Food Safety Authority EFSA and other relevant sources. A third diet was constructed on the basis of research carried out on Mediterranean dietary habits. These three diets have in common a reduced intake of meat and increased consumption of vegetables and fruit. All diets were developed with the restriction of being 'realistic' alternatives, i.e. to avoid radical changes, for example a 100 % vegetarian diet, which would not reach a high level of diffusion in Europe. Accordingly, the shares of food products in the first two alternative diets were modified moderately, whereas the Mediterranean diet was composed of prevailing meat-lean and vegetable-rich dietary patterns in south-east and south-west Europe.

Calculation of impacts related to current diets and alternative diets

The impacts for the baseline diets and the three alternative diets were calculated with the E3IOT model, which is a further developed version of the models used in EIPRO, adapted to the needs of the present study [34]. E3IOT is an environmentally extended input-output model, which maps the purchases and sales of products between industry sectors. This allows calculating the added value that each individual industry sector contributes to a product that is purchased for final consumption. E3IOT additionally provides information on environmental interventions for each industrial sector, which consist of data on emissions and natural resource use. This allows calculating the accumulated environmental impacts across all industry sectors related to the final consumption of individual products.

The calculation of environmental impacts for prevailing and alternative diets showed that current food consumption contributes, with 27 %, to all environmental impacts in the EU-27. A shift from current diets to Scenario 1 diets does not reduce the environmental pressure. The reason is that in Scenario 1 mainly the consumption of vegetables and fish increased, whereas the share of meat in the diet remained unchanged.

The introduction of Scenarios 2 and 3, which in addition to Scenario 1 took a reduced consumption of red meat and an increase of chicken meat into account, led to a reduction of 8 % of environmental impacts generated through food consumption, respectively 2 % of the total environmental impacts caused by consumption in the EU-27. This substantial reduction of environmental impacts reflects the changed shares of meat in the diet and confirms by that the prominent role of meat production in environmental impacts generated along the food chain.

A number of changes in the alternative diets resulting from the WHO diet recommendations, like the reduced intake of trans-fatty acids and salts or the increased consumption of fibre, have not been taken into account as no major change in environmental impacts could be expected from them.

An important remark to be made is that Scenarios 1 and 2 have about 20 %, and Scenario 3 almost 100 %, more fish consumption than the status quo. The E3IOT model did not evaluate biotic depletion of fish, but if no other technologies for fish production are introduced, this is likely to be a severe drawback of this scenario.

First- and second-order effects

In a subsequent step, the analysis was enlarged in two ways. First the redistribution of the household budget across food and non-food products under the restriction of a fixed total budget was analysed (first-order effects). Second, price and substitution effects in the agricultural sector were analysed in greater detail using the partial equilibrium CAPRI model, which is assumed to better reflect the specifities of the European agricultural sector than the E3IOT model and includes agricultural prices as endogenous variables (second-order effects).

With regard to first-order effects, it was shown that a changed household budget for food products on the basis of the alternative diets and the related budget redistribution across non-food products, which was assumed to be proportional to current expenditure, did not lead to environmental impacts that were very different from the baseline scenario. Only in Scenario 2, which contains a diet with less red meat and increased chicken, fish and vegetable consumption, the environmental impact of non-food product consumption increases marginally. The reason is the redistribution of the household

34 Tukker A., Huppes G., Guinée J., Heijungs R., De Koning A., Van Oers L., Suh S., Geerken T., Van Holderbeke M., Jansen B. and Nielsen P. (2006a), *Environmental impact of products (EIPRO) — Analysis of the life cycle environmental impacts related to the final consumption of the EU-25*, European Commission, JRC, Institute for Prospective Technological Studies, Technical Report EUR 22284 EN.

budget to non-food products due to the reduced purchase of relatively expensive meat products.

The analysis of second-order effects took into account price and substitution effects and revealed that the agricultural sector does not respond to a changed demand of specific food products with a corresponding reduction of the production of these products. The reaction of the agricultural sector includes increased export and reduced import of these products, for example beef and pork in Scenarios 2 and 3, as well as substitution effects, for example the increased production of vegetables and chicken. As a result, the production figures calculated with CAPRI do not lead to the kind of reductions of impact-intensive processes in the food and agricultural sectors that took place without taking second-order effects into account. Accordingly the environmental improvements caused by a change in European diets are substantially smaller than initially calculated with the E3IOT model. The environmental impacts generated through total final consumption in the EU27 in scenario 2 and 3 were reduced by 1%.

This result implies that a change in European diets has only a marginal impact on the environment. However, a shift towards alternative diets in Europe as developed in this study is nevertheless recommendable for two reasons. First, the study results analyse the impact on the European environment caused by changes to European diets. The trade balance of meat products as calculated with CAPRI shows that imports of these products decrease while exports increase. That in turn implies that red meat production figures in non-European countries decrease, which might imply reduced environmental pressure in the respective non-European countries. In other words, the CAPRI calculation shows that the environmental benefits from a changed diet in the EU-27 are not occurring exclusively in Europe, but are distributed globally. However, the results from this study are not sufficient to strongly support such a hypothesis without additional research. Second, alternative diets in this study have been developed from the perspective of healthier nutrition. The assumption of increasing health through changed dietary patterns remains valid, independently of the environmental implications as calculated in the E3IOT and CAPRI models. The benefits arising from a large-scale reduction of obesity, diabetes, cardiovascular diseases or even cancer is sufficient justification in itself. From this perspective, a positive conclusion from this study is therefore that a shift to healthier diets in Europe has no negative environmental impacts, but even has marginal improvements.

Policy measures stimulating the diffusion of healthy diets

Insights from a broad set of behavioural and systemic theories that were reviewed for this study show that changes in the behaviour of consumers and producers face important constraints. Such constraints consist of 'landscape factors' like the existing physical context (meta-structures), overarching values in society (meta-values), and interdependencies that have been developed in the production–consumption regime itself, such as habits and routines, bounded rationalities, etc. As a result it appears that recourse to awareness-raising policies such as information campaigns and product labelling is not sufficient to change long-established structures and routines in European dietary patterns.

Keeping in mind that the alternative diets developed in this study do not imply radical changes from current diets in the identified five country clusters, our policy review shows that various measures could be an effective means to stimulate such a change. Such suggestions include:

(1) working with retailers and main industry players in the food industry on 'choice editing' for sustainable and healthy food as

an enabling factor for consumers to choose more healthy diets in an easy way; stimulating them to practise 'sustainability and health marketing' as a motivational factor;

(2) stimulating proactive businesses in developing healthier food products in response to trends like the need for convenience food and healthy living, and stimulating them to use bargaining power to diffuse sustainability and health standards in the supply and downstream chains;

(3) organising information campaigns, promoting sustainability and health labelling, and stemming the advertising for unhealthy dietary habits;

(4) introducing sustainable public procurement of healthy food, in particular in public institutions and organisations (hospitals, canteens of government organisations); in particular, introducing healthy meals in schools seems to be promising due to the educational effect;

(5) setting indirect incentives via, for example, healthcare systems, like lower insurance fees if a certain physical health is strived for by individuals.

The overall conclusion can therefore be summarised as follows.

(1) A change to diets recommended by health authorities and institutes in the EU-27 has a twofold benefit: it will help decrease food-related diseases like obesity, type II diabetes, cardiovascular diseases and cancer, but will also reduce the environmental impacts related to food consumption with up to 8 %, respectively 2 % of environmental impacts generated by all final consumption.

(2) The suggested diet changes are not radical, but concern changes where regular diet recommendations are superimposed on the prevailing diets, differentiated in five country clusters in the EU. Extreme suggestions such as Europe switching to a vegetarian diet have not been done. It is hence likely that a concerted action by policy, business and consumer organisations in implementing the aforementioned type of measures could make significant contributions to the type of diet changes suggested.

(3) The suggested diet changes do imply changes in the structure of agricultural and food production sectors. The dynamic modelling exercise with the CAPRI model showed that the agricultural sector will adapt by embarking on new production patterns, or by finding export markets for their products. This implies that the impact on existing production structures would be limited, and that the environmental benefits from a change in diet in the EU-27 occur at a global level.

8. References

- Albreht T., Kecke M., Alexe D.-M., Coleman M. P. and Martin-Moreno J. M. (2008), 'Making progress against cancer in Europe in 2008', *Eur J. Cancer* 44: 1451–1456.

- Allender S., Scarborough P., Pete V., Rayner M., Leal J., Luengo-Fernandez R. and Gray A. (2008), *European cardiovascular disease statistics*, 2008 edition, available from: www.heartstats.org, accessed on 12 August 2008.

- Anonymous (2003), *Diet, nutrition, and the prevention of chronic diseases*, report of a joint WHO/FAO expert consultation, WHO Tech Rep Ser 916.

- Anonymous (2004), *Nordic nutrition recommendations — Integrating nutrition and physical activity*, fourth edition, Nordic Council of Ministers, Copenhagen.

- Arab L. and Steck-Scott S. (2004), 'Cancer and diet' (pp. 341–356), in: Gibney M. J., Marghetts B. M., Kearney J. M. and Arab L. (eds), *Public health nutrition*, The Nutrition Society, Blackwell Science.

- Balanza R., García-Lorda P., Pérez-Rodrigo C., Aranceta J., Bulló Bonet M. and Salsa-Salvadó J. (2007), 'Trends in food availability determined by the Food and Agricultural Organization's food balance sheets in Mediterranean Europe in comparison with other European areas', *Publ Health Nutr* 10(2): 168–176.

- Berrina F., DeAngelis R., Sant M., Rosso S., Lasota M. B., Coebergh J. W., Santaquilani M. and the Eurocare Working Group (2007), 'Survival for eight major cancers and all cancers combined for European adults diagnosed in 1995–99: Results of the Eurocare-4 study', *Lancet Oncol* 8: 773–783.

- Brunner E. J., Mosdøl A., Witte D. R., Martikainen P., Stafford M., Shipley A. J. and Marmot M. G. (2008), 'Dietary patterns and 15-y risks of major coronary events, diabetes, and mortality', *Am J. Clin Nutr* 87(5): 1414–1421.

- Brussaard J. H., Lowik M. R., Steingrimsdottir L., Moller A., Kearney J., De H. S. and Becker W. (2002), 'A European food consumption survey method — Conclusions and recommendations', *Eur J. Clin Nutr* 56 (Suppl. 2): S89–S94.

- Buzina R., Suboticanec K. and Sari M. (1991), 'Diet patterns and health problems: Diet in southern Europe', *Ann Nutr Metab* 35 (Suppl. 1): 32–40.

- Carlson Gielen A. and McDonald E. M. (2002), 'Using the precede-proceed planning model to apply health behaviour theories' (pp. 409–436), in: Glanz K., Rimer B. K. and Marcus Lewis F. (eds), *Health behaviour and health education, Theory, research and practice*, Jossey-Bass, San Francisco, CA.

- Charter M., Gray C., Clark T. and Woolman T. (2008), 'Review: The role of business in realising SCP', in: Tukker A., Charter M., Vezzoli C., Sto E. and Munch Andersen M. (eds), *System innovation for sustainability. Perspectives on radical change to sustainable consumption and production*, Greenleaf Publishing Ltd, Sheffield.

- Collingridge, D. and Reeve C. (1986), *Science speaks to power. The role of experts in policymaking*, Frances Pinter Publishers, London.

- Contaldo F., Pasini F. and Mancini F. (2003), 'Beyond the traditional interpretation of the Mediterranean diet', *Nutr Metab Cardiovasc Dis* 13(3): 117–119.

- De Beaufort C. E., Reunanen A., Raleigh C., Storms F., Kleinebreil L., Gallego R., Giorda C., Midthjell K., Jecht M., De Leeuw I., Schober E., Boran G. and Tolis G. (2003), 'European Union diabetes indicators. Factor or fiction?', *Eur J. Publ Health* 13 (Suppl. 3): 51–54.

- Derwent R. G., Jenkin M. E., Saunders S. M. and Pilling M. J. (1998), 'Photochemical ozone creation potentials for organic compounds in northwest Europe calculated with a master chemical mechanism', *Atmos. Environ.* 32(14-15): 2429–2441.

- EFSA (2008), 'Food based dietary guidelines. Scientific opinion of the Panel on Dietetic Products, Nutrition and Allergies', Question No EFSA-Q-2005-015c (agreed on 2 July 2008 for release for public consultation), European Food Safety Authority.

- Fernández E., Gallus S. and La Vecchia C. (2006), 'Nutrition and cancer risk: An overview', *J. Br Menopause Soc* 12(4): 139–142.

- Geels F. W. (2005), *Technological transitions and system innovations: A co-evolutionary and socio-technical analysis*, Edward Elgar, Cheltenham.

- Gibbons F. X., Gerrard M., Blanton H. and Russel D. W. (1998), 'Reasoned action and social reaction: Willingness and intention as independent predictors of health risk', *J. Pers Soc Psychol.*, May, 74(5): 1164–80.

- Goedkoop M. and Spriensma R. (2001), *The eco-indicator 99 — A damage oriented method for life cycle impact assessment*, Methodology Report, third edition, Pré Consultants.

- Gore A. (2006), *An inconvenient truth. The planetary emergency of global warming and what we can do about it,* Rodale Press, Inc. Emmaus, PA.

- Guba E. G. and Lincoln Y. S. (1989), *Fourth generation evaluation*, Sage Publications, Newbury Park/London/New Delhi.

- Guinée J. B. (ed.), Gorrée M., Heijungs R., Huppes G., Kleijn R., De Koning A., Van Oers L., Wegener Sleeswijk A., Suh S., Udo de Haes H. A., De Bruijn J. A., Van Duin R. and Huijbregts M. A. J. (2002), *Handbook on life cycle assessment: Operational guide to the ISO standards*. *Series: 'Eco-efficiency in industry and science'*, Kluwer Academic Publishers, Dordrecht.

- Gussow J. D. (1995), 'Mediterranean diets: Are they environmentally responsible?', *Am J. Clin Nutr* 61(6): 1383S–1389S.

- Hajer M. A. (1995), *The politics of environmental discourse: Ecological modernisation and the policy process*, Clarendon Press, Oxford.

- Hardin-Fanning F. (2008), 'The effects of a Mediterranean-style dietary pattern on cardiovascular risk', *Nurs Clin North Am* 43(1): 105–115.

- Hart, S. and Milstein M. B. (1999), 'Global sustainability and the creative destruction of industries', *Sloan Management Review*, autumn 1999, p. 23.

- Health Council of the Netherlands (2006), *Guidelines for a healthy diet 2006*, Health Council of the Netherlands, The Hague.

- Hekkert, M.P., R.A.A. Suurs, S.O. Negro, S. Kuhlmann and R.E.H.M. Smits (2007), *Functions of innovation systems: A new approach for analysing technological change*, Technological Forecasting and Social Change, Volume 74, Issue 4, May 2007, Pages 413-432.

- Heijungs R., De Koning A., Suh S. and Huppes G. (2006), 'Toward an information tool for integrated product policy: Requirements for data and computation', *Journal of Industrial Ecology* 10(3): 147–158.

- Heijungs R., Guinée J. B., Huppes G., Lankreijer R. M., Udo de Haes H. A., Wegener Sleeswijk A., Ansems A. M. M., Eggels P. G., Van Duin R. and De Goede H. P. (1992), *Environmental life cycle assessment of products. Guide and backgrounds*, CML, Leiden University, Leiden.

- Heijungs R. and Suh S. (2002), *The computational structure of life cycle assessment*, Kluwer Academic Publishers, ISBN 1-4020-0672-1.

- Hisschemöller, M. (1993), 'De democratie van problemen. De relatie tussen de inhoud van beleidsproblemen en methoden van politieke besluitvorming' [The democracy of problems. The relation between policy problems and methods for political decision-making]. Ph.D. thesis, Vrije Universiteit van Amsterdam, VU Uitgeverij, Amsterdam.

- Houghton J. T. et al. (eds) (2001), *Climate change 2001 — The scientific basis*, Cambridge University Press, Cambridge.

- Huijbregts M. A. J. (1999a), *Priority assessment of toxic substances in LCA. Development and application of the multi-media fate, exposure and effect model USES-LCA*, IVAM Environmental Research, University of Amsterdam, Amsterdam.

- Huijbregts M. A. J. (1999b), *Ecotoxicological effect factors for the terrestrial environment in the frame of LCA*, IVAM Environmental Research, University of Amsterdam, Amsterdam.

- Huijbregts M. A. J. (1999c), *Life cycle impact assessment of acidifying and eutrophying air pollutants. Calculation of equivalency factors with RAINS-LCA*, Interfaculty Department of Environmental Science, University of Amsterdam, Amsterdam.

- Huijbregts M. A. J. (2000), *Priority assessment of toxic substances in the frame of LCA. Time horizon dependency of toxicity potentials calculated with the multi-media fate, exposure and effects model USES-LCA*, Institute of Biodiversity and Ecosystem Dynamics, University of Amsterdam, Amsterdam.

- Huppes G., Davidson M. D., Kuyper J., Van Oers L., Udo de Haes H. A. and Warringa G. (2007), 'Eco-efficient environmental policy in oil and gas production in the Netherlands', *Ecological Economics* 61(1): 43–51.

- Huppes G., De Koning A., Suh S., Heijungs R., Van Oers L., Nielsen P. and Guinée J. B. (2006), 'Environmental impacts of consumption in the European Union: High-resolution input-output tables with detailed environmental extensions', *Journal of Industrial Ecology* 10(3): 129–146.

- James W. P., Duthie G. G. and Wahle K. W. (1989), 'The Mediterranean diet: Protective or simply non-toxic?', *Eur J. Clin Nutr* 43 (Suppl. 2): 31–41.

- Janz N. K., Champion V. L. and Strecher V. J. (2002), 'The health belief model' (pp. 45–66), in: Glanz K., Rimer B. K. and Marcus Lewis F. (eds), *Health behaviour and health education. Theory, research and practice,* Jossey-Bass, San Francisco, CA.

- Jégou, F. (2008), 'Social innovation and design of promising solutions towards sustainability — Emerging demand for sustainable solutions (EMUDE)', in: Tukker A., Charter M., Vezzoli C., Sto E. and Munch Andersen M. (eds), *System innovation for sustainability. Perspectives on radical change to sustainable consumption and production*, Greenleaf Publishing Ltd, Sheffield.

- Jenkin M. E. and Hayman G. D. (1999), 'Photochemical ozone creation potentials for oxygenated volatile organic compounds: Sensitivity to variations in kinetic and mechanistic parameters', *Atmos. Environ* 33(8): 1275–1293.

- Kafatos A., Verhagen H., Moschandreas J., Apostolaki I. and Van Westerop J. J. (2000), 'Mediterranean diet of Crete: Food and nutrient content', *J. Am Diet Assoc* 100(2): 1487–1493.

- Karamanos B., Thanopoulou A., Angelico F., Assaad-Khalil S., Barbato A., Del Ben M., Dimitrijevic-Sreckovic V., Djordjevic P., Gallotti C., Katsilambros N., Migdalis I., Mrabet M., Pekova M., Roussi D. and Tenconi M. T. (2002), 'Nutritional habits in the Mediterranean Basin. The macronutrient composition of diet and its relation with the traditional Mediterranean diet — Multi-centre study of the Mediterranean Group for the Study of Diabetes (MGSD)', *Eur J. Clin Nutr* 56: 938–991.

- Kemp R. and van den Bosch S. (2006), *Transitie-experimenten. Praktijkexperimenten met de potentie om bij de dragen aan transities* [Transition experiments. Practical experiments with the potential to contribute to transitions], Kenniscentrum SysteemInnovaties en Transities, p/o TNO, Delft.

- Keys A. (1995), 'Mediterranean diet and public health: Personal reflections', *Am J. Clin Nutr* 61 (Suppl.): 1321S–1323S.

- Keys A. (ed.) (1970), 'Coronary heart disease in seven countries', *Circulation* 41 (Suppl.): 1–211.

- Kouris-Blazos A., Gnardellis C., Wahlqvist M. L., Trichopoulos D., Lukito W. and Trichopoulou A. (1999), 'Are the advantages of the Mediterranean diet transferable to other populations? A cohort study in Melbourne, Australia', *Br J. Nutr* 82: 57–61.

- Kushi L. H., Lenart E. B. and Willet W. C. (1995a), 'Health implications of Mediterranean diets in light of contemporary knowledge. 1. Plant foods and dairy products', *Am J. Clin Nutr* 61 (Suppl. 6): 1407S–1415S.

- Kushi L. H., Lenart E. B. and Willet W. C. (1995b), 'Health implications of Mediterranean diets in light of contemporary knowledge. 2. Meat, wine, fats, and oils', *Am J. Clin Nutr* 61 (Suppl. 6): 1416S–1427S.

- Leontief W. W. (1970), 'Environmental repercussions and the economic structure: An input-output approach', *Review of Economics and Statistics* 52(3): 262–271.

- Lloyd-Williams F., O.'Flaherty M., Mwatsama M., Birt C., Ireland R. and Capewell S. (2008), 'Estimating the cardiovascular mortality burden attributable to the European common agricultural policy on dietary saturated fats', *Bulletin of the World Health Organization* 86: 535–541.

- Maibach E. W., Rothschild M. L. and Novelli W. D. (2002), 'Social marketing' (pp. 437–461), in: Glanz K., Rimer B. K. and Marcus Lewis F. (eds), *Health behaviour and health education. Theory, research and practice*, Jossey-Bass, San Francisco, CA.

- Mandelbaum M. (2002), *The ideas that conquered the world. Peace, democracy and free markets in the twenty-first century*, Public Affairs/Perseus Book Group, New York.

- McMichael A. J., Powles J. W., Butler C. D. and Uauy R. (2007), 'Food, livestock production, energy, climate change, and health', *Lancet* 370: 1253–1263.

- Montaño D. E. and Kasprzyk D. (2002), 'The theory of reasoned action and the theory of planned behaviour (pp. 67–98), in: Glanz K., Rimer B. K. and Marcus Lewis F. (eds), *Health behaviour and health education. Theory, research and practice*, Jossey-Bass, San Francisco, CA.

- Naska A., Oikonomou E., Trichopoulou A., Wagner K. and Gedrich K. (2007), 'Estimations of daily energy and nutrient availability based on nationally representative household budget survey data — The Data Food Networking (DAFNE) project', *Public Health Nutrition* 10: 1422–1429.

- Nestle M. (1999), 'Meat or wheat for the next millennium? Animal versus plant foods in human diets and health: Is the historical record unequivocal?', *Proceedings of the Nutrition Society* 58: 211–218.

- Nielsen A. M., Weidema B. P., Dalgaard R. and Halberg N. (2003), *LCA food database* (www.lcafood.dk).

- Ocké M. C. and Kromhout D. (2006), 'Diet in relation to health and disease', in: Van Kreijl C. F., Knaap A. G. A. C. and Van Raaij J. M. A. (eds), *Our food, our health. Healthy diet and safe food in the Netherlands*, National Institute for Public Health and the Environment.

- Oldenburg B. and Parcel G. S. (2002), 'Diffusion of innovations' (pp. 312–334), in: Glanz K., Rimer B. K. and Marcus Lewis F. (eds), *Health behaviour and health education. Theory, research and practice*, Jossey-Bass, San Francisco, CA.

- Oliver J. E. and Silman A. J. (2006), 'Risk factors for the development of rheumatoid arthritis', *Scand J. Rheumatol* 35(3): 169–174.

- Papadaki A. and Scott J. A. (2002), 'The impact of eating habits of temporary translocation from a Mediterranean to a northern European environment', *Eur J. Clin Nutr* 56: 455–461.

- Porter, M. (1985), *Competitive advantage. Creating and sustaining superior performance*, The Free Press, New York.

- Ramachandran A. and Snehalatha C. (2004), 'Diabetes mellitus' (pp. 330–340), in: Gibney M. J., Marghetts B. M., Kearney J. M. and Arab L. (eds), *Public health nutrition*, The Nutrition Society, Blackwell Science,

- RIVM (2006), 'What determines consumer eating behaviour and risk perception?' (pp. 241–260), in: Van Kreijl C. F., Knaap A. G. A. C. and Van Raaij J. M. A. (eds), *Our food, our health. Healthy diet and safe food in the Netherlands*, National Institute for Public Health and the Environment.

- Rogers E. M. (1995), *Diffusion of innovations*, fourth edition, The Free Press, New York.

- Rosegrant M. W., Leach N. and Gerpacio R. V. (1999), 'Meat or wheat for the next millennium? Alternatives for world cereal and meat consumption', *Proceedings of the Nutrition Society* 58: 219–234.

- Sabatier P. A. (1987), 'Knowledge, policy-oriented learning, and policy change. An Advocacy Coalition framework'. *Knowledge*, Vol. 8, No 4: 649–692.

- Santarelli R. L., Pierre F. and Corpet D. E. (2008), 'Processed meat and colorectal cancer: A review of epidemiological and experimental evidence', *Nutr Cancer* 60(2): 131–144.

- Scholl G. (2008), 'Product service systems — Taking a functional and a symbolic perspective on usership', in: Tukker A., Charter M., Vezzoli C., Sto E. and Munch Andersen M. (eds), *System innovation for sustainability. Perspectives on radical change to sustainable consumption and production*, Greenleaf Publishing Ltd, Sheffield.

- Schön D. A. and M. Rein (1994), *Frame reflection. Towards the resolution of intractable policy controversies*, Basic Books, New York.

- Schumacher E. F. (1973), *Small is beautiful*, Harper and Row Publishers, New York.

- Shove E. (2003), *Comfort, cleanliness and convenience. The social organisation of normality*, Berg Publishers, Oxford.

- Shove E. (2004), 'Efficiency and consumption: Technology and practice , *Energy and Environment* 15, No 6: 1053–1065.

- Simon H. A. (1957), 'Theories of decision-making in economics and behavioural science', *American Economic Review* 49: 253–83.

- Simopoulos A. P. (2001), 'The Mediterranean diets: What is so special about the diet of Greece? The scientific evidence', *J. Nutr* 131(11): 3065S–3076S.

- Spaargaren, G. (1997), The Ecological Modernization of Production and Consumption. *Essays in Environmental Sociology*, Netherlands, Wageningen: Landbouw Universiteit.

- Stern N. (2006), *The economics of climate change. The Stern Review*, Cambridge University Press, Cambridge.

- Stø E., Throne-Holst H., Strandbakken P. and Vittersø G. (2008), 'Review: A multi-dimensional approach to the study of consumption in modern societies and the potentials for radical sustainable changes', in: Tukker A., Charter M., Vezzoli C., Sto E. and Munch Andersen M. (eds), *System innovation for sustainability, perspectives on radical change to sustainable consumption and production*, Greenleaf Publishing Ltd, Sheffield.

- Suh S. (2004), *CEDA 3.0 User's guide*, CML, Leiden University.

- Tischner U. and E. Sto (2009), 'System innovation for sustainability. Sustainable consumption and production in the food area' (in press), Greenleaf Publishing Ltd, Sheffield.

- Triandis H. C. (1977), *Interpersonal behaviour*, Brooks/Cole Publishing Company, a division of Wadsworth Publishing Company, Inc., Monterey, California.

- Trichopoulou A. (2001), 'The Mediterranean diet: The past and the present', *Nutr Metab Cardiovasc Dis* 11 (Suppl. 4): 1–4.

- Trichopoulou A. and Critselis E. (2004), 'Mediterranean diet and longevity, *Eur J. Cancer Prev* 13(5): 453–456.

- Trichopoulou A., Naska A. and Oikonomou E. (2005), 'The DAFNE databank: The past and future of monitoring the dietary habits of Europeans', *Journal of Public Health* 13: 69–73.

- Trichopoulou A. and Vasilopoulou E. (2000), 'Mediterranean diet and longevity', *Br J. Nutr* 84 (Suppl. 2): S205–S209.

- Tukker A., Eder P. and Suh S. (2006b), 'Environmental impacts of products: Policy relevant information and data challenges', *Journal of Industrial Ecology* 10(3): 183–198.

- Tukker A., Huppes G., Guinée J., Heijungs R., De Koning A., Van Oers L., Suh S., Geerken T., Van Holderbeke M., Jansen B. and Nielsen P. (2006a), *Environmental impact of products (EIPRO) — Analysis of the life cycle environmental impacts related to the final consumption of the EU-25*, European Commission, JRC, Institute for Prospective Technological Studies, Technical Report EUR 22284 EN.

- Tukker A. (2008), 'Conclusions: Change management for SCP', in: Tukker A., Charter M., Vezzoli C., Sto E. and Munch Andersen M. (eds) (2008), *System innovation for sustainability. Perspectives on radical change to sustainable consumption and production*, Greenleaf Publishing Ltd, Sheffield.

- Tukker A., Charter M., Vezzoli C., Sto E. and Munch Andersen M. (eds) (2008), *System innovation for sustainability. Perspectives on radical change to sustainable consumption and production*, Greenleaf Publishing Ltd, Sheffield.

- Tyus N. C., Freeman R. J. and Gibbons M. C. (2006), 'Development of a replicable process for translating science into practical health education messages', *J. Natl Med Assoc* 98(9): 1505–9.

- Verheijden M. W., Van der Veen J. E., Van Zadelhoff W. M. A, Bakx C., Koelen M. A., Van de Hoogen H. J. M., Van Weel C. and Van Staveren W. A. (2003), 'Nutrition guidance in Dutch family practice: Behavioural determinants of reduction of fat consumption', *Am J. Clin Nutr* 77: 1058S–1064S.

- Weinberg, A.M. (1972), *Science and Transscience*, Minerva, Vol. X Nr. 2, pp 209-222.

- WHO (2002), *The World Health Report 2002. Reducing risks, promoting healthy life,* World Health Organization, Geneva.

- WHO Regional Office for Europe (2003), *Food based dietary guidelines in the WHO European region*, World Health Organization, Copenhagen.

- WHO/FAO (2003), *Diet, nutrition and the prevention of chronic diseases*, report of a joint WHO/FAO expert consultation, World Health Organization, Geneva.

- Willett W. (2001), *Eat, drink and be healthy. The Harvard Medical School guide to healthy eating*, Fireside, New York.

- WMO (1992), *Scientific assessment of ozone depletion: 1991 — Global ozone research and monitoring project — Report No 25*, Geneva.

- WMO (1995), *Scientific assessment of ozone depletion: 1994 — Global ozone research and monitoring project — Report No 37*, Geneva.

- WMO (1999), *Scientific assessment of ozone depletion: 1998 — Global ozone research and monitoring project — Report No 44*, Geneva.

- World Cancer Research Fund and American Institute for Cancer Research (2007), *Food, nutrition, physical activity and the prevention of cancer: A global perspective*, AICR, Washington, DC.

European Commission

EUR 23783 EN — Joint Research Centre — Institute for Prospective Technological Studies

Title: Environmental Impacts of Diet Changes in the EU

Authors: Arnold Tukker, Sandra Bausch-Goldbohm, Marieke Verheijden, Arjan de Koning, René Kleijn, Oliver Wolf, Ignacio Pérez Domínguez

Luxembourg: Office for Official Publications of the European Communities
2009

EUR — Scientific and Technical Research series — ISSN 1018-5593
ISBN 978-92-79-11774-9
DOI 10.2791/88996

Abstract

The report is a scientific contribution to the European Commission's Integrated Product Policy framework, which seeks to minimise the environmental degradation caused throughout the life cycle of products.

This report first presents an overview of the environmental impact cause by current dietary habits in EU27. It then develops three alternative diets on the basis of health recommendations from EFSA, WHO and other organisations, and calculates the changes in environmental impacts achievable through a shift towards these diets. Finally the report analyses policy measures which stimulate the uptake of healthy diets by consumers.

The report shows that current dietary habits in Europe are responsible for 27% of all environmental impacts in Europe. A shift to healthier diets shows that the contribution to overall environmental impacts in Europe can be reduced to 25% in case of reduced consumption of red meat. The contribution reduces to just 26% if indirect effects such as household budget re-distribution and price and substitution effects in the agricultural sector are taken into account. Because food and nutrition are strongly rooted in traditions and habits, policy measures aiming at stimulating a change towards healthy diets need to include a combination of different instruments, ranging from consumer awareness raising to public procurement activities.

The report is accompanied by a first Annex report containing details on sources of information, methodology, data and results.

A second Annex report describes the underlying environmentally extended Input-Output model in detail.

The mission of the Joint Research Centre is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of European Union policies. As a service of the European Commission, the Joint Research Centre functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

LF-NA-23783-EN-C

JRC
EUROPEAN COMISSION

Publications Office
Publications.europa.eu

ISBN 978-92-79-11774-9

9 789279 117749