Towards a sustainable, healthy and affordable Belgian diet

Optimising the Belgian diet for nutritional and environmental targets

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This study contributes to the objective of Eat4Change, a European project aiming at the transition towards more sustainable consumption and production in Belgium and Europe, with a special focus on the livestock sector.

Optimeal® is a software package for optimisation of diets on health and sustainability. It was developed by Blonk Consultants in cooperation with Voedingscentrum (the Netherlands Nutrition Centre). Optimeal® and the included environmental data have been applied in several peer-reviewed scientific papers.

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›optimeal‹

Executive summary

Context

Our global food system is under immense pressure: it needs to accommodate the needs for a growing population, whilst limiting its environmental impact. Currently, the global food system is responsible for 21-37% of global greenhouse gas emissions (IPCC, 2019), and is a key driver of deforestation, biodiversity loss and land degradation worldwide. At the same time, unhealthy food consumption patterns are responsible for a significant disease burden, associated with non-communicable diseases such as diabetes, ischemic heart disease and colorectal cancer (Afshin et al., 2019).

As shown by influential studies like the EAT-Lancet report (Willett et al., 2019), changing our diets towards more plant-based products instead of animal-sourced products, can play a key role in both reducing environmental impacts and improving health outcomes. Through this study, WWF Belgium aims to investigate how such a diet would look like for the Belgian context. Using Optimeal® software, the current Belgian diet was optimized in order to meet nutritional guidelines as set by the Belgian government, and to limit global warming associated with food production to 1.5 degrees above pre-industrial levels.

This study contributes to the objective of Eat4Change, a European project aiming at the transition towards more sustainable consumption and production in Belgium and Europe, with a special focus on the livestock sector.

More specifically, by 2024 targeted European Youth will:

- Have greater awareness of the impact of diets on "People and Planet" and a critical understanding of their role as consumers and active citizens;
- Contribute to SDGs and climate actions by embracing more sustainable diets and influencing peers;
- Support engagement with corporations and policy makers for improved practices and policy coherence.

Methodology

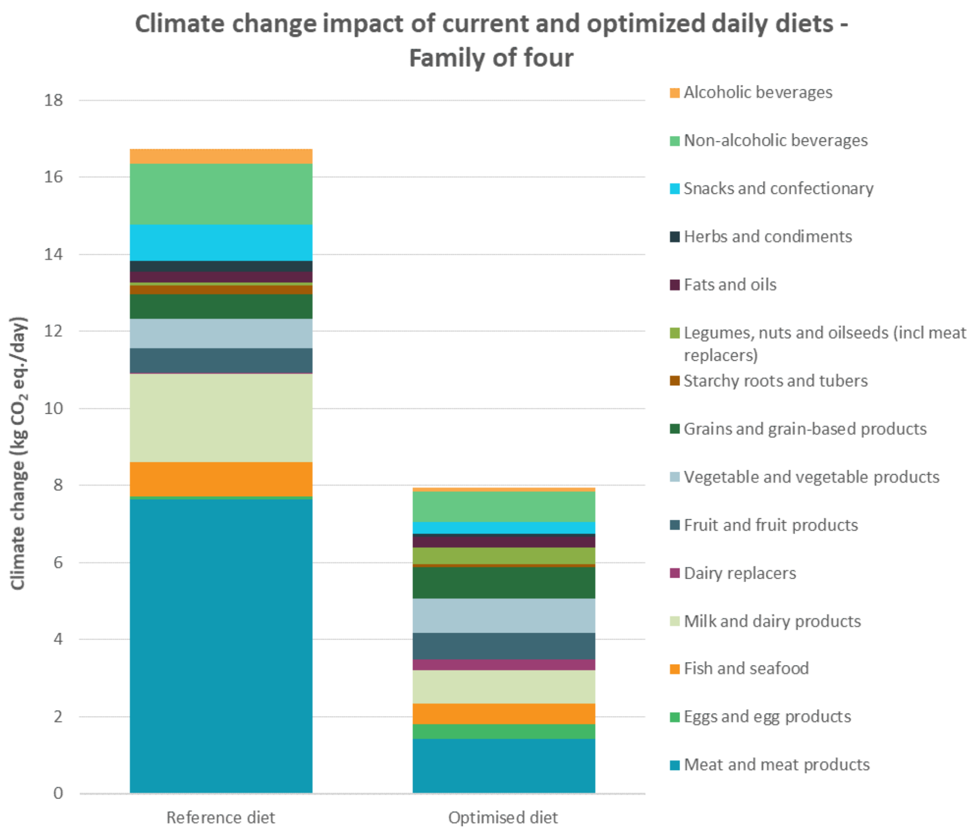
The composition of the current Belgian diet was based upon EFSA's European Food Consumption database, and was linked to environmental impact data derived from Blonk Consultants' RIVM database, and to nutritional data from Nubel. To guide the optimization process in Optimeal, constraints were set on individual nutrients, on food groups (through food based dietary guidelines), and on greenhouse gas emissions (constraint for 2030, ensuring global warming stays below 1.5 degrees). Optimeal uses quadratic programming to find a diet that meets all constraints, whilst remaining close to the original diet.

This assessment has been carried out for 3 individual diets (adults, adolescents and children), based on which the overall impact for a family of four has been established (consisting of two adults, one adolescent and one child). Next to climate change, it was also examined how the optimized diet influences other properties, including land use, biodiversity and expenditure.

Results

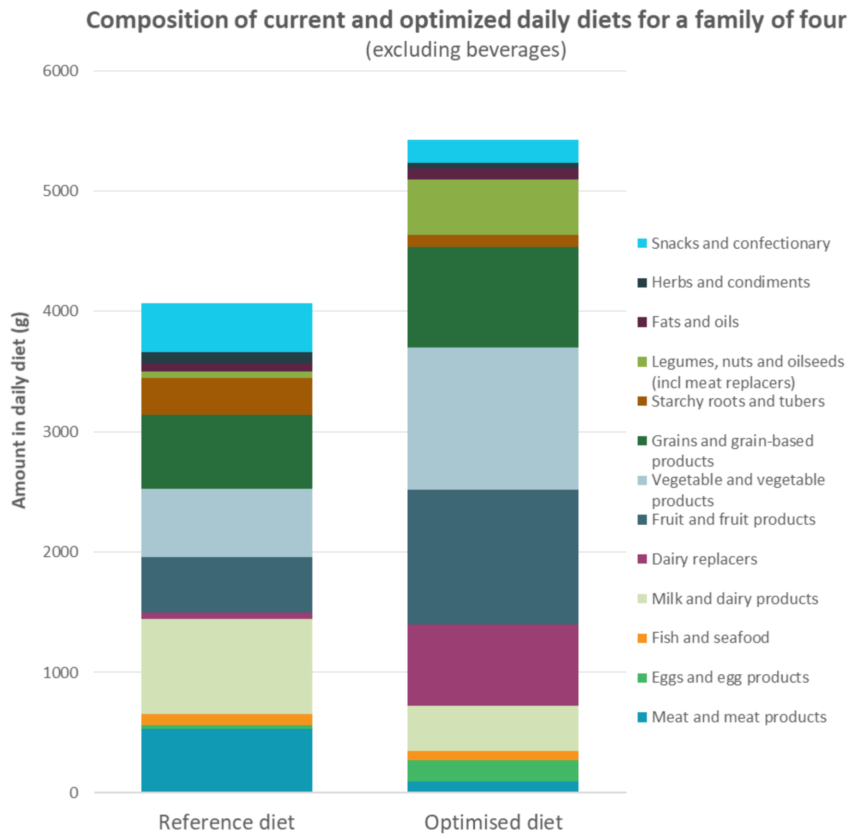
Dietary composition and carbon footprint

This optimised diet, as depicted in below figure, provides a sustainable and healthy diet for all family members as it adheres to all Belgian nutritional guidelines set for the individual family members, and ensures that carbon emissions per person do not exceed the 1.5 degrees target for 2030. The carbon footprint of the diet of the family of four more than halves; from 16.7 kg CO_2-eq/day to 8.0 kg CO_2-eq/day.



The dietary changes that have led to this reduced environmental impact and improved health outcomes can be summarised as follows:

- The optimised diet is characterised by a higher share of plant-based products, particularly those with a high nutritional quality, such as fruits, vegetables, legumes, nuts, plant-based dairy replacers, oilseeds and grain-based products. In this way the diet adheres to all nutritional and food based dietary guidelines (such as recommended intake of fruits, vegetables, vitamins and minerals), which were not met in the reference diet.
- Animal-sourced products decrease considerably, due to their relatively high environmental burden. Meat can still be consumed in an optimised diet, but in much lower quantities (18% of the original amount). Dairy products reduce by 53% and are largely replaced by plant-based alternatives. Eggs are the only animal-sourced foods of which the quantity increases in the optimised diet, as they can deliver important nutrients for a relatively low environmental impact.
- The quantity of products that contain high level of fats, salt and added sugar (including snacks, confectionary, soft drinks, and processed meat) reduce significantly. This is also reflected in a decreased NOVA score, which is an indication of the degree of food processing. The share of minimally processed products increases, linked to a higher consumption of fruit and vegetables. Processed and highly processed products on the other hand (including soft drinks, processed meat, snacks and desserts), have decreased.



Environmental impacts

Next to climate change, the food system is a primary driver of biodiversity loss around the world. In order to estimate the impact of diets on biodiversity, the indicator "damage to ecosystems" has been used. This indicator aggregates several individual environmental indicators (global warming, water consumption, ecotoxicity, eutrophication, acidification and land use), to provide a rough indication of the impact on freshwater, marine and terrestrial species. The sharp decline (-44%) in the impact of the optimised diet indicates that pressures on ecosystems are significantly lower for diets that are both sustainable and nutritious. This is also reflected by the lower land use: the land surface necessary to support food production reduces by 37% for the optimized diet, thus reducing the pressure on (already fragile) natural areas. This is also attributed to the reduced consumption of animal products, which require a large share of land to accommodate crops necessary to feed the animals.

Cost of the diet

Currently, a family of four in Belgium spends on average 172 euros on food and drinks for an entire week. The optimised diet leads to a cost reduction: the average expenditure drops to 158 euros per week. This leaves some room to switch to certified ethically or sustainably produced products, such as organic, Utz/Rainforest Alliance or Fairtrade. It was evaluated how much of these certified alternatives can be introduced for a selected number of products without increasing the total cost of the weekly basket. For a selected group of products (fruits, vegetables, meat, dairy, coffee, and tea) it would be possible to purchase 30% of certified products, without exceeding the original weekly budget.

Conclusion

This study demonstrates the double role that diets can play towards both achieving global climate targets and contributing to better public health. A shift from animal-based products towards plant-based products has the potential to keep global warming below 1.5 degrees, limit the expansion of agricultural land, and avert negative impacts on biodiversity. At the same time, this diet would reverse unhealthy eating patterns by lowering the consumption of food high on sugar, salt and saturated fats (associated with obesity and a variety of non-communicable diseases). Instead, the diet meets all nutritional guidelines as set by the Belgian government – ensuring the recommended intake of vitamins, minerals and important food groups, such as fruits, vegetables, and legumes.

This shift towards more plant-based diets does not entail higher food expenditures for Belgian families. On the contrary, the costs of the diet reduces by 9%, and thus leaves room to purchase certified products that stimulate environmental sustainability, as well as social responsibility, in the production chain.

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1. Introduction

The global food system faces tremendous challenges: it needs to accommodate the needs of a growing population, which reaches over 10 million by the end of this century (United Nations: Department of Social and Economic Affairs, 2019), whilst also staying within limits of the planetary boundaries. The global food system is already responsible for an estimated 21-37% of global greenhouse gas emissions (IPCC, 2019), which is likely to increase as a result of the growing population and changing diets.

In order to prevent far-reaching climate change impacts, the global temperature rise needs to be limited to 1.5 degrees above pre-industrial level, as underpinned by the Paris Agreement. With its significant contribution to greenhouse gas emissions worldwide, the global food system can play an important role in achieving this target. At the same time, food production is vulnerable to the effects of climate change, which leads to projected yield reductions of up to 10-15% through rising temperatures, changing precipitation patterns, and a higher frequency of extreme events (IPCC, 2019).

Food production is also the primary cause of biodiversity loss in the world, and the biggest driver of conversion of natural ecosystems into cropland or pasture. Of the world's agricultural land, 78% is attributed to animal farming, including grazing lands for animals as well as arable lands used for animal feed production (Benton, Bieg, Harwatt, Pudasaini, & Wellesley, 2021). Furthermore, agriculture affects ecosystems through high use of chemical fertilizers, leading to an accumulation of nutrients in water bodies, also referred to as eutrophication. The resulting excessive growth of algae can damage aquatic organisms and deteriorates water quality. Nearly all freshwater and coastal marine ecosystems in the world are affected by some degree of eutrophication (Smith & Schindler, 2009).

Our food consumption does not only impact the environment, but also our health. Dietary risk factors (over or under consumption of fruits, vegetables, processed meat and salt), are associated with a high global burden of non-communicable diseases, such as diabetes, ischemic heart disease and colorectal cancer (Afshin et al., 2019).

Influential studies pinpoint diets as a major opportunity to reduce both GHG emissions and improve health outcomes (IPCC, 2019; Willett et al., 2019). The EAT-Lancet report has defined a planetary health diet, a diet that is rich in plant-based foods, low on animal-based foods, and limits the amount of saturated fats, highly processed foods and added sugars. By optimizing human health and minimizing climate change impacts, such a diet can achieve both the SDGs and the Paris Agreement.

Our daily food choices can thus greatly impact both the environment and our health. It is therefore essential that we know what constitutes a diet that is both sustainable and healthy. WWF Belgium has initiated this study to translate these global ambitions to the Belgian context. What changes would the Belgian diet have to undergo to meet both nutritional and environmental targets? This study contributes to the objective of Eat4Change, a European project aiming at the transition towards more sustainable consumption and production in Belgium and Europe, with a special focus on the livestock sector.

Blonk Consultants was commissioned to provide an answer to this question, and has used its Optimeal ® software to model how the Belgian diet would have to be altered in order to limit global warming to 1.5 degrees and to meet all nutritional guidelines as set by the Belgian health authorities, whilst staying as close as possible to the current diet.

After describing the objectives, used data and methodology (chapters 2 and 3), this report gives detailed insights into how a sustainable and healthy diet looks like for adults, adolescents, and children (chapter 4). Next to focusing on the impact on nutrition and climate change, it also considers the impacts on biodiversity and affordability.

2 Objectives and research questions

Global challenges such as malnutrition, diet-related diseases, climate change and biodiversity loss, necessitate an integrated approach that considers both nutritional and environmental aspects in the selection of our diets. The objective of this study is to find a healthy and sustainable diet, which complies with nutritional and environmental targets and is acceptable in terms of dietary and price changes expected from consumers.

Several influential studies have underpinned the significant influence that diets can have on achieving both health and environmental targets (IPCC, 2019; Willett et al., 2019). WWF Belgium aims to investigate what changes the average Belgian diet needs to undergo by 2030 in order to meet nutritional constraints and to limit global warming to 1.5 degrees above pre-industrial levels.

The dietary shifts are calculated for three different age groups: adults (18 to 64 years old), adolescents (10 to 17 years old) and children (3 to 9 years old). Using the insights from these separate diets, a weekly food basket for a family of four can be composed. This weekly food basket aims to translate theoretical findings to the practical reality of consumers and makes the results more tangible.

This study presents answers to the following research questions:

- What dietary changes are needed for the current Belgian diet to meet nutritional guidelines as well as greenhouse gas (GHG) targets?
- What is the impact of the current and optimised diet on other environmental indicators?
- What impact does this dietary shift have on food expenditure for consumers?
- What share of certified organic and Fairtrade products could be included in the diet without exceeding the current expenses?

Besides nutritional properties and price, the Nutri-score (a nutrition label for products) and NOVA-score (indicating level of processing of products) are reported for every food product, and the shares of each Nutri- and NOVA group are reported for the overall diet. Next to the carbon footprint, several indicators that represent the environmental impact of our diets are considered, including land use, freshwater eutrophication and the aggregated “damage to ecosystems” indicator.

3 Methodology

The current Belgian diet is optimised for nutritional and sustainability targets using Optimeal ® 3.0, a software package developed by Blonk Consultants in cooperation with the Netherlands Nutrition Centre.[1] This software finds solutions that meet all nutritional and environmental requirements, yet avoids large deviations from the reference diet. It does so by minimizing the summation of the quadratic differences in the consumption amounts (in grams) of each food item.

The starting point of the optimisation is the Belgian reference diet. Nutritional properties and environmental properties are known for each product in the reference diet. The nutritional constraints (based on Belgian nutritional guidelines) and environmental constraints (based on allowable carbon footprint of food consumption per person per day to stay below 1.5-degrees warming) determine the guidelines for the optimisation. The next chapters will elaborate the used data and methodology.

3.1 Reference diet

To increase acceptability of the optimised diet among consumers, it is desired that this diet stays as close to the current diet at possible. The reference diet for each of the three age groups (adults, adolescents and children) is thus an important starting point for this study. Data is obtained from the EFSA European Food Consumption Database, which compiles data from the latest Belgium national food consumption survey (Belgische nationale voedselconsumptiepeiling) conducted in 2014 (De Ridder, Lebacq, Ost, Teppers, & Brocatus, 2016). The study population included Belgian citizens between 3 and 64 years of age. A total of 3461 people was interviewed on their daily food intake for two 24-hour recalls[2].

3.1.1 Composition of the reference diet

The basis for the current diet is Belgium dietary survey data that was compiled by the European Food Safety Authority (EFSA) in the EFSA European Food Consumption Database. This dataset describes the consumed food products in Belgium, using seven levels of detail, L1 to L7, with L1 being the most aggregated level. The basis for the diet is the L3 level, differentiating between 224 different food products.

Manual adaptations were required to get to a diet that comprises around 175 products. The following requirements were set for the individual products and the diet as a whole.

Each individual product should:

- Sufficiently specify the product to define its environmental and nutritional properties.
- Not represent more than 50% of the L1 group.
- Represents a significant fraction of the daily intake (in grams). No strict line is defined, exclusion or aggregation can be considered when consumed less than 0.1 grams/day.

The defined products as a group should:

- Represent a regular, varied Belgian diet.
- Represent a variety of products in each L1 group.
- Provide sufficient options for healthy and sustainable diets (e.g. plant-based alternatives for dairy and meat products). Supplements are excluded from the study.
- Does not contain less than 150 and not more than 200 products.

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[1] Optimeal® has been used in analyses which have been published in several scientific journals. A full list can be found here: https://www.optimeal.nl/news/publications/

[2] A recognized problem within dietary surveys that rely on self-reporting, is underreporting of food intake (Barbara et al., 2003). As correction for this phenomenon is challenging, the total energy intake of the baseline diet might not reach the lower limit of the nutritional guidelines and might be increased in the optimised diets.

To comply with these requirements, the products from level L3 were in some cases split up into the products defined in group L4 or L5, and in some cases aggregated to the L2 or L1 level. In case products did not meet these requirements, the product was entirely excluded from the diet. In that case, all other products belonging to the same L1 group were scaled up to compensate for the excluded quantity.

3.2 Constraints

In order to optimise the diet, targets need to be set that are able to quantify the characteristics of a healthy and sustainable diet. These constraints or boundaries can have an upper limit (maximum), lower limit (minimum), or both. The environmental target for example, concerns an upper boundary that represents the maximum amount of carbon dioxide equivalents associated with the diet. Many of the nutrients on the other hand, only have a lower boundary. Below it is described based on which criteria these boundaries were defined.

3.2.1 Nutritional constraints

The nutritional constraints define the maximum or minimum intake of macro- and micro-nutrients necessary to obtain a healthy and nutritionally sound diet. These minimum or maximum quantities are the boundaries that are used for the optimisation process. If for example, the diet is too low or too high on a certain nutrient, the quantity of food products within the diet will be altered in a way that the diet is able to provide the required quantity of that nutrient.

The nutritional recommendations for the Belgian population, as defined by the Superior Health Council of Belgium (Hoge Gezondheidsraad, 2019), were used to constitute upper and lower boundaries for macro- an micronutrients. The following nutrients are taken into consideration:

Table 1: Nutritional properties considered during the optimisation.

Macronutrients (unit)	Vitamins (unit)	Minerals (unit)
Energy (kcal)	Vitamin A (mg)	Calcium (mg)
Protein (g)	Vitamin B1 (mg)	Sodium (mg)
Fat (g)	Niacin (mg)	Iodine (µg)
Saturated fat (g)	Vitamin B2 (mg)	Iron (mg)
Mono-unsaturated fat (g)	Vitamin B6 (mg)	Potassium (mg)
Poly-unsaturated fat (g)	Folic acid (µg)	Phosphorous (mg)
Omega-3-fatty acids (g)	Vitamin B12 (µg)	Zink (mg)
Omega-6-fatty acids (g)	Vitamin C (mg)	Copper (mg)
Carbohydrates (g)	Vitamin D (µg)	Magnesium (mg)
Fiber (g)	Vitamin E (mg)	Selenium (mg)
Cholesterol (mg)		
Water (g)		

Three separate sets of nutritional constraints were developed: for adults, adolescents and children. Whenever separate values were given for females and males, an average was taken. The required energy intake depends on how active a person is, and were based on low to moderate physical activity level (PAL 1.4-1.6). The complete list of constraints set can be found in Annex A.

3.2.2 Food-based dietary guidelines

Next to guidelines for individual nutrients, the Belgian Health Council also has recommendations for food groups, which are called food-based dietary guidelines (FBDGs). An example is the well-known recommendation to eat 250 grams of fruit and 300 grams of vegetables a day.

For adults, the FBDGs are completely based on the recommendations from the Belgian Health Council (Hoge Gezondheidsraad, 2019). These recommendations however only apply for adults, not for adolescents and children. For the latter two groups, recommendations are based on an older document (ViGeZ, 2014), which lists FBDGs for all age groups. Their advice for adolescents and children is mirrored to the FBDGs for adults, to ensure consistency. For example, VIGeZ (2014) indicates adults should eat 2 pieces of fruit and adolescents 3 pieces. To obtain the mirrored quantity for adults, the ratio adolescent/adult is applied on the original FBDGs, meaning that (3/2)*250 = 375 g of fruits should be consumed by adolescents.

A few assumptions had to be made as for some food groups no quantitative guidelines were provided:

- For fish it is recommended to eat 1-2 portions a week. A portion size of 140 grams was assumed, in line with the Livewell publication (Macdiarmid et al., 2011; WWF, 2017).
- The recommendation for drinks with added sugar is to consume as little as possible. Based on our judgement, the boundary has been set to half a glass (125 ml) per day. For children and adolescents, VIGeZ (2014) recommends to only consume soft drinks on special occasions, and hence an arbitrary boundary has been set on 2 glasses per week for adolescents (71.4 ml/day) and 1 glass per week for children (35.7 ml/day)

Table 2. Food based dietary guidelines (daily quantities), based on ViGeZ, 2014.

Food group	Adults		Adolescents		Children		Criteria from VIGeZ (2014) on which quantities for adolescents and children are based
	min	max	min	max	min	max	
Whole grain products (g)	125.0		125.0		92.1		Adolescents: same as adults Children: 5-9 slices of bread vs 7-12 for adults
Fruit (g)	250.0		375.0		250.0		Adolescents: 3 pieces of fruit vs 2 pieces for adults Children: same as adults
Vegetables (g)	300.0		300.0		275.0		Adolescents: same as adults Children: 250-300 g of veg vs 300 for adults
Legumes (g)	100.0		100.0		87.5		Adolescents: same as adults Children: 75-100g meat/fish/eggs/legumes vs 100 g for adults
Seeds and nuts (g)	15.0		15.0		13.1		Not available; same assumptions as legumes
Milk and dairy products (g)	250.0	500.0	333.3	666.7	250.0	500.0	Adolescents: 4 glasses of milk vs 3 for adults Children: same as adults
Fish and seafood (g)	20.0	40.0	20.0	40.0	17.5	35.0	Adolescents: same as adults Children: 75-100g meat/fish/eggs/legumes vs 100 g for adults
Red meat (g)		42.9		42.9		37.5	Adolescents: same as adults Children: 75-100g meat/fish/eggs/legumes vs 100 g for adults
Processed meat (g)		4.3		4.3		3.8	Adolescents: same as adults Children: 75-100g meat/fish/eggs/legumes vs 100 g for adults
Drinks with added sugar (ml)		125.0		71.4		35.7	Based on own assumptions: Adults: 1 glass every 2 days Adolescents: 2 glasses per week Children: 1 glass per week

It should be noted that next to dairy products, also dairy replacers (soy milk) have been classified as dairy when it comes to the FBDGs. As the included replacer is fortified with minerals and vitamins, it presents a viable (in terms of some relevant nutrients such as calcium) and sustainable alternative for dairy products.

3.2.3 Environmental constraints

For climate change, a constraint has been set that represents the maximum allowable carbon footprint of the daily food consumption per person to meet the 1.5 degree target as set by the Paris Agreement. This reduction target is based on the IPCC's 1.5 degree assessment study (IPCC, 2018), which presents four pathways that can limit global warming to 1.5 degrees by 2050, and presents associated agricultural emission reductions for methane, carbon dioxide and nitrous oxide. These emission reductions are applied to the overall emissions of the agricultural sector in 2010, which is derived from the FAO analysis of agricultural emissions 1990-2011 (Tubiello et al., 2014) combined with the sum of emissions related to agrochemical production, food processing, distribution and consumption which was derived from Vermeulen (Vermeulen, Campbell, & Ingram, 2012). This amounts to a total of 8.9 Gton CO_2eq emissions for the global food system in 2010. Applying the derived reduction percentages for the greenhouse gases, results in a target of 6.3 Gton CO_2eq for the global food system in 2030. When dividing this by the population forecast of 2030 (United Nations: Department of Social and Economic Affairs, 2019) and the total number of days in a year, the maximum daily share of allowable emissions per person per day amounts to 2.04 kg CO2-eq. In this methodology, each person (regardless of their age and geospatial characteristics) is allocated a fair share of the global carbon budget. The calculated daily, personal carbon budget for food is thus equal throughout all analysed age groups. This methodology is explained in more detail in the paper of (Broekema et al., 2020).

3.2.4 Food product constraints

Minimum and maximum product constraints help to ensure that the optimised diet is acceptable to the general consumer. Maximum product constraints ensure that the optimised diet does not contain large amounts of individual products which are generally not consumed in large quantities. Minimum product constraints ensures that no individual product is excluded from the optimised diet and thus contributes to a varied diet. The Belgian Food Consumption survey, retrieved from the EFSA Comprehensive European Food Consumption Database (Bel & De Ridder, 2018a, 2018b), was used to define these product constraints.

The 99th percentile of food consumption was taken as the maximum constraint. This allows for reasonable dietary changes in the light of healthy, sustainable and adoptable diets. The minimum consumption level of every product is set to 20% of the current diet. In the case of processed meat, this minimum value contradicted the food based dietary guidelines, and was lowered to 10% of the current consumption.

3.2.5 Additional constraints

Price

In case the price of the diet which is optimised on both nutrition and environmental properties exceeds the price of the baseline diet (and it would not interfere with other constraints), an additional constraint was set on the price. This constraint sets the maximum price of the optimised diet to the price of the baseline diet and is only applied in the third scenario (optimised on both nutritional and environmental targets).

Water

Due to the negative environmental impact of packaging and the high quality of tap water in Belgium, consumption of unbottled water is preferred over bottled water. For the third scenario, consumption of bottled water is thus set to maximum of 300 ml. To prevent a lower total intake of drinking water, the minimum value for unbottled water is set to the total amount of consumed water in the reference diet minus 300 ml. These constraints will not influence the total amount of consumed drinking water, but merely shift the intake of bottled water to unbottled water.

3.3 Food products

3.3.1 Nutritional properties

Nutritional properties of all food products are required to compare the reference diets and the optimised diets to the Belgian nutritional guidelines (Hoge Gezondheidsraad, 2019). Nutritional properties are obtained from the Belgium nutritional table, available from Nubel (Nutriënten België) at internubel.be. All the food products in the three reference diets were matched to (prepared) food products in the nutritional table. In case specific nutrients for products are not available in the Nubel, average European nutritional properties were obtained from EFSA (EFSA, 2018). An overview of the nutritional properties which are included is displayed in Table 1. Some nutritional properties are not part of the nutritional guidelines but are added for additional insights.

3.3.2 Environmental properties

3.3.2.1 Impact indicators

Environmental properties for the food products in the reference diets are needed to calculate the environmental impact of the reference diets and optimised diets and to be able to compare the environmental impact of the diets to the environmental target. Environmental properties of all food products in the reference diet are determined using the Life Cycle Assessment (LCA) methodology, according to ISO 14040/ 14044 standards (ISO, 2006a, 2006b), as further explained in Annex B. This means that the full life cycle is considered in the calculation of the environmental impact of the food products: cultivation, processing, transport, assembly, packaging, distribution, retail, consumption and waste treatment. The final life cycle stages, from distribution to end-of-life, were modeled according to defaults provided by the Product Environmental Footprint (European Commision, 2017) methodology.

The two most important environmental impact indicators that were included in this study are climate change (kg CO_2eq) and land use (m^2). Land use serves as a proxy for the impact on biodiversity. Next to that, the endpoint indicator “damage to ecosystems” (species lost/year) was included. This indicator assesses the impact on freshwater, marine and terrestrial species by aggregating and weighting midpoint indicators including global warming, water consumption, ecotoxicity, eutrophication, acidification and land use. A drawback of this indicator is, that quite some assumptions are necessary to transform the midpoints to endpoints, making the result not very accurate and reliable. However, it can provide a general indication of the level of damage to ecosystems. The ReCiPe impact assessment method (source) has been used to calculate the environmental impact for all indicators.

Optimisation constraints are only set for climate change, but results will be displayed for all environmental indicators.

3.3.2.2 Background database

To quantify the environmental impact of the (optimised) Belgian diet, LCIs from background databases are linked to the food products. As no dedicated LCA food database is available for Belgium, the RIVM database was the main source of environmental data. This is a cradle-to-end of life database commissioned by the Dutch National Institute for Public Health and the Environment (RIVM) and developed by Blonk Consultants. The database contains full lifecycle (from cultivation up until consumption) LCIs of nearly 200 food products (De Valk, Hollander, & Zijp, 2016). Although this database is specifically built for the Dutch market, it is assumed that the results are also representative for the Belgium market. The RIVM database is therefore the preferred source for environmental properties. In case no representable product was found in the RIVM database, the Optimeal database was consulted. This latter database is developed by Blonk Consultants contains full lifecycle LCI’s of over 160 products, representable for the average European market.

3.3.2.3 Forecasting of environmental impact

Since we optimise the diets for the year 2030, it is necessary to project the environmental impact of the diets to 2030. This is needed as there are some (ongoing) technological changes that will lead to a higher efficiency of food production in 2030.

Such changes include, amongst other things, improved cultivation techniques, more efficient processing and the use of cleaner energy sources. Next to sustainability, also cost reduction and environmental policies are driving factors for these changes. As a result of these trends, more food can be produced within the aforementioned carbon budget. The climate impact trend analysis of the Menu for Tomorrow study (Kramer & Blonk, 2015) formed the basis for projections of the environmental impact of food products in 2030.

This section will provide a summary of the implemented projections:

- As a result of improved efficiency at farm level, the impact of crop cultivation on all environmental indicators is reduced with 5% (Zhang et al., 2015).
- As a result of improved animal welfare (and thus longer lifespan, slower growth and more movement) the feed conversion ratio is expected to increase with 10% for pork and 20% for broilers (Hoste, 2009).
- Conservative estimates project a 2% reduction in methane emissions from enteric fermentation in dairy systems and 5% reduction in GHG emissions related to manure management.
- Nitrogen efficiency is expected to increase in the coming years. It is expected that in 2030, a 30% lower input of N-fertilizers will provide the same (or improved) fertilization. All environmental impact associated with N-fertilizers are thus expected to reduce with 30%.
- More efficient technologies are expected to reduce the overall environmental impact of transport by 10% and of thermal energy by 5%. These projections are considered in all lifecycle stages.
- The prognoses of the Carbon intensity reduction of average European electricity production projects a reduction of 70% between 2010 and 2050. Based on this outcome, but slightly more conservative, a 30% reduction on all environmental indicators from 2010- 2030 is applied to all electricity used in any life cycle stage (Capros et al., 2013).
- Continuous innovations in packaging are expected to reduce overall packaging emissions with 5% by 2030.
- Food waste at consumer and retail is reduced by 20% between 2010-2030 (assumption)

3.3.3 Nutri and NOVA scores

The Nutri-score, originating from France, is used in Belgium to label the nutritional content of food products, enabling consumers to see immediately whether a product is nutritious and stimulating them to make more healthy choices. The score ranges from category A (best, or: most healthy) to E (worst, or: least healthy), and is calculated based on the quantity of calories, saturated fats, sugars, salt, protein, fibres, fruits, pulses, vegetable and nuts in a product.

For all food products in the reference diet, the Nutri-score was calculated using an excel tool as available on the website of the Belgian Federal Public Service on Health, Food Chain Safety and Environment (https://www.health.belgium.be/en/nutri-score-calculation-tool), using the nutrients derived from NUBEL as input. The tool also provides a raw score in numbers, which can be converted to one of the categories.

Next to the Nutri-score, the NOVA score was assessed for all food products. This score represents the level of processing. Many highly processed foods (such as soft drinks, processed meats and energy dense foods high on sugar, fat and salt) are associated with obesity and various non-communicable diseases (Monteiro, Cannon, Lawrence, Costa Louzada, & Pereira Machado, 2019). The NOVA classification differentiates between four groups:

- Group 1: unprocessed and minimally processed foods, such as fruit, vegetables, eggs, milk, fruit juices (without added sugar), coffee
- Group 2: processed culinary ingredients, such as oils, butter, sugar, salt

- Group 3: processed foods, such as canned/bottled vegetables, salted nuts, canned fish, smoked meats
- Group 4: ultra-processed foods, such as soft drinks, sweet or salty snacks, chocolate, candies, ice cream, cookies

3.3.4 Prices

For each of the food products in the reference diet, the average supermarket price was obtained. This was achieved by looking up the price of each product on the websites of three of the biggest retailers in Belgium: Colruyt group (representing 26.6% of the Belgium market), Carrefour (representing 18.7%) and Delhaize (representing 18.6%) (Bolla & Lappin, 2018). For each food item, the price of non-certified products, as well as the price of certified products are found, for which organic, Fairtrade, and Utz/Rainforest Alliance labels were considered. In case there is large variety of a product (e.g. many different type of cookies with cheaper supermarket brands and A-brands), an average was taken of the most representative products.

In case the supermarkets didn't have a certified alternative in their product range, this gap was filled in by taking the average ratio certified/non-certified of similar products (e.g. if for a certain vegetable no certified alternative was available, the average ratio of all vegetables was taken).

The prices will aid to understand whether a more nutritious and sustainable diet exceeds the cost of the current diet, and what the price would be if (part of) the products would be certified.

3.4 Optimisation procedure

3.4.1 Optimisation algorithm

Optimisations are calculated using Optimeal® 3.0, a tool developed by Blonk Consultants in cooperation with the Dutch Nutrition Centre (Blonk Consultants, 2015). The goal of the optimisation is to find a diet as similar as possible to the reference diet while satisfying the set of optimisation constraints.

The optimised diet stays close to the reference diet by minimising the total deviation, which is defined as follows:

$$deviation = \sum_{i=1}^{165} (x_i^* - x_i)^2$$

In this formula, *i* represents each of the 165 food items available, x_i is the amount (in grams) of product *i* in the current average Dutch diet, and x_i^* is the amount (in grams), of the same product *i* in the optimised diet. The optimal diet is found by minimizing the deviation function while adhering to all constraints. In other words, the deviation function sums up the square change, in grams, of the consumption of each food item available. The optimisation goal is to minimize the deviation score. The effect of a quadratic function is that larger deviations result in a much higher deviation score, so that the optimisation tends towards small changes to multiple products instead of large changes in a few products.

3.4.2 Optimisation approach

Diets are optimised for three age groups: adults, adolescents and children. Data templates for each age group, containing all environmental and nutritional information for each food product, the baseline diet and all constraints were loaded into Optimeal 3.0. For each age group, three diet scenarios were calculated:

Scenario 1: This is the baseline diet, representing the current average Belgian diet. The diet is based on the Belgian national food consumption survey. No constraints are in place.

Scenario 2: This scenario corrects for the nutritional guidelines, which in many cases do not adhere to the reference diets. The optimised diets are nutritionally sound and healthy. The environmental impact, costs, Nutri-score and Nova-score ratios associated to this diet are calculated.

Scenario 3: This scenario adds the climate change target for 2030 to scenario 2. Additionally, this scenario limits the costs of the optimised diet to the costs of the reference diets (if this was not yet achieved). The optimised diet is nutritionally sound, meets the 2030 target aiming to limit global warming to 1.5 degrees Celsius, and does not exceed the costs of the reference diet. The impact on the other environmental indicators, costs, Nutri-score and Nova-score are the result.

4 Results and discussion

In this chapter, the results of the optimisation are presented. For each of the three age groups: adults, adolescents and children, the dietary composition and carbon footprint are presented for the three scenarios.

4.1 Optimised diets for adults (18 - 64 years)

In this section, the daily dietary composition for an average adult (average intake across all activity levels, gender and age) in the three defined scenarios are presented.

4.1.1 Dietary composition and carbon footprint of 3 scenarios

Based on the environmental properties of the food products in the diet, the carbon footprint of the current diet is 4.81 kg CO_2eq/day per individual (Table 4). It should be noted that due to underreporting in food consumption surveys (Barbara, Livingstone, & Black, 2003), the intake and thus carbon footprint might be higher in reality. The dietary composition of the current diet is presented in Figure 1. This figure shows that meat and meat products, milk and dairy products, fruit and fruit products, vegetable and vegetable products and grains and grain-based products all represent a comparable share in the daily diet (based on mass).

Optimisation on nutritional constraints (both nutrient intake and food-based dietary guidelines) leads to significant changes in the diet: the amount of meat and meat products has nearly halved, whereas the intake of fruit and vegetable products nearly doubled. Fish and seafood represent a larger part of the daily diet. The intake of legumes, nuts and oilseeds has almost seven-folded in the nutritionally optimised diet. The carbon footprint of the nutritionally optimised diet is 4.30 kg CO_2eq/day per individual (Table 4), and thus slightly lower compared to the current diet.

In the third scenario, the additional constraint on carbon footprint of 2.04 kg CO_2eq/day per individual is implemented. This diet shows an even further decrease in meat consumption, to less than 20% of the amount in the current diet (scenario 1). Also 'snacks and confectionary', 'starchy roots and tubers' and 'fish and seafood' decrease compared to the previous two scenarios. A vast decrease in the intake of milk and dairy products is compensated by an increase in the intake of plant-based dairy replacers and egg products. The intake of fruit and vegetable (products) and legumes, nuts and oilseeds are comparable in scenario 2 and 3.

Table 3 shows that the reduction in meat and meat products in both scenario 2 and 3 are not equal among all types of meat. In the nutritionally optimised diet, a slight increase in poultry consumption is observed, whereas pork and beef and veal meat are strongly reduced. The daily intake of processed meat and lamb are on the lower limit provided in the optimisation. The reason for this lies in the composition of beef, lamb and pork, which all contain considerable amounts of saturated fatty acids. In the third scenario, meat consumption of all types has reached the lower limit of optimisation (80% reduction for most meat products, 90% reduction for processed meat). This is related to the high environmental impact of meat products, which can be explained by several factors. First, the feed conversion ratio (the quantity of feed needed to produce 1 kg of meat) is highest for beef, followed by pork, broilers, laying hens and dairy cows (Fry, Mailloux, Love, Milli, & Cao, 2018). The composition of the diet, however, varies for different types of animals: where poultry and pigs rely mostly on (imported) compound feed, cattle consume a large share of locally produced grass. Secondly, animal husbandry systems have a high global warming impact due to manure storage and manure management, and significantly for cattle, through enteric fermentation (leading to methane emissions, a harmful greenhouse gas).

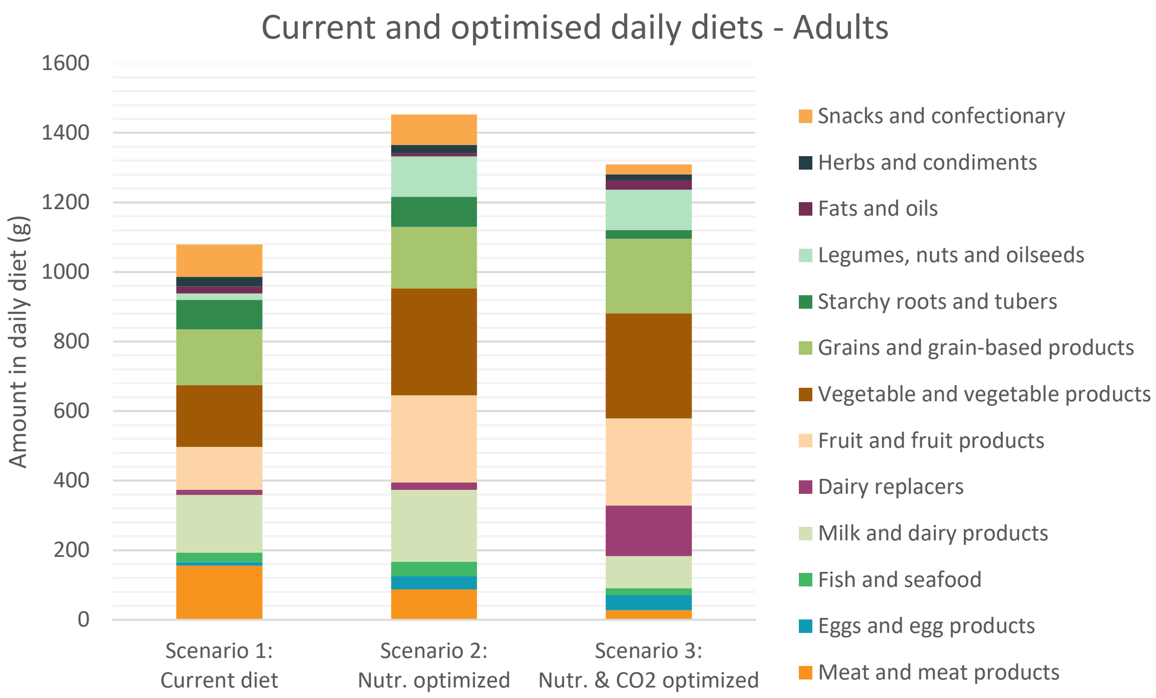

Figure 1. Simplified graph of composition of current and optimised daily diets for Adults, excluding beverages (however, including milk and dairy replacers).

The total amount of fruits and vegetables in the optimised diet vastly increased. The specific types of vegetables that represent a much larger part in the optimized diet are generally vegetables that can be cultivated locally in the full ground, such as parsnips, onions, beetroots, spinach, carrots and leeks. An increase in consumption is seen for many different fruit products, namely apples, pears, stone fruits, kiwi and oranges. In general, fruits and vegetables that are cultivated in greenhouses or imported via air transport will decrease in the optimised diet.

Interestingly, the decrease in meat consumption is not compensated by an increase in consumption of meat replacers in the optimised scenarios. Implementing the food based dietary guidelines leads to a steep rise in the consumption of vegetables and legumes. This means that the nutrients that can be provided by meat replacers (such as protein, fibres, calcium and B-vitamins) are already provided by legumes and vegetables.

It should be noted, however, that replacing meat products with vegan or vegetarian alternatives can have significant nutritional and environmental benefits, especially for products that require little processing, such as tofu, tempeh and seitan. Since in most cases nutrients are added to meat replacers that are normally only (or more abundantly) present in animal-based products, such as vitamin B12 and iron, meat replacers can provide vital nutrients which are especially crucial for diets which are low on animal-based products. Furthermore, meat replacers contain considerably less saturated fats compared to most meat products and can therefore not only be regarded as a good alternative in terms of environmental benefits, but also health benefits. Meat replacers can be an effective way to stimulate the transition to more plant-based diets as their similarity to meat products assures an easy uptake for people that are accustomed to a diet heavy on meat.

The consumption of egg and egg products increases significantly, especially in the third scenario, which is attributed to a comparative high nutrient content provided for a low environmental impact. In the optimised diets, eggs are the main contributors to the intake of Vitamin D and Vitamin B12 (alongside fish, seafood and dairy replacers), relevant providers of protein and iodine, but also a large source of cholesterol.

The nutrients provided by some (plant-based and blended) fats and oils explain the increase of this category in scenario 3. Fats and oils are important contribution to Omega 6 fatty acids and vitamin E in the optimised diets.

Fish consumption was already in line with dietary guidelines, and moves to the lower limit in the optimised diet (scenario 3). A change in the type of fish consumed can be observed, with an increase in the consumption of fatty fish like salmon, which is a good source of vitamin B12, and a decrease in the consumption of cod and other fish. The FBDGs as defined by the Belgian Health Council recommend to consume (preferably fatty) fish once a week, but to limit fish consumption to two portions a week due to environmental concerns and the presence of contaminants in fish (such as heavy metals, dioxins and PCBs).

When it comes to beverages, both optimised diets show a similar intake of drinking water, with a shift from bottled water to unbottled water (partly linked to the constraints as explained in section 3.2). A higher consumption of unbottled water can have nutritional and environmental benefits, especially when it replaces other drinks (with added sugar). The total intake of water in the entire diet reduces only slightly in the third scenario compared to the current diet, however, the sources of water shift. Fruit, vegetables and dairy replacers become important water sources in the optimised diet. This increase is compensated by a reduced intake of alcoholic beverages, juices, coffee and tea. The vast reduction in soft drinks is related to the constraints from the food based dietary guidelines.

Table 3. Detailed composition of the current and optimised daily diets for Adults.

Food groups	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
Beef and veal (g)	41.72	27.38	8.34
Lamb (g)	4.55	0.91	0.91
Meat replacers (g)	1.72	1.27	0.34
Pork (g)	37.67	14.56	7.53
Poultry (g)	37.77	40.37	7.55
Processed meat (g)	33.36	4.29	3.34
Fish and seafood (g)	27.89	40.00	20.00
Cheese (g)	31.95	33.72	6.39
Dairy (g)	133.96	173.48	85.20
Dairy replacers (g)	14.27	21.65	146.19
Eggs and egg products (g)	10.19	38.65	43.53
Snacks, desserts, and other foods (g)	56.74	57.91	21.09
Sugar and confectionery (g)	36.21	29.24	7.24
Fats and oils (g)	20.71	8.93	27.72
Alcoholic beverages (g)	163.79	164.63	58.05
Beverages with added sugar (g)	248.10	125.00	125.00
Coffee (g)	277.11	277.16	255.69
Drinking water (g)	923.35	923.34	923.00
Fruit and vegetable juices (g)	60.08	62.92	16.84
Tea (g)	85.69	85.87	58.00
Grains and grain-based products (g)	161.01	176.89	214.47
Fruit and fruit products (g)	124.18	250.00	250.00
Herbs, spices and condiments (g)	27.28	24.64	16.72
Legumes (g)	12.96	100.00	100.00
Nuts and oilseeds (g)	3.64	15.04	15.03
Starchy roots and tubers (g)	84.00	85.96	25.67
Vegetables and vegetable products (g)	176.88	307.93	301.73

4.1.2 Environmental impact

The steep reduction in climate change impact for the optimised diet (scenario 3) can be attributed to the lower consumption of animal-based products (beef, lamb, cheese and processed meat). Also in scenario 2, in which the diet is only optimised for nutritional properties, the carbon footprint decreases because of lower meat consumption, however to a lesser extent, as dairy consumption increases. The nutrients provided by dairy in scenario 2 are provided by dairy replacers in scenario 3, this leads to a lower carbon footprint.

The land use indicator, which represents the land area necessary to produce food products, is nearly halved in scenario 3. This is also attributed to the reduced consumption of animal products (specifically beef, poultry, processed meat and pork), which require a disproportionate amount of land to grow the crops necessary to feed the animals. The transition to a larger share of plant-based foods in scenario 2 and 3 leads to lower land use, though there is big variation in the type of crops: nuts and oil seeds, for example, have relatively lower yields per hectare (and therefore higher land use impact) compared to other crops like potatoes.

Even though land use on itself is not an indication of biodiversity, it plays an important role: the more land is used for food production, the less land is available for natural areas that can harbour biodiversity. This impact is especially severe in areas where crop cultivation or animal husbandry is a driver of deforestation/ conversion of biodiversity-rich areas, like tropical rainforests. This impact is also captured in the land use change indicator, that represents carbon dioxide emissions as a result of the conversion of natural areas to cropland in the last twenty years. This indicator has been modelled for the three scenarios, though it should be noted that this indicator has limited applicability for the diets modelled in this study (reference year 2030), as it only considers land use change in the past 20 years and can't predict how land use change will develop in the years to come (it is therefore not included in calculating the environmental impact of the diets). For this reason, it should only be regarded as a rough indication of the risk of land use change. For the optimised diet (scenario 3), there is a clear reduction in land use change. Soybeans from South America are currently associated with high land use change emissions, and thus high risk of deforestation, and are an important feed ingredient poultry, cows and pigs. Reduced meat consumption is thus the main driver for the reduced impact on land use change in scenario 2 and 3.

A more high-level indication of the impact on biodiversity is provided by the “Damage to Ecosystems” indicator. This so-called ‘endpoint indicator’ calculates the impact on freshwater, marine and terrestrial species by aggregating and weighting midpoint indicators including global warming, water consumption, ecotoxicity, eutrophication, acidification and land use. A limitation of this approach is that to convert the midpoints (which are well-quantified) into endpoints, a lot of assumptions must be made, which limit the accuracy and meaningfulness of the resulting end-point indicator. Despite this, the indicator gives an easy to interpret indication of the impact on biodiversity and provides a more complete picture than single midpoint indicators (like eutrophication). The table below shows a clear decrease in the damage to ecosystems, hence reduced pressure on biodiversity.

The impact of the diet on freshwater eutrophication decreases in both optimized diets, caused by a lower consumption of meat products and alcoholic beverages. Fertilizer use for feed production are the main contributor to the eutrophication impact of meat production.

Table 4. Environmental properties of the current and optimised daily diets for adults.

Environmental indicators	***Scenario 1: Current diet***	***Scenario 2: Nutrition optimised***	***Scenario 3: Nutrition & GHG optimised***
Climate change (kg CO_2eq)	4.81	4.30	2.04
Damage to ecosystems (species loss*yr)	$6.55*10^{-8}$	$5.79*10^{-8}$	$3.36*10^{-8}$
Land use (m²*a)	3.29	2.96	1.96
Land use change (kg CO_2eq)	0.67	0.59	0.38
Freshwater eutrophication (kg P eq)	$6.03*10^{-4}$	$5.85*10^{-4}$	$3.23*10^{-4}$

4.1.3 Nutrition & Health

When it comes to nutrition, the current Belgian diet does not meet nutritional requirements as defined by the Belgian Health Council. The reference diet is too high on sugar, salt and saturated fats, but too low on omega 3 and 6 fatty acids, fibre, folic acid, poly-unsaturated fats, and several minerals (calcium, copper, iodine, iron, magnesium, zinc, potassium) and vitamins (B1, B6, C, D, E). The diet also doesn't meet most of the FBDGs: the diet contained too few fruits (124 g as opposed to the recommended 250 g), too few legumes (13 g as opposed to the recommended 100 g), too little dairy and dairy products (193 g[3] as opposed to 250 g), too few seeds and nuts (3.46 g as opposed to 15 g), too much processed meat (33 g per day whereas 30g per week is recommended)

[3] This is based on ‘as-is’ amounts

and red meat (84 g per day, whereas 43 g is recommended). Only the current intake of fish was in line with the recommended quantity (28 grams per day), and the intake of whole grain products was very close (122 g as opposed to 125 g).

Both optimised diets (scenario 2 and 3), managed to meet both nutritional guidelines and food based dietary guidelines and can therefore be regarded as nutritionally sound and healthy diets. This is also reflected in the overall Nutri-score of the diet. This Nutri-score is usually calculated for individual products only, but when taking a weighted average of all products in the diet, the 'average' Nutri-score of the diet can be obtained. It should be noted that the Nutri-score is not intended to be used in that way, and this is just a general indication of the nutritional status of a diet.

Table 5. Over- and underconsumption of macro- and micronutrients in the current and optimized diet for Adults.

Nutrient	Current consump-tion level	How the consumption level is altered in the optimised diet (scenario 3)
Sugar	Too high	Reduced intake of soft drinks
Salt	Too high	Reduced intake of processed meat, snacks and cheese
Saturated fats	Too high	Reduced intake of snacks, fats and oils, cheese
Carbohydrates	Too low	Increased intake of grain-based products
Calcium	Too low	Increased intake of vegetables and plant-based dairy drinks
Copper	Too low	Increased intake of grain-based products, legumes and dairy replacers
Omega 3 fatty acids	Too low	Increased intake of (blended) fats and oils
Omega 6 fatty acids	Too low	Increased intake of (blended) fats and oils
Fibres	Too low	Increased intake of grain-based products, legumes and vegetables
Folic acid	Too low	Increased intake of vegetables and grain-based products
Iodine	Too low	Increased intake of eggs and egg products, legumes and herbs and spices
Iron	Too low	Increased intake of vegetables and grain-based products
Magnesium	Too low	Increased intake of grain-based products, vegetables and legumes
Potassium	Too low	Increased intake of vegetables
Vitamin B1	Too low	Increased intake of grain-based products
Vitamin B6	Too low	Increased intake of grain-based products
Vitamin C	Too low	Increased intake of fruits
Vitamin D	Too low	Increased intake of egg and egg-based products
Vitamin E	Too low	Increased intake of (blended) fats and oils
Zink	Too low	Increased intake of legumes, grain-based products and vegetables

The average Nutri-score moves from B to A in the diet that is optimised for both nutrition and climate. Looking at the individual categories, it becomes apparent that the quantity of products with Nutriscore D and E reduce significantly, mainly attributed to a decrease in snacks, desserts, cheese, soft drinks and alcoholic beverages. The quantity products within Nutriscore A and B on the other hand increase, as a result of higher consumption of fruits, vegetables, eggs and plant-based milk replacers.

A steep decrease in intake of meat and dairy products could result in deficiencies of specific nutrients, such as calcium and vitamin B12, B2 and D. In the third scenario, an increase in plant-based dairy replacers (in this study modelled as fortified soy milk) and eggs compensate for the lower intake of meat and dairy.

Table 6. Nutritional properties of the current and optimised daily diets for adults.

Nutri-score indicators	*Scenario 1: Current diet*	*Scenario 2: Nutrition optimised*	*Scenario 3: Nutrition & GHG optimised*
Nutri-score - raw score (p)	2.38 (B)		-0.19 (A)
Nutri-score A (g)	1564.66	1950.22	1903.04
Nutri-score B (g)	518.86	551.32	413.08
Nutri-score C (g)	124.01	138.37	128.16
Nutri-score D (g)	167.46	118.58	108.48
Nutri-score E (g)	461.77	333.25	192.83

4.1.4 Price

Table 7 shows that the average daily price of the Belgian diet reduces from €7.29 in the reference to €6.23 in the optimised diet (scenario 3). A decrease in price is caused by lower consumption of alcoholic beverages, processed meat, beef and snacks. This is however partly compensated by higher expenditure associated with increased consumption of fruits, vegetables, legumes and nuts.

It should be noted that the diet wasn't optimised for the price, meaning that even a lower price would be achievable, if for example fruits or vegetables would be selected with a relative lower price. Because the price of the optimised diet is lower than the reference diet, this leaves some room for higher consumption of certified products, such as organic or Fairtrade products. This is further discussed in Section 4.4.4.

Table 7. Economic properties of the current and optimised daily diets for adults.

Price	*Scenario 1: Current diet*	*Scenario 2: Nutrition optimised*	*Scenario 3: Nutrition & GHG optimised*
Consumer price (€)	€ 7.29	€ 9.21	€ 6.23
Consumer price (bio/fairtrade) (€)	€ 11.81	€ 14.03	€ 9.34

4.1.5 NOVA-score

The NOVA-score represents the degree of processing of products, and differentiates between products that hardly undergo any processing (NOVA group 1), moderately processed products such as fats and oils (NOVA group 2), processed products (NOVA group 3) and products that are highly processed (NOVA group 4). A high share of highly processed foods in a diet can be associated with negative health impacts, however, this is not straight forward. When interpreting these scores, it should thus be considered that not all highly processed foods are by definition unhealthy. For example, also plant-based drinks, fortified foods and baby milk are part of this group and are not unhealthy (unless they contain a lot of added sugar).

As listed in Table 8, the optimised diet (scenario 3) contains a larger share of unprocessed foods (score 1 and 2), which is caused by the higher consumption of fruits and vegetables. The processed and highly processed foods (score 3 and 4) decrease because of lower consumption of alcoholic beverages, soft drinks, processed meat, snacks and desserts. The lower degree of processing is also reflected by the average NOVA-score, which moves from 1.80 to 1.65.

Table 8. Level of processing of the current and optimised daily diets for adults.

NOVA indicators	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
NOVA classification - number (p)	1.80		1.65
NOVA group 1 (g)	1937.73	2292.00	2045.27
NOVA group 2 (g)	18.67	13.61	28.33
NOVA group 3 (g)	383.81	442.17	257.92
NOVA group 4 (g)	496.55	343.97	414.07

4.2 Optimised diets for adolescents (10 – 17 years)

4.2.1 Dietary composition and carbon footprint of 3 scenarios

The total intake of the daily diet increases drastically in the optimised diets, this is due to the deficiency of calories and carbohydrates in the current diet. The shifts in specific food groups observed in the optimised diet for adolescents are similar to those observed for adults, as presented in the previous paragraphs. The carbon footprint of reference diet of adolescents is 3.96 kg CO_2eq/day per individual (Table 10), slightly lower than the current average diet of adults. The composition of the current diet, as shown in Figure 2, shows a relative high intake of animal products: milk and dairy products are a prominent part of the daily intake (in mass). Meat products are consumed in a higher quantity than fruits and vegetables. Eggs and egg products, fish and seafood and legumes are present in very small quantities.

When optimising the diet on nutritional properties and food based dietary guidelines, the total food intake (excluding beverages) increases with over 600 grams. A largest shift is observed for fruit and fruit products, which grows from 83 grams to 375 grams (the lower limit of optimisation). A vast increase is also seen in consumption of vegetables, vegetable products and legumes. Milk and dairy products, as well as egg and egg products increase in the optimised diet, whereas meat and meat products decrease. In this diet, the carbon footprint increased slightly compared to the current diet, to 4.08 kg CO_2eq/day per individual (Table 10).

When adding the constraint for the carbon footprint of 2.04 kg CO_2eq/day per individual (scenario 3), the intake of meat and meat products decreases even further (to the lower limit set for the optimisation), which also applies for dairy products.

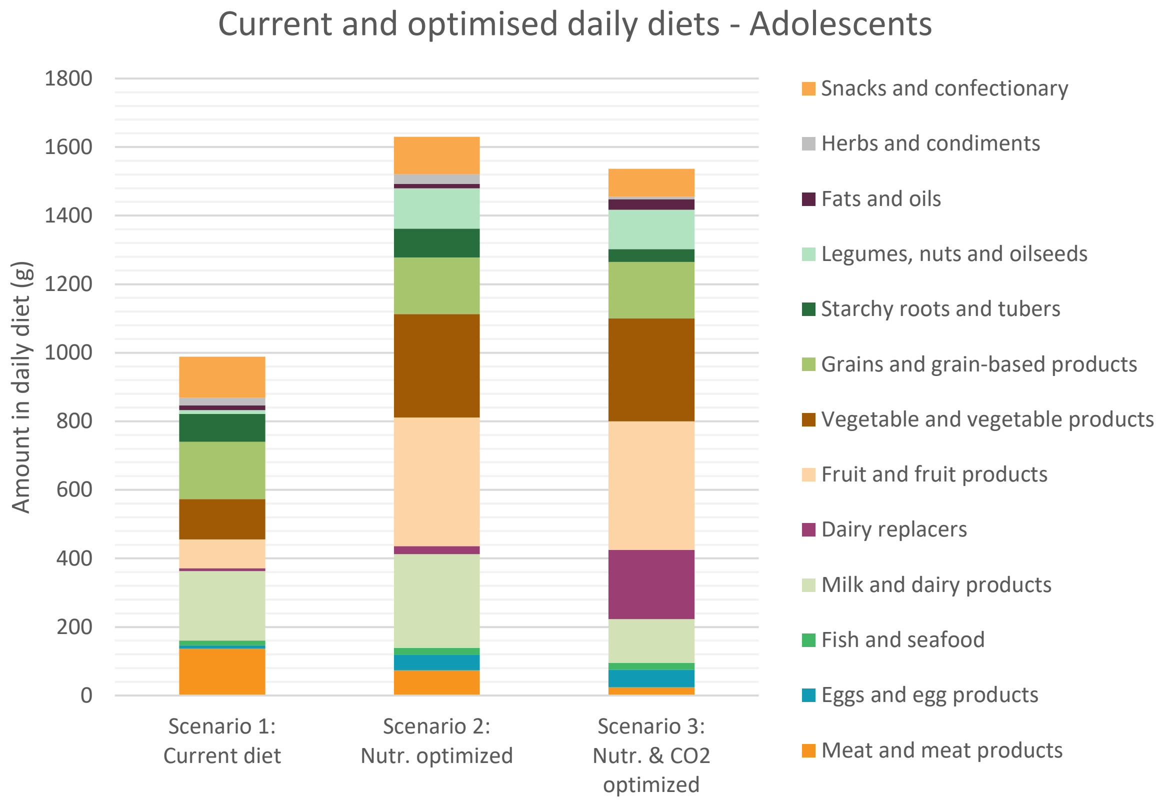

Figure 2. Simplified graph of composition of current and optimised daily diets for adolescents, excluding beverages.

The reasons for the reduced intake of meat products and increased intake of eggs, are identical to those discussed in the section for adults. This section will focus on changes in the optimised diets that are specific to adolescents.

The larger contrast between the current and optimised intake of fruit and fruit products is related to the food based dietary guidelines (FBDGs), which recommend a 50% higher intake of fruits for adolescents than for adults. For similar reasons, the amount of beverages with added sugar reduce a lot in the optimised diets. The FBDGs state that sugary drinks should be consumed as little as possible, the maximum value is thus set to two glasses a week. For adults, the maximum consumption is higher: one glass every two days.

The combined quantity of dairy and dairy replacers is much higher for adolescents than adults in all scenarios. This is related to the higher required intake of calcium for adolescents compared to adults: both milk and dairy replacers are important sources of calcium in the diets, but the milk replacers provide this with a relative lower environmental burden.

The total quantity of snacks, desserts, sugar and confectionary decreases, though interestingly there is a shift from snacks and desserts towards sugar and confectionary. Sugar and confectionary provide carbohydrates for a comparatively lower environmental footprint than deserts and snacks. The total amount of added sugar in the optimised diet is lower compared to the reference.

Table 9. Composition of the current and optimised daily diets for adolescents.

Food groups	*Scenario 1: Current diet*	*Scenario 2: Nutrition optimised*	*Scenario 3: Nutrition & GHG optimised*
Beef and veal (g)	33.15	22.64	6.63
Lamb (g)	2.89	2.18	0.58
Meat replacers (g)	1.18	2.46	0.24
Pork (g)	35.44	12.79	7.09
Poultry (g)	32.25	31.20	6.45
Processed meat (g)	33.53	4.29	3.35
Fish and seafood (g)	14.46	20.00	20.00
Cheese (g)	24.68	26.92	4.94
Dairy (g)	177.26	247.12	122.72
Dairy replacers (g)	9.14	23.30	201.88
Eggs and egg products (g)	9.02	45.60	50.95
Snacks, desserts, and other foods (g)	76.02	71.11	15.20
Sugar and confectionery (g)	44.10	38.39	66.14
Fats and oils (g)	14.04	13.32	30.98
Alcoholic beverages (g)	20.34	0.00	0.00
Beverages with added sugar (g)	292.82	71.43	71.43
Coffee (g)	12.72	13.90	54.47
Drinking water (g)	746.85	749.38	747.00
Fruit and vegetable juices (g)	86.40	91.93	84.12
Tea (g)	25.76	28.14	85.33
Grains and grain-based products (g)	167.20	165.50	163.90
Fruit and fruit products (g)	83.53	375.00	375.00
Herbs, spices and condiments (g)	22.56	27.97	7.18
Legumes (g)	7.94	100.00	100.00
Nuts and oilseeds (g)	1.59	15.04	15.04
Starchy roots and tubers (g)	81.60	84.09	37.17
Vegetables and vegetable products (g)	117.36	301.40	301.40

4.2.2 Environmental impact

Table 10 lists the environmental impacts related to the reference and optimised diets. To meet the set climate target, the climate change impact of the diet for adolescents almost halved. This is mainly attributed to a lower consumption of animal-based products, such as beef, dairy, processed meat and cheese.

The ecosystems score shows the combined impact on biodiversity, by aggregating several indicators (global warming, water consumption, ecotoxicity, eutrophication, acidification and land use). This indicator is a rough indication of possible effects on ecosystems and does not quantify the actual state of biodiversity. Nevertheless, the sharp decline of the indicator in the optimised diet (scenario 3) does indicate that pressures on ecosystems are significantly lower for diets that are both sustainable and nutritious.

This conclusion is also reflected by the individual indicator land use and land use change. The land area (agricultural area) that is needed to accommodate an optimised diet is much lower than the land area required for the current diet. This is caused by lower consumption of animal-based products, which require a large area to produce animal feed. The land use change indicator, which signifies how much land transformation (and associated greenhouse gas emissions) is attributed to food products, shows that the optimised diet is associated with a lower risk for land transformation (such as deforestation). Products with a high risk of land transformation are poultry, eggs and meat products (related to soybeans in feed) and peanuts. The reduced emissions linked to the lower intake of poultry and other meat far outweighs the land use change associated with increased consumption of eggs and peanuts.

The optimized diet shows a decrease in impact on freshwater eutrophication, mainly due to lower consumption of meat products.

Table 10. Environmental properties of the current and optimised daily diets for adolescents.

Environmental indicators	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
Climate change (kg CO_2eq)	3.96	4.08	2.04
Damage to ecosystem (species loss*yr)	$5.41*10^{-8}$	$5.39*10^{-8}$	$3.41*10^{-8}$
Land use (m^2*a)	2.69	2.64	1.89
Land use change (kg CO_2eq)	0.59	0.60	0.38
Freshwater eutrofication (kg P eq)	$4.55*10^{-4}$	$4.97*10^{-4}$	$3.00*10^{-4}$

4.2.3 Nutrition & Health

Like for adults, the current diet of Belgian adolescents does not meet standards as set by the Belgian health authorities. The reference diet contains an excess of added sugar, sodium and saturated fat, whereas it is too low on omega 3 and 6 fatty acids and poly-unsaturated fat, fibre, as well as several vitamins (B1, C, D, and E) and minerals (calcium, copper, iodine, iron, magnesium, zinc). It should be noted that the current diet also contains too few calories and carbohydrates, which is likely related to underreporting of consumption by individuals, and not by a lack of sufficient food intake.

When it comes to the FBDGs, none of them is met; adolescents currently eat too little fish, fruit, vegetables, whole grain products, legumes, dairy products, seeds and nuts, and too much processed meat and red meat.

The optimised diet corrects for all these deviations and is fully in line with both the nutritional guidelines and the food based dietary guidelines. Table 11 indicates the dietary changes made in scenario 2 and 3 needed to comply with the nutritional guidelines that are not satisfied in the current diet.

The average Nutri-score of the diet moves from C to A. The quantity of food with Nutri-score A increases significantly due to a higher consumption of fruits and vegetables. Milk, which also scores an A, is largely replaced by plant-based alternatives. The products that contribute most to the increase of food in category B includes egg and fish. The reduction in products with Nutri-score D and E is attributed to a lower consumption of meat, cheese, soft drinks and snacks. Products with a low Nutri-score (D and E) that do increase in the optimised diet (scenario 3) are sugar and confectionary and fats and oils.

Table 11. Over- and underconsumption of macro- and micronutrients in the current and optimized diet for adolescents.

Nutrient	Current consumption level	How the consumption level is altered in the optimised diet (scenario 3)
Added sugar	Too high	Reduced intake of beverages with added sugar
Calcium	Too low	Increased intake of dairy replacers and drinking water
Carbohydrates	Too low	Increased intake of fruits and grain-based products
Copper	Too low	Increased intake of dairy replacers and legumes
Energy	Too low	Increased intake of fruits, fats and oils, candies, nuts and oilseeds
Omega 3 fatty acids	Too low	Increased intake of (blended) fats and oils
Omega 6 fatty acids	Too low	Increased intake of (blended) fats and oils
Fibres	Too low	Increased intake of legumes
Iodine	Too low	Increased intake of egg and egg products
Iron	Too low	Increased intake of vegetable products
Magnesium	Too low	Increased intake of vegetable products
Poly-unsaturated fat	Too low	Increased intake of (blended) fats and oils
Saturated fat	Too high	Reduced intake of snacks, desserts and other foods and cheese
Sodium	Too high	Reduced intake of processed meat
Vitamin B1	Too low	Increased intake of grain-based products
Vitamin C	Too low	Increased intake of fruits
Vitamin D	Too low	Increased intake of eggs and egg products
Vitamin E	Too low	Increased intake of fats and oils
Water	Too low	Increased intake of fruits
Zink	Too low	Increased intake of vegetables and legumes

Table 12. Nutritional properties of the current and optimised daily diet for adolescents.

Nutri-score indicators	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
Nutri-score - raw score (p)	3.19 (C)		-0.70 (A)
Nutri-score A (g)	1288.95	1947.71	1940.95
Nutri-score B (g)	189.32	241.46	240.73
Nutri-score C (g)	142.25	167.86	172.57
Nutri-score D (g)	177.89	109.49	141.11
Nutri-score E (g)	375.43	118.58	83.81

4.2.4 Price

For the nutritionally optimised diet, a steep price increase can be observed. This is mainly due to increased costs for fruits and vegetables. Also, costs for legumes, fish and seafood increase. Reduced expenditure for beverages with added sugar slightly compensate these trends. In the diet optimised with the carbon (and price) limit, the vast reduction in meat consumption reduces the price to the price of the original diet.

Table 13. Economic properties of the current and optimised daily diet for adolescents.

Price	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
Consumer price (€)	€ 5.56	€ 7.97	€ 5.56
Consumer price (bio/fairtrade) (€)	€ 9.51	€ 12.59	€ 8.51

4.2.5 NOVA

The total quantity of food consumed from NOVA group 1, the least processed foods, increases in scenario 2 and 3, mainly due to an increase in fruit, vegetable and legume consumption.

For the nutritionally optimised scenario, an increase in food products from NOVA group 2 is observed due to an increase in intake of fats and oils and increase in sugar and confectionary (mainly honey). When also optimised for climate change, a further increase is observed for fats and oils, sugar and confectionary in this category reduces.

Products consumed from NOVA group 3 increase in the nutritionally optimised scenario, mainly due to increased consumption of canned legumes and fruit products. For the third scenario the total intake from this category decreases, due to reduced intake of grain-based products, vegetables, cheese, alcoholic beverages and sugar and confectionary from NOVA group 3.

The reduced intake of beverages with added sugar (mainly soft drinks) result in a vast decrease of NOVA group 4 products in scenario 2. An increase compared to scenario 2 is observed for scenario 3, due to the high intake of dairy replacers.

Table 14. Level of processing of the current and optimised daily diet for adolescents.

NOVA indicators	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
NOVA group 1 (g)	1354.11	1951.53	1885.35
NOVA group 2 (g)	12.35	26.14	30.64
NOVA group 3 (g)	221.35	289.33	188.54
NOVA group 4 (g)	586.03	318.11	474.64

4.3 Optimised diets for children (3 – 9 years)

4.3.1 Dietary composition and carbon footprint of 3 scenarios

The average diet of children in Belgium is shown in Figure 3, and has a total carbon footprint of 3.17 kg CO_2eq/day per individual. A large part of the daily intake (in mass) consists of milk and dairy products. Fruits, grains, snacks and confectionary make up a considerable part of the current diet. Vegetables and vegetable products and meat and meat products are consumed in comparable amounts. Legumes, nuts, oilseeds, eggs, fish and seafood represent a small part of the daily diet.

Optimizing the daily diet to comply with the nutritional- and food based dietary guidelines slightly decreases the carbon footprint of the diet to 2.95 kg CO_2eq/day per individual. An overall increase in food intake is found for the optimised diet, this is related to the deficient intake of several (micro)nutrients and noncompliance with the FBDGs of the current diet. An extreme increase is seen in the intake of fruit, vegetables, legumes, nuts, oilseeds and eggs. A considerable increase is also observed in grains and grain-based products. The intake of milk and dairy products and meat and meat products reduces strongly.

Adding the constraints on carbon footprint (2.04 kg CO_2eq/day per individual) and price (equal to the original diet) leads to the continuation of some trends: grains and grain-based products further increase, whereas milk and dairy products and meat and meat products further decrease. The intake of snacks and confectionary in the third scenario is halved compared to the current diet. With the imposed price constraint, the total carbon footprint is reduced to 1.83 kg CO_2eq/day per individual and thus stays below the imposed limit.

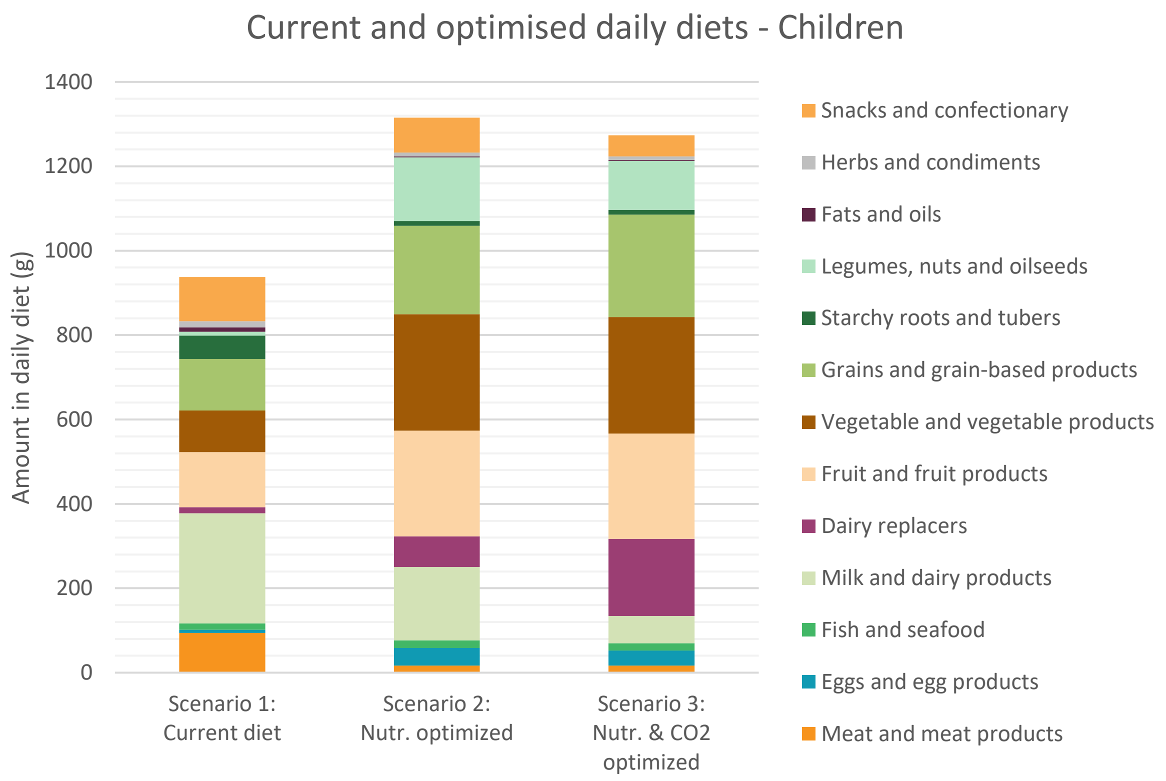

Figure 3. Simplified graph of composition of current and optimised daily diets for children, excluding beverages.

Generally speaking, the dietary changes in the second and third scenario follow the same trends as the diets for adults and adolescents. The reduction in meat, milk and dairy consumption and increase in fruit, vegetable and egg consumption are discussed in the section on the adults diet. This section focuses on changes in the optimised diets that are specific to children.

Contrary to the optimised diets for adults and adolescents, the scenario 2 and 3 diets for children do show an increased consumption of meat replacers. In the nutritionally optimised diet, meat replacers are an important contributor to the intake of Omega 3 and 6 fatty acids, magnesium and proteins, and (to a lesser extend) to calcium, copper and iron.

The current intake of fat in total, and saturated fat specifically, exceeds the recommended value (Table 17). The amount of fats and oils therefore reduces in the optimised diets. Reduced intake of meat products and snacks, desserts, and other foods also reduces the intake of (saturated) fats.

Notable is the vast increase of drinking water in the third scenario, which is related to several factors. Firstly, the current diet is about 200 grams low on total water intake (Table 17). The reduced consumption of soft drinks and milk reduce water intake even further. Although partially countered by dairy replacers and fruit products, water intake must increase in the optimised diets. Secondly, the current diet does not satisfy the calcium requirement (Table 17). With the restriction on price (and carbon footprint), the optimisation finds a solution in using drinking water as a source of calcium. In the third scenario, drinking water is the second contributor to calcium intake (after dairy replacers), it also contributes to the intake of iodine, magnesium and selenium. Despite the extreme increase, the recommended intake of drinking water in scenario 3 is in line with the recommendations of the Voedingsdriehoek (ViGeZ, 2014).

Table 15. Detailed composition of the current and optimised daily diets for children.

Food groups	*Scenario 1: Current diet*	*Scenario 2: Nutrition optimised*	*Scenario 3: Nutrition & GHG optimised*
Beef and veal (g)	21.51	4.30	4.30
Lamb (g)	1.34	0.27	0.27
Meat replacers (g)	0.80	50.16	15.66
Pork (g)	25.09	5.02	5.02
Poultry (g)	22.15	4.43	4.43
Processed meat (g)	24.10	2.41	2.41
Fish and seafood (g)	14.71	17.50	17.50
Cheese (g)	14.96	8.77	12.86
Dairy (g)	245.73	165.27	51.57
Dairy replacers (g)	14.52	72.77	182.38
Eggs and egg products (g)	7.88	42.46	36.11
Snacks, desserts, and other foods (g)	66.82	48.18	13.36
Sugar and confectionery (g)	38.34	34.04	36.45
Fats and oils (g)	10.83	2.16	2.16
Alcoholic beverages (g)	0.22	0.00	0.00
Beverages with added sugar (g)	136.54	35.71	33.10
Coffee (g)	1.90	0.38	0.38
Drinking water (g)	573.42	646.41	1298.22
Fruit and vegetable juices (g)	105.72	21.16	21.16
Tea (g)	11.13	7.69	2.22
Grains and grain-based products (g)	121.59	209.78	242.46
Fruit and fruit products (g)	130.60	250.00	250.00
Herbs, spices and condiments (g)	13.96	9.79	8.84
Legumes (g)	7.05	87.50	87.50
Nuts and oilseeds (g)	1.04	13.17	13.16
Starchy roots and tubers (g)	55.99	11.20	11.20
Vegetables and vegetable products (g)	98.89	276.06	276.06

4.3.2 Environmental impact

The optimised diet for children shows similar environmental benefits as with adults and adolescents. The climate change impact of the reference diet was already relatively low compared to adults and adolescents (related to lower food intake), and even moves to below the threshold of 2.04 kg CO2-eq per person per day in scenario 3. The carbon footprint reduction of the third scenario is mainly related to the lower meat and dairy intake.

The lower environmental burden is also apparent in the other environmental indicators that have been assessed. The Damage to Ecosystems indicator, which gives a holistic (yet simplified) indication of the impact on biodiversity, has declined sharply in the optimised diet, indicating that the production of food in this diet is associated with lower negative impacts to biodiversity.

This biodiversity indicator aggregates several midpoint indicators (global warming, water consumption, ecotoxicity, eutrophication, acidification and land use), which also show a lower environmental impact when studied individually. The area of land used to produce the crops and animals that are part of the diet, decreases by a third. Again, this decrease is mostly related to the reduced intake of dairy and meat in the optimised diet.

The land use change indicator, which represents land conversion in the past 20 years as a result of expansion of agricultural land (expressed as GHG emissions), shows that the risk of land use change is lower in the optimised diet. However, it should be considered that this indicator only represents land use change in the last 20 years and cannot predict land use change associated with the diet of 2030. Land use change emissions mainly reduce in the optimised diet due to lower meat consumption. Also freshwater eutrophication decreases due to lower meat consumption.

Table 16. Environmental properties of the current and optimised daily diets for children.

Environmental indicators	*Scenario 1: Current diet*	*Scenario 2: Nutrition optimised*	*Scenario 3: Nutrition & GHG optimised*
Climate change (kg CO_2 eq)	3.17	2.95	1.83
Damage to ecosystems (species loss*yr)	$4.21*10^{-8}$	$3.11*10^{-8}$	$2.50*10^{-8}$
Land use (m^2*a)	2.01	1.50	1.31
Land use change (kg CO_2 eq)	0.43	0.30	0.23
Freshwater eutrophication (kg P eq)	$3.33*10^{-4}$	$4.12*10^{-4}$	$3.11*10^{-4}$

4.3.3 Nutrition & Health

The current diet consumed by children does not comply with all nutritional guidelines. The diet contains too high quantities of (saturated) fat and sodium, whereas it lacks fibre, omega 3 fatty acids, as well as certain minerals (calcium, copper, iodine, iron, magnesium) and vitamins (B1, C, D, E).

Hardly any of the Food Based Dietary Guidelines (FBDGs) are satisfied in the current diet: the average diet contains too low quantities of fish and seafood, fruits, legumes, nuts and seeds, vegetables and whole grain products. On the other hand, red meat, processed meat and drinks with added sugar are overconsumed. The current diet does comply with the recommended intake of milk and dairy products.

The optimised diets (scenario 2 and 3) do comply with the nutritional guidelines and FBDGs. The nutrients that are outside of the nutritional boundaries and the adaptations proposed in the optimised diet (scenario 3) in order to comply with the nutritional guidelines are presented in Table 17.

Table 17. Over- and underconsumption of macro- and micronutrients in the current and optimized diet for Children.

Nutrient	Current consumption level	How the consumption level is altered in the optimised diet (scenario 3)
Calcium	Too low	Increased intake of dairy replacers and drinking water
Copper	Too low	Increased intake of legumes and dairy replacers
Fat total	Too high	Reduced intake of snacks, desserts and other foods

Omega 3 fatty acid	Too low	Increased intake of nuts and oilseeds
Fibres	Too low	Increased intake of legumes
Iodine	Too low	Increased intake of egg and egg products and legumes
Iron	Too low	Increased intake of grain-based products and legumes
Magnesium	Too low	Increased intake of dairy replacers and legumes
Mono-unsaturated fat	Too low	Reduced intake of legumes
Potassium	Too high	Reduced intake of milk and juices
Saturated fat	Too high	Reduced intake of snacks, desserts and other foods and dairy
Sodium	Too high	Reduced intake of processed meat
Vitamin B1	Too low	Increased intake of grain-based products
Vitamin C	Too low	Increased intake of fruits and vegetables
Vitamin D	Too low	Increased intake of eggs and egg products
Vitamin E	Too low	Increased intake of dairy replacers
Water	Too low	Increased intake of drinking water

The quantity of food with nutriscore A doubled in the third scenario due to a higher consumption of unbottled water, fruits and vegetables. Milk, which also scores an A, is largely replaced by plant-based alternatives. The products that contribute most to category B include grain-based products (increase in scenario 3) egg (increase in scenario 3) and dairy (decrease in scenario 3). Juices represent the largest part of category C products in the current diet, the vast decrease in juices explain the reduction of category C products in scenario 3. The reduction in products with nutriscore D and E is attributed to a lower consumption of meat, cheese, soft drinks and snacks.

Table 18. Nutritional properties of the current and optimised daily diets for children.

Nutri-score indicators	*Scenario 1: Current diet*	*Scenario 2: Nutrition optimised*	*Scenario 3: Nutrition & GHG optimised*
Nutri-score - raw score (p)	2.22 (B)		-0.95 (A)
Nutri-score A (g)	1118.65	1641.95	2292.67
Nutri-score B (g)	170.73	156.27	140.01
Nutri-score C (g)	147.67	113.38	83.99
Nutri-score D (g)	136.95	68.09	64.43
Nutri-score E (g)	192.82	46.87	47.68

4.3.4 Price

The average price of the daily diet for children is much lower compared to the price of the diet for adults (€4.48 versus €7.29). When optimising the diet on the nutritional guidelines, the price of the diet strongly increases, to €7.23. This price increase is mainly related to increased consumption of fruits, meat replacer and nuts and oilseeds.

For the third scenario, a constraint is set on the price of the diet, so that it does not exceed the price of the current diet. Shifts in the relative contribution of food groups to the total price are observed: the contribution of snacks, meat and dairy products reduce, whereas the contribution of legumes, grain-based products and nuts increase.

Table 19. Economic properties of the current and optimised daily diets for Children.

Price	*Scenario 1: Current diet*	*Scenario 2: Nutrition optimised*	*Scenario 3: Nutrition & GHG optimised*
Consumer price (€)	€ 4.48	€ 7.32	€ 4.48
Consumer price (bio/fairtrade) (€)	€ 7.49	€ 11.55	€ 6.61

4.3.5 NOVA

As listed in Table 20, the optimised diet (scenario 3) contains a larger share of unprocessed foods (score 1 and 2), which is caused by the higher consumption of drinking water, fruits and vegetables. The processed and highly processed foods (score 3 and 4) decrease because of lower consumption of soft drinks, fruit juices, snacks and desserts. The quantity of some processed and highly processed foods increased, especially plant-based drinks. The lower degree of processing is also reflected by the average NOVA-score, which moves from 1.89 to 1.47.

Table 20. Level of processing of the current and optimised daily diets for Children.

NOVA indicators	***Scenario 1: Current diet***	***Scenario 2: Nutrition optimised***	***Scenario 3: Nutrition & GHG optimised***
NOVA group 1 (g)	1188.49	1573.56	2152.43
NOVA group 2 (g)	8.68	30.73	33.14
NOVA group 3 (g)	150.55	184.95	133.33
NOVA group 4 (g)	419.10	237.33	309.88

4.4 Overall diet for a family of four

Next to the individual diets of adults, adolescents and children, the overall diet of a family of four (existing of two adults, an adolescent and a child) has been considered. This analysis provides an overview of what the impacts of an optimised diet are at the household level. For more in-depth analysis of dietary changes related to the individual diets, the previous chapters can be consulted.

4.4.1 Dietary composition and carbon footprint

Figure 4 and Table 21 provide an overview of the dietary composition for a family of four, also referred to as 'family basket', for the reference situation as well for the optimised scenario that meets both nutritional and environmental targets.

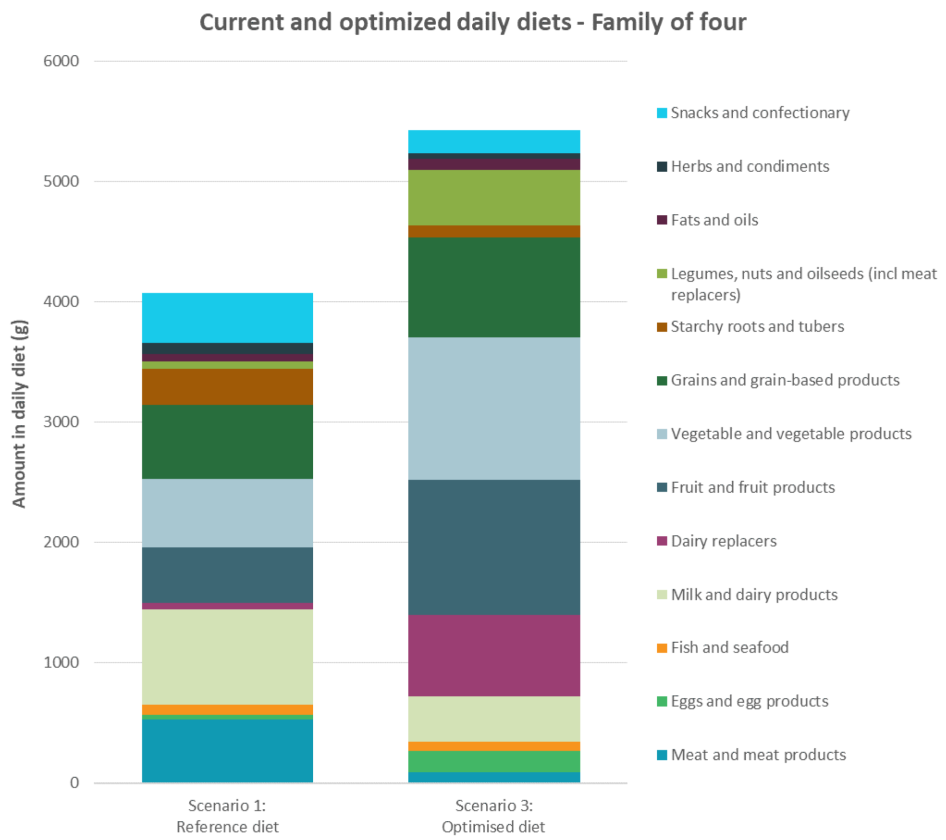

Figure 4. Simplified overview of the current and nutritionally and GHG optimised daily diet of a family of four (excl beverages).

This family basket provides a healthy diet for all family members, as it adheres to all nutritional guidelines set for the individual family members (adults, adolescents, children), both for nutrients as well as for food groups. Simultaneously, it ensures that carbon emissions per person do not exceed 2.04 kg CO_2-eq, the maximum allowable carbon footprint for food consumption per person per day to ensure temperature rise is limited to 1.5 degrees by 2030.

The carbon footprint of the diet of the family of four more than halves; from 16.7 kg CO_2-eq/day to 8.0 kg CO_2-eq/day. The dietary changes that have led to this reduced environmental impact and improved health outcomes can be summarised as follows:

- The optimised diet is characterised by a higher share of plant-based products, including fruits, vegetables, legumes, nuts and oilseeds and grain-based products. These products increase because of the nutritional requirements, and provide a relatively high quantity of nutrients for a low environmental impact.

- Meat, which is linked to a very high environmental burden, can still be consumed in an optimised diet, but in much lower quantities (18% of the original amount).
- The quantity of dairy products also decreases due its high carbon footprint, and is largely replaced by plant-based alternatives.
- Eggs are the only animal-sourced foods that increase, as they can deliver important nutrients (vitamin D and B12) for an acceptable environmental impact.
- The quantity of products that contain high level of fats, salt and added sugar (including snacks, confectionary, processed meat) are reduced.

Table 21 Detailed composition of the current and optimised daily diets for a family of four

Food groups	Current diet (g)	Optimised diet (g)
Beef and veal	90.75	18.15
Beef, veal and pork	81.83	16.36
Lamb	13.33	2.67
Pork	88.52	17.71
Poultry	129.94	25.99
Processed meat	124.35	12.44
Meat replacers	5.43	16.58
Fish and seafood	84.95	77.50
Cheese	103.53	30.58
Dairy	690.91	344.69
Dairy replacers	52.19	676.64
Eggs and egg products	37.27	174.11
Snacks, desserts, and other foods	256.33	70.75
Sugar and confectionery	154.86	117.07
Fats and oils	66.28	88.59
Alcoholic beverages	348.13	116.10
Beverages with added sugar	925.55	354.53
Coffee	568.85	566.23
Tea	208.27	203.55
Fruit and vegetable juices	312.28	138.97
Drinking water	3166.96	3891.22
Grains and grain-based products	610.80	835.28
Fruit and fruit products	462.48	1125.00
Vegetables and vegetable products	570.01	1180.93
Herbs, spices and condiments	91.08	49.45
Legumes	40.92	387.50
Nuts and oilseeds	9.91	58.27
Starchy roots and tubers	305.59	99.71

4.4.2 Environmental impacts

Table 22 lists the key indicators associated with biodiversity. The ‘damage to ecosystems’ indicator is a comprehensive indicator that provides a general indication of the damage to ecosystems inflicted by food production. Despite the inaccurate nature of such a generic aggregated indicator, it still clearly shows a trend of reduced damage to ecosystems. This is mainly caused by the shift from consumption of animal-sourced products to plant-based products. Animal-based products are relatively resource-intensive as they require a large quantity of plant-based inputs to produce a relatively small amount of animal-based products.

This is also illustrated by the individual indicators that are at the basis of this overarching indicator:

- The impact on climate change, a major threat to biodiversity worldwide, more than halves. Figure 5 shows the contribution of different food groups to the total impact of the current and optimised diet on climate change.
- The new diet requires 37% less land surface, and thus reduces pressure on (already fragile) natural areas.
- The pressure on aquatic ecosystems is lowered in the optimised diet, as shown by the freshwater eutrophication indicator.
- Other indicators that contribute to the overall Damage to Ecosystems indicator (results are included in the annex), such as acidification, freshwater and marine eutrophication, all show a reduced environmental impact.

Table 22. Environmental properties of the current and optimised daily diet for a family of four.

Environmental indicator	Reference diet	Optimised diet	Change (%)
Climate change (kg CO_2 eq./day)	16.733	7.950	-52%
Damage to ecosystems (species*yr/day)	$2.27*10^{-7}$	$1.26*10^{-7}$	-44%
Land use (m^2*a/day)	11.275	7.129	-37%
Land use change (kg CO_2 eq./day)	2.360	1.376	-42%
Freshwater eutrophication (kg P eq)	$2.00*10^{-3}$	$1.26*10^{-3}$	-37%

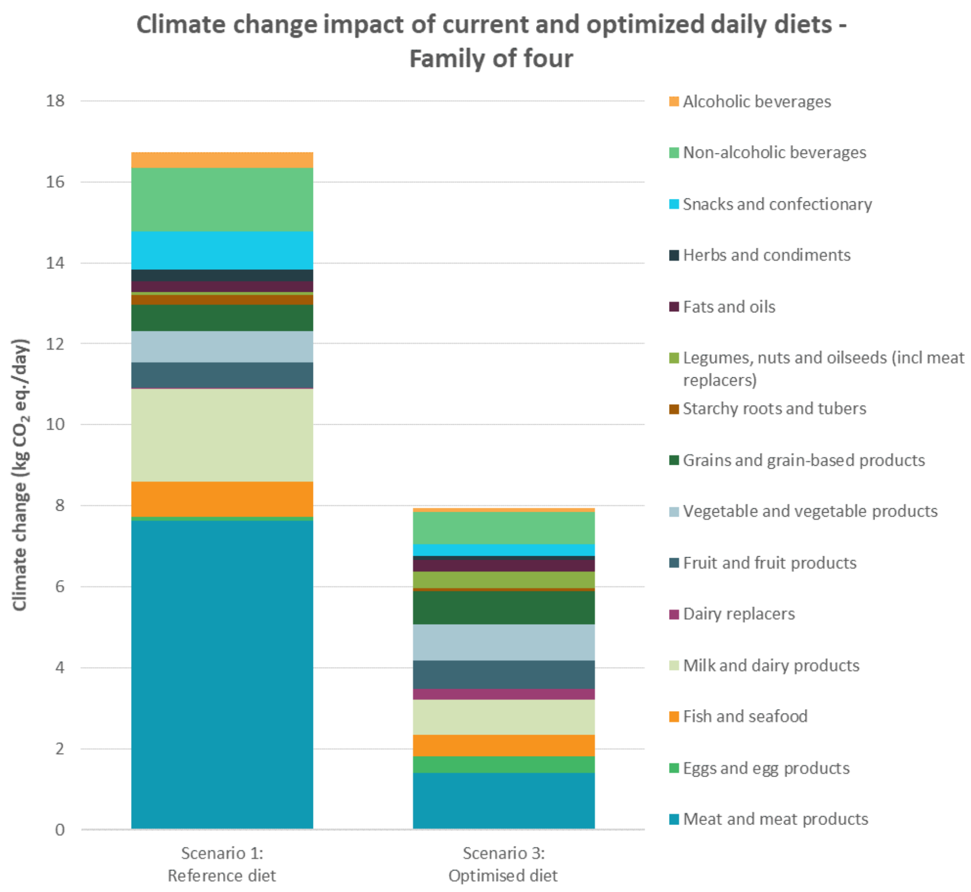

Figure 5. Simplified overview of the impact of the current and optimised daily diet of a family of four (excl beverages) on climate change.

4.4.3 NOVA and Nutri-score

By taking a weighted average of the Nutri-score of all products within the diet, an average Nutri-score for the whole diet can be obtained. It should be noted that a Nutri-score is developed for product-level only, and is not intended to be used for an entire diet. On a diet-level, it can however give a rough and easy-to-interpret indication of the nutritional status of that diet. For the reference diet, the overall Nutri-score was B, and it moves to A for the optimised diet, indicating that the optimised diet contributes to better health and nutrition. As explained in previous chapters, the reference diets for adults, adolescents and children did not meet many of the nutritional and food-based guidelines, whereas the optimised diets corrected for this.

The NOVA score is an indication of the level of processing of foods, and is assessed for the current and optimised diet. Highly processed foods (and especially those that are high on sugar, fat and salt) can be associated with obesity and various non-communicable diseases, however, this is not straight forward. Healthy products can be highly processed, such as (fortified) plant-based drinks, which makes interpretation of the score more difficult. For the family basket, the NOVA score shows an increase in minimally processed products (NOVA group 1 and 2), which is attributed to higher consumption of fruit and vegetables. Processed and highly processed products on the other hand (NOVA group 3 and 4) have decreased. This is attributed to a lower consumption of soft drinks, processed meat, snacks and desserts.

Table 23. Level of processing of the current and optimised daily diets for a family of four.

Nova score	Reference diet	Optimised diet	Change (%)
Nova group 1 (g/day)	6,418	8,128	27%
Nova group 2 (g/day)	58	120	106%
Nova group 3 (g/day)	1,140	838	-26%
Nova group 4 (g/day)	1,998	1,613	-19%

4.4.4 Price

Currently, a family of four spends on average 172 euros on food and drinks for an entire week. This is based on average prices from the three biggest retailers in Belgium, for non-certified products, as can be found in Annex C.

The optimised diet leads to a cost reduction: the average expenditure drops to 158 euros per week. This leaves some room to switch to certified products, such as organic or Fairtrade. These labels are generally considered to be a reference for good production practices of a product, ensuring better conditions for people, animals, and the environment. These products tend to be more expensive because they internalize negative environmental and social externalities in the production cost.

Switching completely to certified products for the optimised diet, would lead to a steep increase (50%) in expenditure, from 158 euros to 237 euros per household per week. Instead, it is more realistic to only opt for certified alternatives for a selected number of products. We therefore also evaluated how much of these certified alternatives can be introduced for a selected number of products without increasing the total cost of the weekly basket.

Table 24 divides all products into a non-certified group (group 1), mostly containing products for which only few certified alternatives are available, and a group for which purchasing certified products is recommended by WWF (group 2). The latter group includes products for which certification can make a significant difference: animal products (meat, dairy, and eggs), fruits, vegetables, coffee and tea. Labels like Utz/Rainforest Alliance and Fairtrade support responsible production of coffee, tea and other plant-based products from mostly developing countries, following different environmental and social criteria. Organic products, which are also included, are produced without the use of agrochemicals and with measures that enhance on-farm biodiversity and animal wellbeing.

To remain at the same expenditure level as the current reference diet, 30% of the products in group 2 can be purchased with a certification label. This indicates that the shift to a sustainable and healthy diet as proposed in this report could benefit ecosystems and increase social justice without compromising on expenses.

Table 24. Division of all product groups into group 1, which are not certified in the optimized diet and group 2, of which 30% certified products can be purchased without increasing to weekly expenditure compared to the current situation.

	Group 1 - 100% non-certified products	**Group 2 30% certified, 70% non-certified products**
Products in this group	• Fats and oils • Alcoholic beverages • Snacks and desserts • Sugar and confectionary • Fruit and vegetable juices • Processed meat • Grains and grain-based products • Legumes, nuts and seeds • Soft drinks • Herbs, spices and condiments • Fish and seafood	• Vegetables • Fruits • Eggs • Beef • Pork • Chicken • Lamb • Dairy products • Coffee and tea • Meat replacers • Dairy replacers • Starchy roots and tubers

5 Conclusions

By means of optimizing of the current Belgium diet of adults, adolescents and children for both nutritional and environmental targets, this study proofs that it is possible to shift to a diet that adheres to nutritional guidelines, and that is in line with the aim to limit global warming to 1.5°C above pre-industrial times.

The optimised diets show a clear shift from animal-sourced foods to plant-based foods. Even though meat products can still be consumed in the optimised diet, the quantity reduces to less than one fifth of the current consumption. Milk and dairy products are reduced, but to a lesser extent (half of the original intake). Eggs are the only animal-sourced food that still play an important role in healthy and sustainable diets, as they provide a high quantity of nutrients for a relatively low environmental impact. In the optimised diet, essential nutrients are provided by plant-based products, and in particular those with a high nutritional quality, including fruits, vegetables, legumes, nuts and plant-based dairy alternatives. Products that contain high level of fats, salt and added sugar (including highly processed foods such as snacks, confectionary, soft drinks and processed meat) are reduced in the optimised diet.

Several biodiversity-related indicators (derived from e.g. land use, land transformation and freshwater eutrophication) suggest that the proposed dietary shift will have a positive effect on ecosystems and thus could contribute to mitigating biodiversity loss.

Weekly expenses of a family of four (consisting of two adults, one adolescent and one child) reduces for the optimised diet. The cost reduction is mainly observed in the diet for adults. This price reduction gives room to purchase more certified products, such as organic or Fairtrade. For a selected group of products (fruits, vegetables, meat, dairy, coffee, and tea) it would be possible to purchase 30% of certified products, without exceeding the original weekly budget. In this way, without compromising on expenses, the shift to a more sustainable and healthy diet can also stimulate socially and environmentally responsible production practices.

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7 Annex

Annex A: Explanation of the LCA methodology

Life Cycle Assessment (LCA) is a method to evaluate and quantify the environmental impact of a product or service. Life Cycle Assessment captures the whole supply chain (from cradle to grave) with its individual stages. From raw-material production, production, distribution, transportation, use and disposal of a specific product (or service). Different environmental impacts are assessed, for instance greenhouse gas emissions, water consumption and fossil depletion.

The goal of an LCA is to get insights in the environmental impacts of a product or service, by quantifying all inputs and outputs of material flows. The results of an LCA can be applied for product development, strategic planning, marketing and communication towards customers.

Figure 6: Example of life cycle approach

Why assess the impact?

There are different motives to assess the impact of a product. Some examples are: decouple environmental impact from growth, reduce resource depletion and create novel products (for example alternative protein sources, energy efficient solutions), establish cost reduction, raise public awareness and involvement (for example regarding deforestation, sustainable fishing, healthy and sustainable nutrition), adaptation of healthy lifestyles.

Steps of an LCA

In order to review all the inputs and outputs and calculate the environmental impacts various steps need to be undertaken. The International Organisation for Standardisation (ISO) provides guidelines related to LCA (ISO 14040 and 14044 (ISO, 2006a, 2006b). Four different steps are proposed, each of them is explained in more detail.

1. Goal & Scope definition

The first step of goal and scope definition involves the stating and justification of the whole study. First, the goal of the study is explained, together with its primary intentions, followed by the intended audience and the involved parties of the study. In order to define the goal of the study the following questions need to be answered: 'What is the reason for carrying out the study?', 'What is the intended application?' and 'What is the targeted audience of the deliverables?'.

The scope definition phase establishes the main characteristics of the whole study. What to analyse and how? The product system is introduced and the scope of the analysed product system is explained (e.g. cradle-to-grave or cradle-to-gate). Hereby, the following items are important to outline: function, functional unit, alternatives and reference flow(s) of the product(s). Eventually, the results and comparison will be based on the reference flow(s).

2. Inventory analysis: Data collection

The life cycle inventory (LCI) stage estimates the consumption of resources and quantifies the waste flows and emissions caused or attributable to the tray's life cycle. LCA, each and every flow should be followed until its economic inputs and outputs have all been translated into environmental interventions (=emission or resource), from economy to environment or vice versa. To do this, three different system boundaries need to be defined:

- Economy-environmental system boundary: describes which processes belong to the economy and environment.
- Cut-off: discusses the processes that are irrelevant or not taken into consideration during the whole LCA study.

- Allocation: assigning the environmental impacts of multifunctional systems. Three different multifunctional processes exist: coproduction, recycling and combined waste processing. In each of the scenarios the environmental impacts need to be allocated over de different functional flows. The allocation method can either based of physical properties of the flows (mass or energy content), economic value or substitution (avoided product).

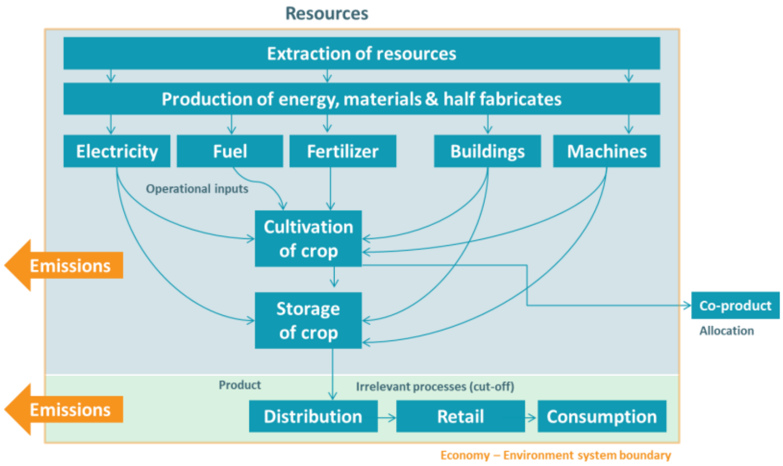


Figure 7: Example of the cradle-to-gate system boundaries that is applied for agricultural products.

At this stage data needs to be collected and modelled. This forms the main part of the LCA studies. It gives inputs for the Life Cycle Impact Assessment and gives feedback to the initial scope setting. The collected data consists preferably of primary data for the most important processes, the so-called fore-ground processes. Economic flows of these foreground processes are connected to so-called background processes to include inventory data from up- and downstream processes. Background databases can be used for this purpose, examples include Agri-footprint®, ELCD and Ecoinvent database. Result of the LCI is the inventory table, an extensive list of environmental interventions.

3. Impact assessment

During the life cycle impact assessment (LCIA) the inventory tables from the LCI are used to determine the environmental impact of reference flows for different impact categories. This is done by first selecting the impact categories that are relevant for the study. This depends on the type and goal & scope of the study. More information about impact categories, in the next paragraphs.

Next step is to translate the inventory table into impact indicator results (impact categories). This is usually performed using specialized software, like Simapro. The following steps are performed to get from the inventory table to impact category results. This can be best explained using the impact category “climate change” as example, but works similarly for all impact categories.

- Classification – the software classifies the emitted greenhouse gasses from the inventory table. Hereby all, non-greenhouse gasses are lest out from the analysis for this impact category.
- Characterisation – the impact of each greenhouse is calculated based on the mass and potency of the greenhouse gas in respect to the indicator unit. The indicator unit for global warming at mid-point level is kg CO_2-equivalents. Each kg of emitted carbon dioxide is 1 kg CO_2-eq., however methane is a more potent greenhouse gas and each kg of emitted methane is equivalent to 25 kg of CO_2. The potency of the greenhouse gasses or “characterisation factors” for greenhouse gasses are derived from IPCC and updated from time to time.
- Normalisation – this is an optional step to compare the significance of the footprint to the total impact of the world or European region. This can give an idea about the significance of the category impact.
- Weighting - this is an optional step to aggregate indicator results of various impact categories into a single score. However, weighting has always been a controversial issue in LCA studies (Finnveden, Eldh, & Johansson, 2006) and is therefore usually not performed.

4. Interpretation

The final phase of the LCA discusses the overall result from the previous steps. Interpretation begins with a consistency and completeness check to determine the soundness of the study. The contribution and sensitivity analysis helps to bolster the robustness of the results in preparation of the discussion and conclusion of the report. Each of the four optional steps are discussed in more detail.

- Consistency check: the objective of the consistency check is to determine whether assumptions, methods, models and data are consistent with the goal and scope of the study.
- Completeness check: ensure that the information and data used for this study are available and complete.
- Contribution analysis: illustrates the main contributing processes for each impact category. This helpful in understanding the product system(s) better.
- Sensitivity analysis: assesses the influence on the results of variations in process data, model choices and other variables. During the sensitivity analysis some of the important parameters are deliberately changed in order to determine the robustness of the results.

What follows is the discussion and the conclusion of the main research question for the study.

Presenting results in LCA studies

LCA results can be shown in multiple ways, at midpoint and at endpoint level. Midpoint are considered to be a point in the environmental cause-effect chain mechanism of a particular impact category (See *Figure 8*), prior to the endpoint at which characterization factors can be calculated to reflect the relative importance of an emission or extraction in a life cycle inventory (Bare, Hofstetter, Pennington, & Haes, 2000). Both midpoint and endpoint level indicators have complimentary merits and limitations. Results at mid-point indicators are argued to be more certain but can have lower relevance for decision support. Whereas endpoint indicators are considered to have higher relevance but lower certainty.

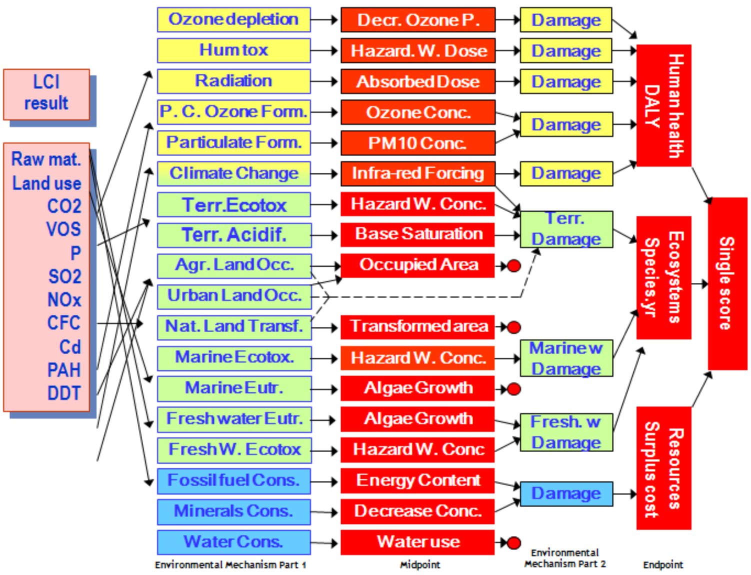


Figure 8: Graphic illustration of basic differences between the midpoint and the endpoint results (Goedkoop et al., 2013)

Because endpoints have lower certainty and involves the controversial process of weighting different impact categories, mid-points are always used to present results of LCA studies performed by Blonk Consultants. As default, impact categories from ReCiPe (version 1.13) are used to present results, using the hierarchical version. ReCiPe is chosen, since it is the most recent and harmonized indicator approach available in life cycle impact assessment. Optionally the mid-point results can be aggregated into a single score end-point result using the ReCiPe endpoint method.

Definitions used in LCA

Following LCA definitions are derived from the LCA handbook (Guinée et al., 2002)

Impact category: a class representing environmental issue of concern to which environmental interventions are assigned, e.g. climate change, loss of biodiversity.

Category indicator: A quantifiable representation of an impact category, e.g. infrared radioactive forcing for climate change.

Category unit: Unit to express the category indicator.

Characterisation factor: a factor derived from a characterisation model for expressing a particular environmental intervention in terms of a common unit of the category indicator.

Characterisation method: a method for quantifying the impact of environmental interventions with respect to a particular impact category; it compromises a category indicator, a characterisation model and characterisation factors derived from the model.

Characterisation unit: used to express the indicator result which is the numerical result of the characterisation step for a particular impact category, e.g. 12 kg CO2-equivalents for climate change.

Impact categories

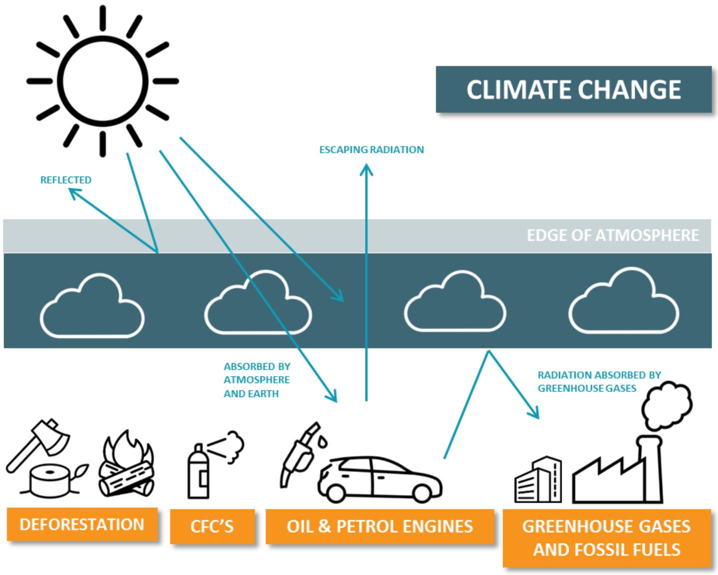
An LCA evaluates the environmental impact of a product or service. There exist various impact categories, such as climate change, freshwater eutrophication and agricultural land occupation. *Table 25* gives an overview of the impact categories, defined by ReCiPe methodology. In order to transform the extensive list of life cycle inventory results into a limited number of indicator scores the ReCiPe methods has been developed. These indicator scores express the relative severity on an environmental impact category.

Table 25: category indicators, units, characterisation factors, indicators results for 18 ReCiPe impact categories

Impact category	Category indicator	Indicator unit (mid-point)	Characterisation factor (mid-point)	Indicator unit (mid-point)	End-point	Indicator unit (end-point)
Climate change	infra-red radiative forcing	W*yr/m^2	GWP_{100}	kg CO_2 eq.	✓ (2x)	DALY + species/yr
Ozone depletion	Stratospheric ozone concentration	ppt*yr	ODP	kg CFC-11 eq.	✓	DALY
Terrestrial acidification	base saturation	yr*m^2	TAP	kg SO_2 eq.	✓	species/yr
Freshwater eutrophication	phosphorus concentration	yr*kg/m^3	FEP	kg P eq.	✓	species/yr
Marine eutrophication	nitrogen concentration	yr*kg/m^3	MEP	kg N eq.		
Human toxicity	hazard-weighted dose	m^2*yr	HTP	kg 1,4-DB eq.	✓	DALY
Photochemical oxidant formation	photochemical ozone concentration	kg	POFP	kg NMVOC	✓	DALY
Particulate matter formation	PM_{10} intake	kg	PMFP	kg PM10 eq.	✓	DALY
Terrestrial ecotoxicity	hazard-weighted dose	m^2*yr	TETP	kg 1,4-DB eq.	✓	species/yr
Freshwater ecotoxicity	hazard-weighted dose	m^2*yr	FETP	kg 1,4-DB eq.	✓	species/yr
Marine ecotoxicity	hazard-weighted dose	m^2*yr	METP	kg 1,4-DB eq.	✓	species/yr
Ionising radiation	absorbed dose	man*Sv	IRP	kBq U235 eq.	✓	DALY
Agricultural land occupation	occupation	m^2	ALOP	$m_2$anually	✓	species/yr
Urban land occupation	occupation	m^2	ULOP	$m_2$anually	✓	species/yr
Natural land transformation	transformation	m^2	NLOP	m_2	✓	species/yr
Water depletion	amount of water	m^3	WDP	m_3		
Metal depletion	grade decrease	kg^{-1}	MDP	kg Fe eq.	✓	$
Fossil depletion	upper heating value	MJ	FDP	kg oil eq.	✓	$

Most ReCiPe mid-point impact categories can be translated to end-point result. First, the environmental impact are grouped into three different domains: human heath, ecosystems and resources. Reference unit at end-point are DALY, species lost per year and surplus cost for each domain respectively. These results can then be further aggregated into a single score (points). A short description of climate change is included hereafter.

Climate change (carbon footprint)



Climate change refers to the change in weather patterns. Climate change heats up the earth slowly and is often called global warming. These changes have an impact on the quality of life on earth. Climate change is caused by various factors, such as biotic processes, plate tectonics, variations in solar radiation received by the earth, volcanic eruptions. Besides that, human activities have significant influence on climate change. Examples are fossil fuel combustion, agriculture and deforestation. These processes result in higher concentration of greenhouse gases (GHG's) in the atmosphere. CO_2 is one of the greenhouse gases (GHG) that has an impact on climate change. Besides that, there exist other greenhouse gases that contribute to global warming, for instance methane and nitrous oxide. These other gases, with an impact on climate change, are also included and expressed in equivalents with the same impact as CO_2. For results at mid-point, carbon dioxide is taken as reference unit, therefore 1 kg of CO_2 is 1 kg CO_2 equivalents. More potent greenhouse gasses include methane (34 kg CO_2-eq/kg) and nitrous oxide (298 kg CO_2-eq/kg). Within LCA studies, for the impact category climate change only human activities are taken into account. At end-point results for global warming are presented in human health effects (DALY) and effects on the environment (species lost per year).

Annex B: Nutritional constraints

	3yr to 9yr PAL1.4-1.6 average		10yr to 17yr PAL1.4-1.6 average		18yr to 64yr PAL1.4-1.6 average	
	min	max	min	max	min	max
Energy (KJ)	5736.3	6744.6	8531.4	10426.7	8125.3	9962.9
Energy (kcal)	1371	1612	2039.05	2492.05	1942	2381.2
Protein total (g)	19.7		43		57	
Fat total (g)	30	35	52.0	84.5	49.5	80.8
SAFA (g)		10		26.2		25
MUFA (g)	10	20	26.2	51.8	25	49.5
PUFA (g)	5	10	13.1	26.2	12.5	25
Linoleic acid (g)	4		10.4		9.9	
ALA (g)	1		2.6		2.5	
Cholesterol (mg)		300		300		300
Carbohydrates total (g)	163.2	211.1	242.7	326.3	231.2	311.8
Fibre (g)	15.0		20		25	
Water (g)	1600.0		2125.0		2250.0	
Alcohol (g)		0		0		12.5
DHA+EPA (mg)	250		250		250	
Retinol eq. (µg)	335	1300	612.5	2300	700	3000
Vitamin B1 (mg)	0.9		1.2		1.3	
Vitamin B2 (mg)	1.15		1.35		1.35	
Niacin (mg)	12.14		14.25		15	
Vitamine B5 (mg)	4.4		5		5	
Vitamin B6 (mg)	0.95	8	1.26	16.3	2.5	25
Folate eq. (µg)	134	450	184	700	250	1000
Vitamin B8 (µg)	26.4		31.9		40	
Vitamin B12 (µg)	1.9		3.6		4	
Vitamin C (mg)	80	725	102.5	1500	110	2000
Vitamin D (µg)	10	25	12.5	50	12.5	50
Vitamin E (mg)	9	90	12	125	12.0	150
Vitamin K total (µg)	18.8	372	35.6	833	60	1163
Calcium (mg)	800		1150		950	
Phosphorus (mg)	575		850		800	
Iron (mg)	8.5		12		12.0	
Sodium (mg)	350	950.00	475	1500	600	2000
Fluoride (mg)	1.15	5	2.45	5	3.2	7
Manganese (mg)	1.2		2.3		3	
Iodine (µg)	90	350	125	500	150	600
Potassium (mg)	1400	1700	2250	4050	3000	4000
Magnesium (mg)	230		300		325.0	
Zinc (mg)	6.1	15	9.5	22	9.5	25
Selenium (µg)	25	200	57.5	200	70	300
Copper (mg)	0.85	4	1.25	5	1.45	5
Molybdenum (µg)	33.5	250	53.8	500	65	600
Tryptophan (g)	0.105		0.228		0.274	
Threonine (g)	0.394		0.858		1.026	
Isoleucine (g)	0.504		1.054		1.368	
Leucine (g)	0.964		2.107		2.668	
Lysine (g)	0.767		1.666		2.052	
Valine (g)	0.635		1.397		1.778	
Histidine (g)	0.263		0.564		0.684	

Annex C: Included food products, product groups and prices

Product name	*Product group (as in tables)*	*Consumer price (€)*	*Consumer price certified (€)*
Algae and prokaryotes organisms	Vegetables and vegetable products	2.54	3.60
Animal fats and oils (processed fat from animal tissue)	Fats and oils	0.34	0.47
Apples and similar	Fruit and fruit products	0.25	0.47
Aromatic herbs	Vegetables and vegetable products	4.46	6.32
Aubergines and similar-	Vegetables and vegetable products	0.30	0.42
Bananas	Fruit and fruit products	0.15	0.29
Beans (with pods) and similar-	Legumes	0.45	0.64
Beer	Alcoholic beverages	0.31	0.39
Beetroots and similar-	Vegetables and vegetable products	0.24	0.34
Berries and small fruits	Fruit and fruit products	1.42	2.73
Biscuits	Snacks, desserts, and other foods	0.65	0.98
Blended fat and oils	Fats and oils	0.72	0.99
Boiled eggs	Eggs and egg products	0.45	0.60
Bovine and pig fresh meat	50% Beef and veal, 50% Pork	0.75	1.44
Bovine fresh meat	Beef and veal	1.54	2.95
Breakfast cereals, plain	Grains and grain-based products	0.58	0.88
Brined cheese (feta-type and similar)	Cheese	1.26	1.75
Broccoli and similar-	Vegetables and vegetable products	0.27	0.38
Butter	Fats and oils	0.93	1.28
Buttermilk	Dairy	0.19	0.26
Cakes	Snacks, desserts, and other foods	0.69	1.04
Candies (soft and hard)	Sugar and confectionery	0.75	1.20
Canned or jarred legumes	Legumes	0.48	0.58
Canned or jarred peach	Fruit and fruit products	0.37	0.71
Canned or jarred pineapple	Fruit and fruit products	0.41	0.80
Canned tunas and similar	Fish and seafood	1.66	1.66
Canned/jarred vegetables	Vegetables and vegetable products	0.23	0.32
Carrots and similar-	Vegetables and vegetable products	0.10	0.14
Cauliflowers and similar-	Vegetables and vegetable products	0.27	0.38
Celeriacs and similar-	Vegetables and vegetable products	2.00	2.84
Cereal and cereal-like flours (wheat flour white)	Grains and grain-based products	0.10	0.15
Cereal bars	Grains and grain-based products	1.41	2.13
Chocolate milk	Dairy	0.14	0.18
Chocolate spread	Sugar and confectionery	0.63	1.00
Coconut milk	Fruit and vegetable juices	0.55	0.81
Cod	Fish and seafood	1.54	1.54
Coffee beverages	Coffee	0.07	0.09
Compote/jam	Sugar and confectionery	0.28	0.55
Courgettes and similar-	Vegetables and vegetable products	0.24	0.34
Cow milk, semi skimmed (half fat)	Dairy	0.09	0.12
Cow milk, skimmed (low fat)	Dairy	0.10	0.14
Cow milk, whole	Dairy	0.13	0.18
Crackers and breadsticks	Grains and grain-based products	0.71	1.07
Cream and cream products	Dairy	0.48	0.66
Crisp bread	Grains and grain-based products	0.53	0.80
Cucumbers and similar-	Vegetables and vegetable products	0.32	0.46
Cured seasoned pork meat (87% ham and rest bacon)	Processed meat	1.58	3.01
Curly kale	Vegetables and vegetable products	0.92	1.30
Custard/starchy desserts	Snacks, desserts, and other foods	0.47	0.65
Dairy ice creams and similar	Snacks, desserts, and other foods	0.62	0.87
Choux pastry	Snacks, desserts, and other foods	0.97	1.47
Evaporated milk	Dairy	0.77	1.07
Fermented or pickled vegetables	Vegetables and vegetable products	0.35	0.50
Filled chocolate	Sugar and confectionery	1.25	2.00
Fish fingers, breaded	Fish and seafood	0.70	0.70
Fresh raw sausages	Pork	0.98	1.87

Fried eggs	Eggs and egg products	0.45	0.60
Fruit nectars (min. 25-50% fruit as defined in EU legislation)	Beverages with added sugar	0.16	0.24
Garlic and similar-	Vegetables and vegetable products	0.87	1.24
Generic poultry msm	Processed meat	0.29	0.56
Grapes and similar fruits	Fruit and fruit products	0.47	0.89
Head brassica	Vegetables and vegetable products	0.21	0.30
Herbal and other non-tea infusions	Tea	0.02	0.02
Honey	Sugar and confectionery	0.78	1.24
Juice, apple	Fruit and vegetable juices	0.14	0.21
Juice, orange	Fruit and vegetable juices	0.18	0.26
Kiwi	Fruit and fruit products	0.21	0.40
Laminated doughs (bladerdeeg)	Grains and grain-based products	0.53	0.80
Leafy vegetables	Vegetables and vegetable products	1.06	1.50
Leeks and similar-	Vegetables and vegetable products	0.22	0.31
Lemonade from concentrate	Beverages with added sugar	0.04	0.13
Lettuces and salad plants	Vegetables and vegetable products	0.27	0.39
Liver based spreadable-textured specialities	Processed meat	1.13	2.15
Mandarins and similar-	Fruit and fruit products	0.25	0.49
Margarines and similar	Fats and oils	0.38	0.53
Marinated meat	Pork; Beef and veal	1.29	2.47
Mayonnaise, hollandaise and related sauces	Herbs, spices and condiments	0.45	0.67
Meat imitates	Meat replacers	1.47	1.77
Meat sauce	Herbs, spices and condiments	0.67	1.00
Melons (also watermelons)	Fruit and fruit products	0.26	0.50
Milk chocolate	Sugar and confectionery	0.90	1.45
Mixed fruit juice	Fruit and vegetable juices	0.20	0.30
Mozzarella	Cheese	0.73	1.02
Muesli and similar mixed breakfast cereals	Grains and grain-based products	0.38	0.58
Multigrain bread and rolls	Grains and grain-based products	0.43	0.65
Mushroom	Vegetables and vegetable products	0.55	0.78
Mussels	Fish and seafood	0.44	0.44
Oat bran	Grains and grain-based products	0.25	0.38
Olives	Fruit and fruit products	1.44	2.76
Onions and similar-	Vegetables and vegetable products	0.20	0.28
Oranges and similar-	Fruit and fruit products	0.17	0.33
Other (mixed) fruit and vegetable juices or nectars (Multivitamin juice)	Fruit and vegetable juices	0.19	0.28
Pancake	Grains and grain-based products	0.37	0.57
Pangas catfish	Fish and seafood	1.20	1.20
Parsnips and similar-	Vegetables and vegetable products	0.31	0.44
Pasta and similar products	Grains and grain-based products	0.18	0.27
Pastry based on laminated dough	Snacks, desserts, and other foods	1.26	1.91
Peanut butter	Nuts and oilseeds	0.83	0.99
Peanuts	Nuts and oilseeds	0.76	0.91
Pears and similar-	Fruit and fruit products	0.21	0.40
Peas	Legumes	0.27	0.33
Peas (with pods) and similar-	Legumes	0.82	1.16
Peppers and similar-	Vegetables and vegetable products	0.34	0.48
Pig fresh meat	Pork	0.96	1.83
Potato crisps or sticks	Snacks, desserts, and other foods	0.61	1.08
Potato starch	Herbs, spices and condiments	0.57	0.57
Potatoes and similar-	Starchy roots and tubers	0.16	0.16
Poultry	Poultry	0.97	1.85
Preserved or partly preserved sausages	Processed meat	1.09	2.09
Preserved tomatoes not concentrated	Vegetables and vegetable products	0.16	0.23
Processed and mixed breakfast cereals	Grains and grain-based products	0.61	0.93
Processed cheese and spreads	Cheese	1.04	1.44
Quark	Dairy	0.35	0.48

Raisins	Fruit and fruit products	0.66	1.27
Rice	Grains and grain-based products	0.35	0.53
Rice crackers	Grains and grain-based products	0.92	1.31
Ripened cheese	Cheese	1.08	1.50
Rusk	Grains and grain-based products	0.58	0.87
Salad dressing	Herbs, spices and condiments	0.69	1.03
Salmon	Fish and seafood	2.73	2.73
Salt	Herbs, spices and condiments	0.94	1.40
Seasoning mixes	Herbs, spices and condiments	4.36	6.48
Shallots and similar-	Vegetables and vegetable products	0.49	0.69
Sheep fresh meat	Lamb	1.72	3.28
Shortcrust (pies -tarts)	Snacks, desserts, and other foods	0.90	1.37
Shrimps and prawns	Fish and seafood	2.43	2.43
Smoked salmon	Fish and seafood	3.29	3.29
Soft drinks	Beverages with added sugar	0.11	0.38
Sour cream products	Dairy	0.69	0.96
Soya drink	Dairy replacers	0.15	0.18
Spices	Herbs, spices and condiments	11.62	13.85
Spinach-type leaves	Vegetables and vegetable products	0.58	0.82
Sportdrink/energy drink	Beverages with added sugar	0.28	0.96
Spring onions and similar-	Vegetables and vegetable products	1.26	1.79
Sprouts, shoots and similar	Vegetables and vegetable products	1.79	2.54
Stock cubes or granulate (bouillon base)	Herbs, spices and condiments	0.02	0.03
Stone fruits	Fruit and fruit products	0.44	0.85
Strawberries and similar-	Fruit and fruit products	1.58	3.04
Sugars (mono- and di-saccharides)	Sugar and confectionery	0.11	0.18
Sweet corn and similar-	Vegetables and vegetable products	0.34	0.48
Sweet potato	Starchy roots and tubers	0.35	0.35
Syrups (molasses and other syrups)	Sugar and confectionery	1.43	2.28
Tea beverages	Tea	0.01	0.02
Tomato ketchup and related sauces	Herbs, spices and condiments	0.36	0.53
Tomato-containing cooked sauces	Vegetables and vegetable products	0.58	0.86
Tomatoes	Vegetables and vegetable products	0.43	0.61
Tree nuts (mixed nuts)	Nuts and oilseeds	2.06	2.46
Turnips and similar-	Vegetables and vegetable products	0.23	0.33
Unleavened or flat bread and similar	Grains and grain-based products	0.54	0.82
Unsweetened spirits and liqueurs	Alcoholic beverages	2.59	3.22
Vegetable fats and oils, edible	Fats and oils	0.51	0.71
Vinegar	Herbs, spices and condiments	0.62	0.93
Waffle	Snacks, desserts, and other foods	0.61	0.93
Water (bottled)	Drinking water	0.03	0.03
Water (unbottled)	Drinking water	0.00	0.00
Water-based ice creams	Snacks, desserts, and other foods	1.53	2.44
Wheat bread and rolls	Grains and grain-based products	0.33	0.49
White sauces	Herbs, spices and condiments	0.75	1.11
Whole eggs	Eggs and egg products	0.45	0.60
Wine, red	Alcoholic beverages	0.66	0.83
Wine, white and Sparkling	Alcoholic beverages	0.65	0.81
Witloof	Vegetables and vegetable products	0.84	1.19
Yeast leavened pastry	Snacks, desserts, and other foods	0.63	0.95
Yoghurt	Dairy	0.16	0.22
Tofu	Meat replacers	1.47	1.77

Annex D: Environmental properties

Table 26. Environmental properties of the current and optimised diets for adults

Environmental indicators	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
Acidification (kg SO_2 eq)	6.36*10^-2	4.69*10^-2	2.16*10^-2
Climate change (kg CO_2eq)	4.81	4.30	2.04
Ecosystem (species*yr)	6.55*10^-8	5.79*10^-8	3.36*10^-8
Freshwater eutrophication (kg P eq)	6.03*10^-4	5.85*10^-4	3.23*10^-4
Land use (m^2*a)	3.29	2.96	1.96
Land use change (kg CO_2eq)	0.67	0.59	0.38
Marine eutrophication (kg N eq)	1.04*10^-2	7.70*10^-3	4.05*10^-3
Water consumption (m^3)	0.11	0.16	0.08

Table 27. Environmental properties of the current and optimised diets for adolescents.

Environmental indicators	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
Acidification (kg SO_2 eq)	5.29*10^-2	4.54*10^-2	2.08*10^-2
Climate change (kg CO_2eq)	3.96	4.08	2.04
Ecosystem (species*yr)	5.41*10^-8	5.39*10^-8	3.41*10^-8
Freshwater eutrophication (kg P eq)	4.55*10^-4	4.97*10^-4	3.00*10^-4
Land use (m^2*a)	2.69	2.64	1.89
Land use change (kg CO_2eq)	0.59	0.60	0.38
Marine eutrophication (kg N eq)	8.44*10^-3	7.45*10^-3	3.82*10^-3
Water consumption (m^3)	0.08	0.14	0.12

Table 28. Environmental properties of the current and optimised diets for children.

Environmental indicators	Scenario 1: Current diet	Scenario 2: Nutrition optimised	Scenario 3: Nutrition & GHG optimised
Acidification (kg SO_2 eq)	4.08*10^-2	1.97*10^-2	1.61*10^-2
Climate change (kg CO_2 eq)	3.17	2.95	1.83
Ecosystem (species*yr)	4.21*10^-8	3.11*10^-8	2.50*10^-8
Freshwater eutrophication (kg P eq)	3.33*10^-4	4.12*10^-4	3.11*10^-4
Land use (m^2*a)	2.01	1.50	1.31
Land use change (kg CO_2 eq)	0.43	0.30	0.23
Marine eutrophication (kg N eq)	6.19*10^-3	3.59*10^-3	2.89*10^-3
Water consumption (m^3)	0.08	0.10	0.11

Annex E: Detailed results

The complete dataset containing all parameters describing the current and optimised diets can be found in a separate Zip-file. In these files, the nutritional and environmental properties of the food products are included, as well as the consumed amounts in the current and optimised diet. Several properties of the overall diet are presented, such as total intake of specific nutrients, total environmental impact (on different indicators) and total price.

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