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Analysis of food and environmental impacts as a scientific basis for Swiss dietary recommendations

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Abbreviations

EF	Environmental Footprint
FCN	Federal Commission for Nutrition
FOEN	Federal Office for the Environment
FSVO	Federal Food Safety and Veterinary Office
GHG	Greenhouse gas
ISO	International Organization for Standardisation
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
NCD	non-communicable diseases
SCN	Swiss Society for Nutrition
SDG	Sustainable development goals
UVEK	Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation (English: DETEC)
UZL	Umweltziele Landwirtschaft BAFU

Zusammenfassung "Analyse der Auswirkungen von Lebensmitteln auf die Umwelt als wissenschaftliche Grundlage für Schweizer Ernährungsempfehlungen"

Die Ernährung wirkt sich auf die menschliche Gesundheit und die natürliche Umwelt aus. Ihr Anteil an den Gesamtumweltbelastungen durch den Schweizer Endkonsum beträgt je nach Bewertungsmethode etwa 20-25%. Diese Umweltschäden wirken sich wiederum auch auf die menschliche Gesundheit aus. So führen z.B. Hitzeperioden im Sommer auf Grund der Klimakrise zu Todesfällen. Wenn sich Empfehlungen für die Ernährung nur auf einen der beiden Aspekte konzentriert, leiden sowohl die menschliche Gesundheit als auch die Umwelt. Daher werden in diesem Bericht, beide Aspekte der Ernährung zu vereint, um Nachhaltigkeit auf gesunde und umweltfreundliche Weise zu gewährleisten.

Vom Bundesamt für Lebensmittelsicherheit und Veterinärwesen (BLV) wurde im Jahr 2020 ein Projekt zur Anpassung der Schweizer Ernährungsempfehlungen in Auftrag gegeben. ESU-services ¨wurde für das Arbeitspakets 4 "Nachhaltigkeit" des Projekts "Ernährungsempfehlungen für die Schweizer Bevölkerung" beauftragt. Im Projektverlauf gab es u.a. unterschiedliche Meinungen über die Priorisierung von Gesundheits- und Nachhaltigkeitsaspekten und die Zusammenarbeit mit ESU-services wurde daraufhin vom Vertragspartner CHUV aufgekündigt.

Für ESU-services ist die Ökobilanzforschung zur umweltfreundlichen Ernährung seit 25 Jahren ein wichtiges Anliegen. Dieser Bericht und die darin enthaltenen Auswertungen wurden aus eigenen Mitteln der ESU-services auf Grundlage der langjährigen Erfahrung erarbeitet.

Der Bericht liefert eine wissenschaftliche Grundlage für die Überarbeitung der Ernährungsempfehlungen in der Schweiz. Die folgenden Schlüsselfragen werden beantwortet:

- Welche Umweltauswirkungen haben verschiedene Lebensmittel und welche haben besonders hohe Umweltauswirkungen?
- Welche Synergien oder Zielkonflikte bestehen zwischen Gesundheit und ökologischer Nachhaltigkeit bei der Ernährung? Wie können die Zielkonflikte gelöst werden?
- Welche Ergebnisse zu Synergien und Zielkonflikten sind für die Schweiz von Bedeutung und sollten bei der Überarbeitung der Ernährungsempfehlungen berücksichtigt werden?

Um die Umweltauswirkungen von Lebensmitteln (Konsum) zu bewerten, wird eine Ökobilanz (LCA) für eine Liste von Lebensmittelgruppen durchgeführt. Die Bewertung der Umweltbelastungen wird mit der Schweizer Methode der ökologischen Knappheit 2021 durchgeführt. Die Ökobilanz umfasst die Produktion, die Verarbeitung, den Transport, die Lagerung und den Vertrieb bis hin zum Supermarkt.

Um die Umweltauswirkungen der Lebensmittel zu bewerten, werden verschiedene funktionelle Einheiten gewählt, um die unterschiedlichen Ernährungsfunktionen der untersuchten Lebensmittel abzudecken. Die Umweltauswirkungen werden pro 100 g, pro 100 kcal und pro Nährwert des Lebensmittels berechnet.

Bei Verwendung der Masse als funktionelle Einheit führen tierische Produkte und Ölprodukte zu den höchsten Umweltauswirkungen der betrachteten Lebensmittel. In Bezug zu Kalorien haben vor allem Fleischprodukte und Fisch im Vergleich zu den anderen Lebensmittelgruppen hohe Auswirkungen.

Für jeden Nährwert werden spezifische Arten von Lebensmitteln aufgezeigt, die die in den Ernährungsempfehlungen empfohlene Tageszufuhr umweltfreundlich decken können. Der tägliche Bedarf

an Proteinen kann beispielsweise durch Getreide gedeckt werden, ohne die hohen Umweltauswirkungen des Fleischkonsums zu verursachen.

Mit den Ergebnissen der Ökobilanz der Lebensmittel werden für alle in dieser Studie untersuchten Produktgruppen von Lebensmitteln Konflikte und Synergien zwischen Gesundheit und ökologischer Nachhaltigkeit beschrieben. Die meisten Konflikte können durch die Verwendung alternativer Produkte gelöst werden. So können beispielsweise tierische Produkte durch Fleischersatzprodukte oder andere pflanzliche Produkte ersetzt werden, um eine bestimmte Ernährungsfunktion zu erfüllen.

Die Umweltauswirkungen hängen stark von der Produktion, der Verarbeitung, des Transports, der Lagerung usw. ab, selbst bei ähnlichen Lebensmitteln. Um das Verständnis dafür zu verbessern, wie diese Aspekte die Umweltauswirkungen beeinflussen, werden die Ergebnisse der Studie durch eine Diskussion über die verschiedenen Phasen des Lebenszyklus der Lebensmittel unterstützt. Die landwirtschaftliche Produktion hat dabei in der Regel die größten Auswirkungen während des gesamten Lebenszyklus von Lebensmitteln.

Aus den Ergebnissen der Ökobilanz für Lebensmittel und der Diskussion der Lebenszyklusphasen werden Verbesserungspotenziale für die Produktion und den Konsum von Lebensmitteln aufgezeigt. Auf der Produktionsseite kann eine Verringerung der Umweltauswirkungen durch eine umweltfreundlichere Anpassung der Produktionsprozesse erreicht werden. Dies kann entweder durch politische Maßnahmen oder durch eine Änderung des Konsumverhaltens der Verbraucher erfolgen. Die Reduzierung des Konsums von tierischen Produkten weist das größte Reduktionspotential auf. Um eine ausreichende Versorgung mit Nährstoffen zu gewährleisten, kann die empfohlene Tagesdosis durch Fleischersatzprodukte oder einfache pflanzliche Produkte abgedeckt werden. Bei pflanzlichen Produkten helfen der Verzehr von saisonalen und lokalen Produkten sowie die Reduzierung energieintensiver Verarbeitungsschritte und Verpackungen, Umweltschäden zu vermeiden. Die Minimierung von Lebensmittelabfällen ist eine weitere Option im Lebenszyklus von Lebensmitteln, durch die eine Verringerung der Umweltauswirkungen erreicht werden kann, ohne dass gesundheitliche Aspekte in Frage gestellt werden. Schließlich ist die Reduzierung des übermäßigen Konsums eine wirksame Maßnahme zur Verringerung der Umweltauswirkungen und zur Verbesserung der menschlichen Gesundheit.

Als Schlussfolgerung enthält der Bericht eine angepasste Version der Schweizer Ernährungsempfehlungen, die die in dieser Studie erarbeiteten Nachhaltigkeitsaspekte beinhalten. Die bisherigen Ernährungsempfehlungen wurden mit diesen Informationen dieser Studie aktualisiert und werden in Tabelle 1 pro Produktgruppe zusammengefasst.

Während wir an diesen Empfehlungen arbeiteten, erkannten wir, dass es notwendig ist, verschiedene Zielgruppen in der Bevölkerung mit unterschiedlichen Ernährungsanforderungen spezifischer zu informieren. Insbesondere für die täglichen einzelnen Nährstoffe scheinen empfohlene Aufnahmen teilweise höher zu sein als das, was mit einer normalen Ernährung erreicht werden kann. Daher müssen diese Empfehlungen weitere Überarbeitungen und Anpassungen an die Bedürfnisse von z. Kind, Frauen, Männer, ältere Menschen, aktiv oder andere Bevölkerungsgruppen.

Tabelle 1: Ernährungsempfehlungen mit Hinweise zur besseren Berücksichtigung von Nachhaltigkeitsaspekten (rot markiert).

Kategorie	Portionen	Bevorzugte Optionen
 Süßigkeiten, gesüßte Getränke, andere Genussmittel & Alkohol	1 Stück Zucker 10g Schokolade 1 Tasse Kaffee 3 dl Bier 1 dl Wein	Nur zu besonderen Anlässen und in Maßen genießen
 Öle, Fette & Nüsse	2-3 Esslöffel Pflanzenöl 20-30g Nüsse/Samen 10g Butter, Margarine, Sahne	Mindestens die Hälfte des Pflanzenöls sollte Rapsöl sein. Hochwertige Öle (Oliven, Weizenkeime, ..) sollten nicht zum Braten/Rösten verschwendet werden. Öle sollten in umweltfreundlichen Flaschen verpackt sein (keine schweren Glasflaschen).
 Milchprodukte, Fleisch, Fisch, Eier & Tofu	150-200g Joghurt / Quark / Hüttenkäse 30 g Hartkäse / pflanzliche Alternative 60 g Weichkäse / pflanzliche Alternative 150-200 g Quark / Hüttenkäse / pflanzliche Alternative 2-3 Eier 100-120g Fleisch / Fisch / pflanzliche Alternativen	3 Milchprodukte oder pflanzliche Getränke mit Kalziumzusatz 1 proteinreiches Lebensmittel vorzugsweise mit pflanzlichen Proteinen (z.B. aus Soja, Erbsen, Molke). Ausgewogene Auswahl aller Arten von Fleischprodukten (mager, fettarm, fettreich, verarbeitet), um Lebensmittelverschwendung zu vermeiden. Maximal einmal im Monat Fisch.
 Getreide, Kartoffeln & Hülsenfrüchte	75-125g Brot / Gebäck 60-100g Hülsenfrüchte 180-300g Kartoffeln 45-75g Cracker/Mehl/Nudeln/Reis/Mais/Getreide	Vollkornprodukte
 Gemüse und Obst	120g/ 2dl	3 Gemüse, 2 Früchte, Saft kann 1 Portion ersetzen Beste Wahl: saisonal angebautes Obst und Gemüse Wenn lokale, saisonal angebaute, konservierte oder tiefgekühlte Lebensmittel nicht verfügbar sind, sollten per Schiff, Zug oder LKW importierte Lebensmittel bevorzugt werden. Keine Produkte aus beheizten Gewächshäusern oder aus dem Lufttransport.
Getränke 	1-2 l	Leitungswasser, Kräutertee & in Maßen: Säfte aus saisonal angebauten Früchten oder Konzentrat.

Wir sehen nachhaltige Entwicklung als einen gemeinsamen Prozess. In diesem Sinne nehmen wir Rückmeldungen und Anregungen zu diesem Bericht gerne entgegen, um ihn zu gegebener Zeit zu überarbeiten.

Summary: “Analysis of food and environmental impacts as a scientific basis for Swiss dietary recommendations”

Nutrition has an impact on human health and the natural environment. Its share of the total environmental impact of Swiss final consumption is about 20-25%, depending on the assessment method. This environmental damage in turn also affects human health. For example, periods of heat in summer lead to deaths due to the climate crisis.

If nutritional recommendations are only focusing on one of the two aspects, both, human health and the environment suffer. Therefore, this report tries to merge both aspects of nutrition, to ensure sustainability in a healthy and environmentally friendly way.

The Federal Food Safety and Veterinary Office (FVSO) initiated in 2020 a revision of the Swiss dietary recommendations. ESU-services was commissioned for the lead of the “sustainability” in work package number 4 of the project “Dietary recommendations for the Swiss population”. During the project, there turned out to be different opinions about the prioritisation of health and sustainability aspects and the cooperation with ESU-services was terminated by the commissioner CHUV without payment for the planned report.

For ESU-services, life cycle assessment research on environmentally friendly nutrition has been an important concern for 25 years. The report and the evaluations were therefore compiled from ESU-services' own resources based on this long-term experience.

The report provides a scientific basis for the dietary recommendations in Switzerland. The following key questions are answered:

- What is the environmental impact of different foods and which ones have particularly high environmental impacts?
- What synergies or conflicting goals exist between health and environmental sustainability in terms of nutrition? How can the conflicting goals be solved?
- Which results regarding synergies and conflicting goals are of importance for Switzerland and should be considered in the revision of the nutritional recommendations?

To evaluate the environmental impact of food (consumption), a life cycle assessment (LCA) is performed on a list of food items. The impact assessment is conducted using the ecological scarcity 2021 method. The LCA includes the production, processing, transport, storage, and distribution up to and including the supermarket.

To assess the environmental impact of the food items, different functional units are chosen to cover the different nutritional functions of the studied food items. Environmental impacts are calculated per 100 g, per 100 kcal and per nutritional value of the food.

When using mass as the functional unit, animal products and oil products lead to the highest environmental impacts of the considered food items. Concerning their calorific value, especially meat products and fish lead to high impact compared to the other food groups.

For each nutritional value specific types of food are pointed out which can cover the recommended daily intake in a relatively environmentally friendly way. The daily demand of proteins for example can be covered by grains without causing the high environmental impacts of meat consumption.

With the results from the impact assessment of the food items, conflicts and synergies between health and environmental sustainability are described for different food items covered in this study. Most of

the conflicts between health and environment can be solved by using alternative products. Concerning for example animal products, they can be replaced with meat substitutes or other plant products to cover a certain nutritional function.

The environmental impact strongly depends on the way of production, processing, transportation, storage etc., even for similar food products. To increase the understanding on how these aspects influence environmental impact, the results from the LCA are supported by a discussion on the distinct phases of the life cycle of the food products. The relevance matrix shows that for most product groups. The agricultural production has the highest impact throughout the life cycle of food products.

From the results of the LCA on food items and the discussion on its life cycle phases, improvement potentials for the production and consumption of food are pointed out. On the production side, reduction of environmental impact can be achieved by the adaption of production processes in an environmental friendlier way. Either this is implemented through policy measures or through a change in consumption behaviour of the consumer. Reducing the consumption of animal products shows the highest reduction potential. To ensure sufficient provision of nutrients, their daily recommended intake can be covered with meat substitutes or other plant-based products. For plant-based products, consuming seasonal and local products, and reducing energy intensive processing steps and packaging help to prevent environmental damage. Minimizing food waste is the last point in the life cycle of food where reduction potential for environmental impact is contained without conflicting health aspects. Finally, reducing overconsumption is an effective measure to reduce environmental impact and improve human health.

As a conclusion, the report provides an adapted version of the Swiss nutritional recommendations containing the sustainability aspects which were elaborated by ESU-services in this study. The proposed revisions for the Swiss recommendations according to this report are shown in Tab. 5.1.

While working on these recommendations we also recognized that it might be necessary to better address different target groups in the population with different nutritional demands. Especially for the single nutrients daily recommended intakes seem to be partly higher than what can be achieved with a normal diet. Thus, these recommendations need further revisions and adaptation to the needs of e.g. Childs, women, men, elderly, active, or other groups of population.

Tab. 1.1 Nutritional recommendations, including the sustainability aspects discussed in this report. Clarifications for better consideration of sustainability aspects marked in red.

Category	Portions/ day	Portion size	Preferred options
Sweets, sweetened beverages, luxury foods & alcohol	0	1 piece of sugar 10g chocolate 1 cup of coffee 3 dl Beer 1 dl wine	Enjoy only on special occasions and in moderation
Oils, fats & nuts		2-3 Tbsp vegetable oil 20-30g nuts / seeds 10g butter, margarine, cream	At least half the vegetable oil should be rape seed oil High value oils (olive, wheat germ, ..) should not be wasted for frying/roasting. Oils should be packed in environmentally friendly bottles (no heavy glass bottles).
Milk products, meat, fish, eggs & tofu	4	2dl plant drink / milk 150-200g yoghurt / quark/ cottage cheese 30g hard cheese / plant-based alternative 60g soft cheese/ plant-based alternative 150-200g quark /cottage cheese / plant-based alternative 2-3 eggs 100-120g seitan / tofu / meat / fish / Quorn / plant-based alternatives	3 milk products or plant-based drinks with calcium supplement 1 protein-rich food preferably with plant proteins (e.g. from soy, peas, whey). Balanced choice of all types of meat products (lean/low-fat, fatty, processed) to avoid food waste. Fish maximum once a month.
Grains, potatoes & legumes	3	75-125g bread / pastry 60-100g legumes 180-300g potatoes 45-75g crackers/ flour/ pasta/ rice / corn / grains	Wholemeal products
Vegetables & fruit	5	120g/ 2dl	3 vegetables, 2 fruit, juice can replace 1 portion Best choice seasonally grown fruits and vegetables If local seasonally grown, canned, or deep-frozen foods is not available food imported by ship, train, or truck should be preferred. No products from heated greenhouse or air-transported
Beverages		1-2 l	Tap water, herbal tea & in moderation: juices from seasonally grown fruits or concentrate

We see sustainable development as an ongoing and discursive process. Therefore, we are happy to receive comments and suggestions for improvement for a possible revision of this report.

Overview on this study

The following Tab.1.2 shows the key characteristics for this report.

Tab.1.2 Key characteristics of the project

Title	Analysis of food and environmental impacts as a scientific basis for Swiss dietary recommendations
Authors	Niels Jungbluth, Martin Ulrich, Karen Muir, Christoph Meili, Maresa Bussa, Samuel Solin, ESU-services Ltd.
Commissioner	ESU-services GmbH
Products and variants investigated	Food consumption in Switzerland and foods items (groups of single foods) defined for this report
Scenarios	None
Functional unit or declared unit	Impacts are calculated per weight (100g) and nutritional value (e.g. kcal).
Scope	Life cycle from cradle-to-supermarket including agricultural production, processing, packaging, distribution, and intermediate transport. Not including transport from supermarket, cooking at home, household food waste etc.
Location	Situation for the supply in Switzerland is considered. Import mixes are not calculated if not yet available. For products produced in Switzerland, the goal is to determine the impacts of Swiss primary production. Foreign products are investigated with the data easily available (GLO mix or country specific) data without further research on real import mixes.
Key questions of the study	• What is the environmental impact of different food items and which ones have particularly high environmental impacts? • What synergies or conflicting goals exist between health and environmental sustainability in terms of nutrition? How can the conflicting goals be solved? • Which results regarding synergies and conflicting goals are of importance for Switzerland and should be considered in the revision of the nutritional recommendations?
Standard to be applied	Based on ISO 14040/44 (International Organization for Standardization (ISO) 2006a, b).
Product category rules	None
Comparative study	Yes
Publication	Yes
LCA software	SimaPro 9 (SimaPro 2023)
Background databases[1]	Background data: ESU database (ESU-services 2024b) Food data in the following priorities: 1. ESU database for food production and consumption (ESU-services 2024a) 2. Global WFLDB database (Nemecek et al. 2015) 3. French Agribalyse (Koch et al. 2015) database for some food products not found in the other databases 4. Dutch Agri-footprint (Blonk Agri-footprint BV 2022)
Foreground data	Modelling by ESU-services and documented within ESU database for food production and consumption (ESU-services 2024a)
Life cycle impact assessment (LCIA)	Eco-points according to the Ecological Scarcity Method (BAFU 2021) Global Warming Potential according to IPCC (IPCC 2021) for a time horizon of 100 years including the additional effect from air transport (Jungbluth & Meili 2019) European environmental footprint method (Sala et al. 2018)
Internal validation	Internal validation by LCA experts at ESU-services.

1 Further information about the databases ESU-services uses in its projects can be found on the webpage on https://esu-services.ch/address/tender/

1 Introduction

In Switzerland, around 30% of the total environmental impact results from food purchases (Jungbluth et al. 2011). Food systems emit greenhouse gases (GHG) and other pollutants at all stages of the life cycle, from agricultural production to manufacturing, storage and distribution by the food industry as well as food preparation, consumption, and waste disposal by individuals.

Recent evidence shows that diets based on dietary guidelines have a significant environmental impact (Springmann et al. 2020); hence, a compromise between health and environmental sustainability must be found to achieve the best of both worlds. For instance, reducing the consumption of meat and dairy products may reduce environmental impact, yet be accompanied by nutritional challenges for selected nutrients (Millward & Garnett 2010). In France, for example, diets of high nutritional quality were not necessarily associated with low environmental impact (Vieux et al. 2013). When considering the sustainability of foods, it is important to consider their nutritional value as well as environmental and social impacts (Werner et al. 2014).

1.1 Original project goals

The Federal Food Safety and Veterinary Office (FVSO) commissioned a consortium coordinated by the Centre Hospitalier Universitaire Vaudois (CHUV) to provide the scientific basis for the Swiss dietary recommendations update. ESU-services was responsible for leading the working group on environmental aspects. The following goals were set:

- The influence of food on the development of NCDs (non-communicable diseases) is shown with the help of the FCN report (Federal Commission for Nutrition) and more recent literature.
- International dietary recommendations are presented as a table, and differences and similarities are shown.
- Foods that are relevant for the population in Switzerland should be part of the Swiss dietary recommendations and are defined and justified.
- The impact of food on the environment is shown with the help of life cycle assessments (LCA). Synergies and trade-offs between healthy and ecologically sustainable nutrition are presented by ESU-services based on current literature.
- Environmental data for further use in a statistical model are elaborated by ESU-services.

This report was planned as part of "work package 4: Link between food and environmental impacts", which addresses the fourth goal of the project (The impact of food on the environment is shown with the help of LCA. Synergies and trade-offs between healthy and ecologically sustainable nutrition are presented based on current literature). The methodology, results, and interpretation of the life cycle assessment are described in this report.

1.2 Health damages due to environmental pollution and nutrition-related diseases

Healthy and sufficient nutrition as well as environmentally sustainable nutrition are highly interconnected, and they should not be considered exclusively. The consumption of "healthy" but environmentally unsustainable food could as well be considered "unhealthy" - maybe not on an individual level, but on a broader, global scale. Fig. 1.1 shows the estimated global deaths per year from dietary risks, environmental pollution and malnutrition in the year 2017 (Stanaway et al. 2018), and as a reference, deaths due to COVID-19[2] in the years 2020 and 2021. Environmental pollution is a relatively common cause of death. As nutrition contributes a major share to the environmental impacts of consumption (see chapter 3.1.2), it can be argued, that an individually healthy but ecologically unsustainable nutrition could also be unhealthy. Furthermore, overconsumption in some parts of the population and malnutrition in other parts is another conflict. The nutritional situation in Switzerland is good and major health impacts arise from malnutrition (e.g. to much fat, calories, sugar, salt) and not from nutrient deficits. This study tries to find synergies between these different fields and provide data to evaluate nutrition on this broader scale. On the other side we refrain from over-optimising nutritional recommendations on the expense of increased environmental impacts.

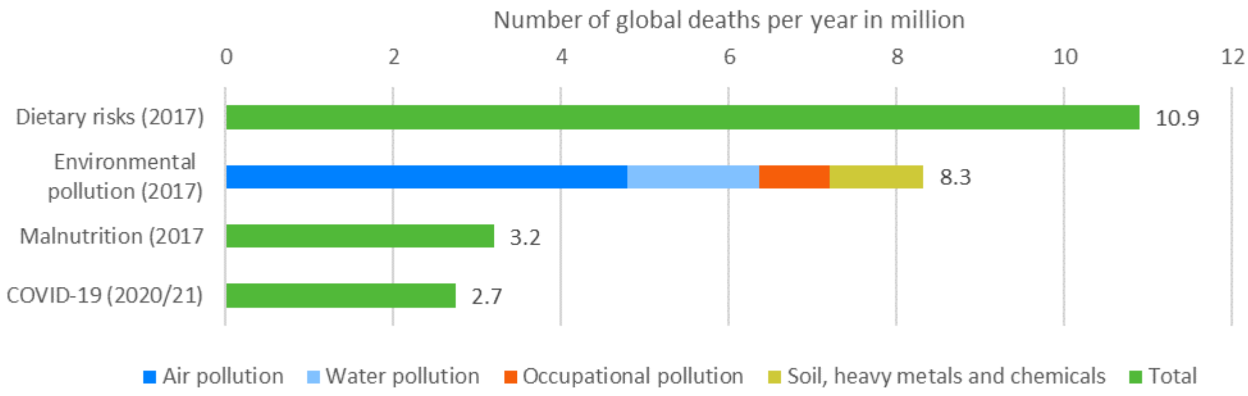


Fig. 1.1 Global estimated death per year in millions from dietary risks, environmental pollution and malnutrition in the year 2017 (Stanaway et al. 2018), as well as deaths due to COVID-19[2] in the years 2020 and 2021. For environmental pollution, the total amount of deaths is shown for the different pollution risk factors.

1.3 Questions and ambitions set by Federal stakeholders

The FSVO initiated a project that identifies synergies and trade-offs regarding healthy and sustainable nutrition in Switzerland and makes proposals how they can be considered in the revision of the nutrition recommendations.[3]

During the project, ambitions by the FSVO were than formulated as[4] "… *that the update of the Swiss dietary recommendations focuses on a balanced diet to promote health and prevent non-communicable diseases. Sustainability (ecological) is one aspect of this and will be considered as long as sustainability does not lead to conflicting goals with health.*"

The authors of this report consider a limited focus for nutritional aspects and deprioritisation of indirect health effects in dietary recommendations given by the Swiss authorities to be insufficient.[6] A sustainable development needs to consider all aspects in a reasonable manner and cannot put one goal above the others. Therefore, despite the deprioritisation, the environmental aspects of nutrition are discussed in this report in the necessary detail.

2 Average of the sum of global deaths due to COVID-19 from the year 2020 and 2021. Retrieved from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases, 19.01.2022

3 https://www.blv.admin.ch/blv/de/home/lebensmittel-und-ernaehrung/ernaehrung/empfehlungen-informationen/schweizer-lebensmittelpyramide.html

6 https://www.tagesanzeiger.ch/lebensmittelpyramide-zu-wenig-oeko-150038815584

6 https://www.tagesanzeiger.ch/lebensmittelpyramide-zu-wenig-oeko-150038815584

6 https://www.tagesanzeiger.ch/lebensmittelpyramide-zu-wenig-oeko-150038815584

Therefore ESU-services investigate the link between the Swiss food system, dietary recommendations, and sustainable recommendations in this report independently from the original project and only with own funds. This report aims to propose initial solutions for conflicting objectives.

1.4 Definition of food items

As part of the work a list of food items covering the full range of foods relevant from an environmental and individual human health point of view was defined. The aim was to include all relevant basic foods, while highly processed foods and mixed dishes were not considered directly.

In order to match the two project goals of investigating the environmental impacts from field to shop and limiting the list of life cycle inventories to 30-50, ESU-services based the whole discussion on a list of food items which on the one side groups single foods according to the type of products (e.g. vegetables, meat, milk), but also already considers possible issues from an environmental point of view (e.g. distinction of animal milk and plant drinks), or nutritional issues (e.g. the content of relevant nutrients in fish).

The list was compiled by ESU-services, and on the current version of the food pyramid of the Swiss Society for Nutrition (SCN), while considering environmental relevance and LCI data availability.

1.5 Methodology for assessing environmental impacts

The environmental analysis of the food items was carried out using life cycle assessment (LCA). LCA is a method used to assess the environmental impacts of products or services. It usually considers the whole life cycle, evaluating the environmental impacts from cradle to grave, which means from resource extraction to the disposal of the product, including any waste generated during production. Further information can be found in Annex B.

2 Goal and Scope

The first step of any LCA is to define and describe the goal and scope of the study. In general, methodological choices were taken in accordance with the ecoinvent database (Frischknecht et al. 2007a). The goal and scope definition includes a description of:

- the goal of the study, including the intended audience and application of the results of the study,
- the product system,
- the functional unit,
- the system boundaries,
- allocation (if necessary),
- the environmental indicators and impact assessment methods applied,
- data sources,
- assumptions and limitations,
- critical review

2.1 Key questions

Based on the technical specifications, the goals in view of nutritional recommendations were to answer the following questions:

1. What is the environmental impact of different foods and which ones have particularly high environmental impacts?
2. What synergies or conflicting goals exist between health and environmental sustainability in terms of nutrition? How can the conflicting goals be solved?
3. Which results regarding synergies and conflicting goals are of importance for Switzerland and should be considered in the revision of the nutritional recommendations?

2.2 Scope

2.2.1 Product system

The system analysed includes the food items defined by ESU-services. It is available as part of the ESU food database. The items were determined to represent the basic foods consumed in Switzerland that are relevant from an environmental and individual health perspective.

Fig. 2.1 shows the current version of the food pyramid of the Swiss Society for Nutrition[7], along with the main function of each category and the analogous categories determined in the project.

[7] https://www.sge-ssn.ch/ich-und-du/essen-und-trinken/ausgewogen/schweizer-lebensmittelpyramide/

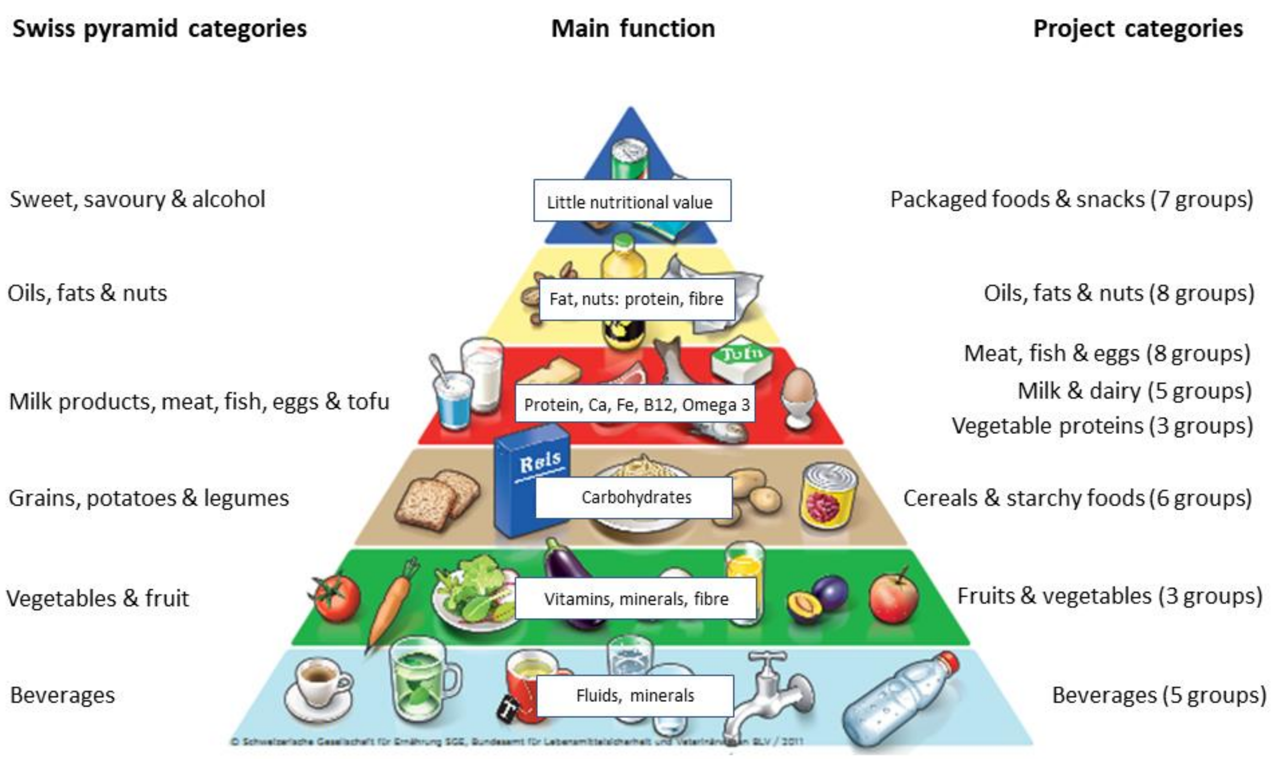


Fig. 2.1 The food pyramid of the Swiss Society for Nutrition with the main function of each category and the corresponding categories. More detail on the groups within each category can be found in the complete list of food items and are described in more detail in Chapter 3.

The nutritional recommendations according to the latest version of the food pyramid of the Swiss Society for Nutrition pyramid are shown in Tab. 2.1.

Tab. 2.1 Nutritional recommendations according to the latest version of the food pyramid of the Swiss Society for Nutrition[5]

Category	Portions/ day	Portion size	Preferred options
Sweet, savoury & alcohol			Enjoy in moderation
Oils, fats & nuts		2-3 Tbsp vegetable oil 20-30g nuts / seeds 10g butter, margarine, cream	At least half the vegeta-ble oil should be rape seed oil
Milk products, meat fish, eggs & tofu	4	2dl milk 150-200g yoghurt / quark/ cottage cheese 30g hard cheese 60g soft cheese 100-120g meat /fish/ tofu/ seitan / Quorn 2-3 eggs	3 milk products 1 protein-rich food
Grains, potatoes & leg-umes	3	75-125g bread / pastry 60-100g legumes 180-300g potatoes 45-75g crackers/ flour/ pasta/ rice / corn / grains	wholemeal
Vegetables & fruit	5	120g/ 2dl	3 vegetables, 2 fruit, juice can replace 1 portion
Beverages		1-2 l	Water, fruit & herbal tea

This study considers the life cycle of the food items including the following life cycle stages:

- Agricultural production
- Food processing
- Packaging
- Distribution in the supermarket
- Intermediate transports

All known inputs and outputs were considered in these life cycle stages, and the authors are confident that the most relevant aspects were included.

Fig. 2.2 shows the product system of the study.

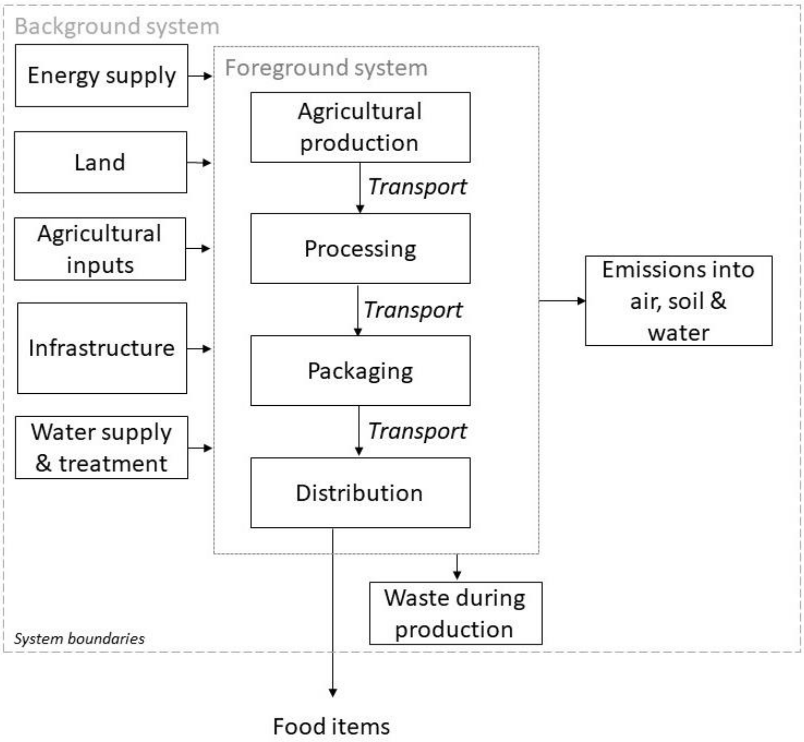


Fig. 2.2 Product system for the LCA of food items

For this report we focus on dietary choices and not on possible improvement options in the agricultural production which might be indicated by labels like integrated or organic production. Therefore, the analysis focuses on state-of-the-art production in Switzerland (often according to integrated production or Ökologischer Leistungsnachweis).

A comparison between different production patterns like organic, integrated, or conventional production is not in the focus of this report. As known from several studies there are often no general conclusions regarding the advantages and disadvantages of organic vs conventional production. The outcome also depends on value choices on the weighting of different environmental aspects.

2.2.2 Functional unit

As part of the goal and scope, the functional unit for which the environmental impacts are quantified is defined. Generally, several definitions for a functional unit can be found in LCA studies for food products. Often quite different products e.g. a beef and vegan burger, are compared just on the basis of mass. This might give wrong incentives for an unhealthy but more environmentally friendly nutrition if the content of nutrients differs considerable.

Another easy to apply measurement is the impact per energy content (kcal) of food. This reflects the main purpose of satisfying the hunger with the food. On the other side it can be argued that in Western societies there is often an overconsumption and thus the energy content is not the limiting factor for a healthy diet. It might even be a disadvantage to consume as much energy as possible for the lowest impact if this leads to overweight in the population. These two functional units were defined during the planning stages of the project:

- 100 g of food item at the supermarket
- 100 kcal of food item at the supermarket

Other options to compare food is e.g. per portion or per meal. This reflects also how consumer might plan their food intake and which food items might be seen as interchangeable.

In a comparative LCA at least information about the content of main nutrients relevant for the specific product group should be provided to allow the reader to judge if different options really can be perceived as equal for the intended function in the diet.

A further option would be to compare only products which from the nutritional quality have a comparable rating. For this e.g. the nutri-score rating might be applied and only products from one group with the same nutri-score can be compared. This was not fully applicable here due to lack of information.

The main function of food is to provide nutrients, many of which cannot be determined from weight or energy content. It was therefore deemed necessary to apply other functional units in this study. The main conflict seems to be the provision of nutrients with animal products, which often show a quite high environmental impact. Therefore, the following nutrients that are difficult to get without meat and animal products are investigated in more detail[8]:

- 64 g protein at the supermarket[9]
- 4 µg vitamin B12 at the supermarket
- 1.5 g omega-3 fatty acids[10] at the supermarket
- 1 g of calcium at the supermarket
- 15 mg iron[11] at the supermarket
- 150 µg iodine at the supermarket
- 14 mg zinc[12] at the supermarket
- 1.4 mg riboflavin (vitamin B2)[9] at the supermarket
- 15 µg vitamin D at the supermarket
- 70 µg selenium at the supermarket

[8] https://www.sge-ssn.ch/media/Merkblatt-Vegane-Ernaehrung-2021.pdf
[9] Represents the recommended daily intake for a person weighing 80 kg
[10] Represents 0.7% of energy intake of a 2000 kcal diet
[11] Represents the recommended daily intake for women between 19-51 years old, the recommended intake for men is lower
[12] Represents the recommended daily intake for men, the recommended intake for women is lower

These values represent the recommended daily intake for adults. Swiss reference values[13] were applied if available and DACH reference values[14] were used otherwise. The higher value was applied when recommendations differ for men and women. These nutrients are of particular importance as it can be difficult to meet the recommended daily intake when following a diet without or with a reduced intake of meat and animal products, which is often recommended to reduce the environmental impact of food consumption.

The amount of nutrients in different food items has been evaluated from different data sources[15]. The basic data are shown in Tab. 2.2.

Tab. 2.2 Portion size, share of edible parts and nutrients considered for the food items

Food items WP4 (Sustainability)	Edible part	Unit	Portion size	100 kcal energy	64 g protein	4 µg vitamin B12	1.5 g omega-3 fatty acids	1 g of calcium	15 mg iron	150 µg iodine	14 mg zi	1.4 mg riboflavin (vitamin B2)	15 µg vitamin D	70 µg selenium
Zielwert	CH	100		100	64	4	1.5	1000	15	150	14	1.4	15	70
	2021				1									
	%	g	g	kcal	g	µg	g	mg	mg	µg	mg	mg	µg	µg
Milk for drinking	100%	100	200	62	3.20	0.2	0.8	120.0	-	9.7	0.4	0.2	0.1	1.2
Yogurt	100%	100	100	84	3.93	0.3	0.7	125.8	0.1	7.3	0.5	0.2	0.1	-
Fresh cheese	100%	100	30	217	14.18	0.7	4.2	259.8	0.1	13.5	1.2	0.3	0.2	-
Cheese - soft	100%	100	30	325	19.40	1.5	6.5	440.0	0.2	17.0	2.2	0.4	0.4	-
Cheese- hard	95%	100	30	375	25.31	1.5	6.9	823.7	0.3	25.9	3.6	0.4	0.5	-
Red Meat - Beef, Veal, Lamb, Pork, horse	90%	100	110	153	22.71	5.1	2.9	9.5	2.2	2.5	3.9	0.3	1.7	7.9
Poultry	100%	100	110	145	23.36	0.5	2.6	7.5	0.6	6.1	1.1	0.2	1.0	19.7
Processed meats	100%	100	110	311	19.04	1.5	11.9	11.7	2.1	1.6	2.4	0.2	0.5	9.8
Fish, omega-3 poor	100%	100	110	113	21.62	3.1	0.8	26.0	0.9	87.4	0.7	0.1	2.2	25.3
Shellfish	100%	100	110	79	14.03	2.6	0.5	34.4	1.7	107.4	1.7	0.1	-	-
Fish, omega-3 rich	100%	100	110	171	19.50	6.0	3.7	11.8	0.6	43.2	0.4	0.1	7.6	-
Eggs	95%	100	110	140	12.60	1.3	3.7	48.0	1.8	39.0	1.2	0.3	1.8	21.0
Legumes	100%	100	60	338	25.82	-	1.2	108.0	6.4	1.9	3.3	0.2	-	-
Meat subsitutes, vegan, minimally processed	100%	100	110	221	28.82	0.0	2.1	74.0	2.9	3.5	1.1	0.0	-	39.7
Meat subsitutes, vegan, highly processed	100%	100	110	199	17.88	0.7	6.3	46.0	2.8	-	-	-	-	-
Egg-based meat alternatives	100%	100	110	129	13.67	0.6	1.8	48.0	1.0	-	7.6	-	-	-
Milk alternatives	100%	100	200	42	1.58	0.2	0.4	88.3	0.2	11.1	0.2	0.0	0.4	20.0
Grains	100%	100	60	319	12.32	-	1.8	41.0	4.9	2.3	4.1	0.1	-	-
Bread	100%	100	100	264	9.20	0.0	1.0	29.0	1.5	2.7	1.2	0.1	0.1	2.9
Crackers	100%	100	30	469	8.62	0.1	8.5	60.6	1.7	4.4	1.1	0.2	0.2	3.2
Flour	100%	100	60	342	12.15	-	0.2	20.7	2.3	1.7	2.0	0.1	-	3.8
Rice	100%	100	60	353	7.43	-	0.5	24.9	0.6	2.1	1.5	0.0	-	13.0
Pasta	100%	100	60	352	12.83	-	0.3	26.3	2.8	1.9	1.9	0.1	-	68.5
Potatoes & other Tubers	100%	100	240	76	2.00	-	-	6.0	0.4	4.0	0.3	0.1	-	-
Polenta	100%	100	60	350	8.80	-	0.4	4.0	1.0	2.5	0.4	0.0	-	-
Vegetable fats	100%	100	10	724	0.40	0.1	37.3	10.0	0.1	1.5	-	0.0	5.0	-
vegetable oils, omega 3 rich	100%	100	10	810	-	-	38.5	0.3	-	-	0.0	-	-	-
vegetable oils, omega 3 poor/ other oils	100%	100	10	852	0.40	-	16.9	1.5	0.1	-	-	-	-	-
vegetable oils, omega 9 rich	100%	100	10	810	-	-	67.6	-	0.1	0.1	-	-	-	-
Animal fats (Butter)	100%	100	10	692	1.53	0.1	18.4	39.0	-	3.8	0.3	0.0	1.4	0.3
Nuts & Seeds	100%	100	25	590	18.89	-	20.8	147.5	3.8	5.6	3.7	0.2	-	29.6
Olives	100%	100	25	165	1.35	-	10.7	69.0	4.4	3.3	0.1	-	-	-
Avocados	70%	100	120	144	1.80	-	8.9	16.0	1.0	1.0	0.6	0.2	-	-
Cream	100%	100	30	303	2.26	0.3	7.4	77.1	0.1	12.7	0.3	0.2	0.4	-
Cream alternatives	100%	100	30	195	2.50	-	16.0	11.0	2.0	-	-	-	-	-
Fruits	90%	100	120	57	0.70	-	-	15.0	0.3	1.2	0.1	0.0	-	-
dried Fruits	100%	100	30	280	2.70	-	0.3	63.0	2.1	4.6	0.6	0.1	-	-
Vegetables	90%	100	120	26	1.30	-	-	27.0	0.4	2.6	0.2	0.1	-	-
Salad	90%	100	120	14	1.30	-	-	31.0	0.4	3.3	0.2	0.1	-	-
Mineral water	100%	100	200	-	-	-	-	19.3	-	2.3	-	-	-	0.1
tap water	100%	100	200	-	-	-	-	7.0	-	-	-	-	-	-
Tea	100%	100	5	-	-	-	-	-	-	1.0	-	-	-	-
Coffee	100%	100	7	253	11.20	-	-	170.0	4.4	20.0	0.5	0.1	-	-
Soft drinks	100%	100	200	39	-	-	-	5.0	0.1	1.9	-	0.0	-	-
Fruit juices (100%)	100%	100	100	48	0.30	-	-	8.9	0.2	2.1	0.1	0.0	-	-
Chocolate	100%	100	20	539	6.83	0.2	11.0	192.0	2.8	7.3	1.5	0.3	0.1	-

13 https://www.sge-ssn.ch/grundlagen/lebensmittel-und-naehrstoffe/naehrstoffempfehlungen/empfehlungen-blv/

14 The DACH reference values for nutrient intake are published jointly by the German, Austrian and Swiss Societies for Nutrition. The abbreviation DACH is derived from the usual country codes for Germany (D), Austria (A) and Switzerland (CH). https://www.sge-ssn.ch/grundlagen/lebensmittel-und-naehrstoffe/naehrstoffempfehlungen/dachreferenzwerte/

15 The main source of data for nutrient contents was https://naehrwertdaten.ch/de/.

A disadvantage of such an approach with several functional units is the difficulty in interpreting diverging results.

If the results are intended to provide information for specific groups of consumers, e.g. children, elder people or active people, this might also be a factor for the interpretation as these groups might have different nutritional requirements. This is not considered here in the generic guidelines for a sustainable food consumption.

2.2.3 Scenarios and sensitivity analysis

None.

2.2.4 System boundaries

Different starting points and system boundaries were discussed during the project as described in chapter 3.1.3 and Fig. 3.3. It was decided that the study investigates the different food items from cradle-to-supermarket. Not included in this study are:

- Transport from supermarket,
- Storage or cooking at home,
- Household food waste,
- Disposal of waste packaging.

2.2.5 Geographic scope

Situation for the supply in Switzerland is considered. Import mixes are not calculated if not yet available. For products produced in Switzerland, the goal was to determine the impacts of Swiss primary production. Foreign products are investigated with the data easily available (e.g. global mix or any available country specific data that seemed plausible).

2.2.6 Temporal scope

The most recent version of the fore- and background databases were used, which have most recently been updated in 2022. Some datasets are older.

2.2.7 Technical scope

This study considers the current state-of-the-art production technology as recorded in the underlying background data.

2.2.8 Uncertainty analysis

No uncertainty analysis was carried out for this study.

2.3 Impact assessment methods

For the study, the main impact assessment method is:

- Assessment of different types of environmental impacts into air, water, and soil and assessment of energy, water, land and other resource uses according to the ecological scarcity method 2021 (BAFU 2021). The ecological scarcity method is widely applied in Switzerland.

For quality control, additional impact assessment methods were also applied:

- Global Warming Potential, GWP for short, also known as the carbon footprint or greenhouse gas emissions (IPCC 2021), with a time horizon of 100 years, including additional influences of air transport (Jungbluth & Meili 2019). GWP is widely applied worldwide, as climate change is the most important environmental issue.
- The European environmental footprint method is used in some figures for quality checks (Sala et al. 2018). Today it is the standard LCIA method on a European level and the basis for the default method for EPDs.

A more detailed description of the impact assessment methods can be found in the Appendix B.

All results presented in this report are re-calculated with foreground data from former studies, but applying the actual ESU-database and the latest LCIA methods.

2.4 Data requirements

2.4.1 Foreground data

The main foreground database for food consumption in Switzerland is ESU-services' food database sold as a commercial database (ESU-services 2024a). In Tab. 2.3, this best solution for the background database is outlined.

Tab. 2.3 Description of the life cycle inventory database applied in the project

	ESU World Food LCA Database
Last update	2022 (e.g. CH vegetable production, novel food products, fish, oil and gas provision)
Datasets for food in addition to ESU background data	2300
Database price (material costs)	7500 Euro (8250 CHF) per SimaPro user
Dataset documentation	Electronically in EcoSpold v1 XML or SimaPro format
Dataset report (PDF)	Not available
Suitable for MoeK 21	Yes. Pesticides are updated with reference year 2020 (no forbidden pesticides in Swiss inventories). Elementary flows for fish production are added.
Datasets for CH primary production	194
Datasets for food processing	Most data for processing developed for CH. Some examples: Bakery:15 Beverages: 90 Convenience: 13 Dairy:46 Fish: 10 Grains: 50 Meat:10 Others:30
Datasets «at supermarket»	> 300
Packaging	Included in dataset at supermarket
Food waste until supermarket	Included

The ESU World Food LCA database includes more than 2500 transparent life cycle inventories (LCI) related to agriculture, food processing and consumption activities (ESU-services 2024a). The data are fully documented in the electronic EcoSpold v1 format. More than 200 customers already rely on data from this database. The following features distinguish this database from others:

- Complete and consistent balancing of all food products relevant to the Swiss market
- Background data recommended by Swiss Federal Authorities
- The whole chain from field to mouth is covered for many products
- All data include information on food waste and water use
- Parameterization for key processes to allow easy adaptation
- All unit process datasets include also flow specific uncertainty information for Monte-Carlo simulations
- Proper electronic documentation for all inputs, outputs and general information in EcoSpold v1 format, many reports freely available on our webpage
- Ongoing development and updates

The food production and consumption inventories developed at ESU-services were initially based on a Ph.D. thesis investigating purchases of meat and vegetables (Jungbluth et al. 2000; Jungbluth 2000). The inventories have been continuously updated and extended since then and are representative for today's agricultural practice. Additional data have been collected in several consulting projects (e.g. Annaheim & Jungbluth 2019; Annaheim et al. 2019; Buchspies et al. 2011; Büsser et al. 2008; Büsser & Jungbluth 2008a, b, 2009a, b, c, d, e; Classen & Jungbluth 2002; Doublet & Jungbluth 2013; Doublet et al. 2013a, b; Eggenberger & Jungbluth 2015a, b; Eggenberger et al. 2016; Flury & Jungbluth 2012; Flury et al. 2013a; Flury et al. 2013b; Flury & Jungbluth 2013; Jungbluth 1997; Jungbluth et al. 2001; Jungbluth & Faist Emmenegger 2005; Jungbluth et al. 2007; Jungbluth et al. 2012-2018; Jungbluth et al. 2013a; Jungbluth et al. 2013b; Jungbluth et al. 2014; Jungbluth & König 2014; Jungbluth & Eggenberger 2015; Jungbluth et al. 2016a; Jungbluth et al. 2016b; Jungbluth et al. 2016c; Jungbluth et al. 2016d; Jungbluth et al. 2016e; Jungbluth et al. 2018c; Jungbluth & Eberhart 2020; Keller et al. 2016; Leuenberger & Jungbluth 2009; Meier et al. 2015; Stucki et al. 2012).

Most data are valid for Switzerland and are based on literature, while some are also based on direct information provided by producers and food industry.

Pesticide emissions are fully covered in the datasets of agricultural production. Data for feed production include imports to Switzerland. The methodology for agricultural emissions has been simplified compared to ecoinvent data. Constant emission factors for nitrate, N_2O, etc. are applied based on fertilizer use. Agricultural datasets include the detailed list of pesticides applied, where information is available. All agricultural datasets also include emissions from peat use and decomposition (Annaheim & Jungbluth 2019). Water use and consumption are included in the database with separate flows for each country and thus allows the use of regionalized impact assessment methods (Flury & Jungbluth 2012; Flury et al. 2012a). Since 2012, information about food waste resulting from the full life cycle of products has also been included in our datasets using a systematic approach (Flury et al. 2012b). Compared to the ecoinvent methodology v2.0, we have introduced more simplifications in general, but there are no major differences in methodological choices. The full database has been modelled using an attributional approach.

The database covers, among others, the following areas of interest:

- Agricultural production services: application of fertilizers, machinery hours
- Vegetable production: spinach, salad, tomatoes, lettuce, potatoes, onions, asparagus, etc.
- Fruits: apples, strawberries, cherries, grapes, oranges, bananas, vine, melons
- Animal products: pork, veal, beef, lamb, poultry, eggs
- Fish: codfish, herring, mackerel, salmon
- Dairy products: butter, milk, milk powder, yoghurt, cheese

- Meat and dairy alternatives: tofu, falafel, Quorn, soy vegetarian mince, vegetable drinks and creams, beyond meat burger, planted chicken, etc.
- Staple food: noodles, pasta, bread, wheat flour
- Drinks: apple & orange juice, mineral water, tap water, beer, wine, milk, coffee, tea, vegan milk drinks
- Sweets: chocolate, ice cream, cakes, bars
- Food processing and preservation (washing, blanching, chilling, freezing, canned food, extrusion, etc.)
- Meals: roast dinner, lasagne, soups, canteen meals, recipes
- Household appliances: cooking stoves and ovens, microwaves, refrigerators, carbonization devices, coffee machines
- Distribution in supermarkets for many products including packaging, storage etc. until the point of sale.
- Food consumption: packages, transports, cooking, consumption patterns

2.4.2 Background data

The background database is ESU Database.[16]

This database is based on ecoinvent v2.2. Adaptations, updates and documentation available from www.lc-inventories.ch are incorporated in the database UVEK LCI Data 2018 (UVEK 2018). 5147 datasets are included in this database.

New and updated datasets included in the UVEK LCI Data 2018 database are

An update of The ESU database (ESU-services 2024b) is based on the UVEK LCI Data 2018 (UVEK 2018). An update of LCI data for crude oil, natural gas and mineral oil products was integrated in this database version (Bussa et al. 2021; Jungbluth et al. 2018a; Jungbluth et al. 2018b; Jungbluth & Meili 2018; Meili et al. 2021a, b). Further LCI datasets have been added e.g. on the provision of tap water in several countries, updates on aluminium production (European Aluminium Association 2018) or new LCI data published by Plastics Europe (PlasticsEurope 2016). Many other data were corrected or slightly updated. There are about 5680 datasets in this database. The ESU database contains 330 new and 690 updated datasets (Tab. 2.4).

16 A detailed description can be downloaded on https://esu-services.ch/address/tender/

Tab. 2.4 Overview of corrections, updates and extensions imported into the ESU database

Changed: 691	New: 332	Dataset	ESU database UVEK	Error corrected
1		basalt, at mine/RER	OK	Fehler bei Berechnung der Gesamt-PM-Emissionen, Fehler bei Berechnung des Land Use
3		anaerobic digestion plant, biowaste; anaerobic digestion plant, agriculture und anaerobic digestion plant covered, agriculture	OK	Ersterer wurde mit Daten aus der Biogasanlage Wauwil (axpo) ergänzt. Neue Daten für Landverbrauch, Beton und Stahl, restliche Daten sind gleich wie v2.2. Letzterer wurde mit "uncovered" harmonisiert, da davon ausgegangen wird, dass covered = uncovered & Folie. Zum Teil wurden die Werte neu gerechnet, zum Teil wurden die nachgefragten Materialien harmonisiert.
2		Irrigating/US and /CH	OK	Country specific water flows implmented
	18	Photovoltaics, Rockwool, Flexcell, flumroc	OK	Import LC-inventories
	42	Flooring Daten, Klingler, Umweltchemie	OK	Import LC-inventories, 42, viele DS Namen Änderungen
1		Bailing	OK	Added disposal of silage foil
1		Poultry manure, dried, at regional storehouse/CH U	OK	Added Nitrogen as a biotic resource input
57		wood cogen, furnaces	OK	Replace wood ash to landfarming to municipal incineration. Landfarming is not allowed for these plants
1		electricity, wood, at distillery	Deleted	Unit war kg statt kWh
1		Process-specific burdens, municipal waste incineration/CH U	OK	Update Dioxin Emission gemäss Dinkel 2012 auf 0.0006 ug/kg
1		naphtha, APME mix, at refinery/kg/RER	OK	Links replaced with Naphtha, at refinery/kg/RER U
4		Datasets "heat, 10kW and 100kW non-modulating/CH U"	OK	Outdated technology. Links replaced with "light fuel oil, average/CH U"
5		waste management infrastructure	OK	Replacement of 10kW heatings with 100kW
3		at mine, datasets	OK	Replacement of 10kW heatings with 100kW
6	20	tap water	OK	Replaced and deleted the outdated datasets from v2.2 and KBOB 2016 with new LCI by ESU
1		Epichlorohydrin, from hypochlorination of allyl chloride, at plant/RER U	OK	Water consumption reduced by factor 1000
1		iron ore, 46% Fe, at mine/GLO	OK	Particles reduced by factor 10 according to Email by World Steel, project trade for BAFU
1		hard coal, at mine/IN	OK	Uncertainty bug corrected. Lognormal instead of Normal
57	1	agricultural products updated emission factors	OK	Added impacts of peat and land transformation, corrected land use categories
1		Peat, at mine/NORDEL	OK	Update inventory
1		carbon black	OK	Crude oil input updated crude oil, import mix, at long distance transport/kg/RER U
12	10	rare earth metals update and Ruthenium	OK	Update with 674 Project data with new price allocation and additional by-products
1		electricity mix, DE	OK	Update 2019
1		natural gas mix, DE	OK	Update 2019
7		Natural gas, low pressure/ CH	OK	Input RER instead of CH for all RER datasets. RER DS linked to CH Input
2		tap water, at user CH/RER	OK	link to new nomenclature of data
	1	activated carbon	OK	new dataset
2		solid manure spreading	OK	nitrogen ressource added
1		crude coconut oil PH	OK	electricity mix adapted
	4	electricity PH	OK	imported
	1	operation barge	OK	old data imported
	1	disposal flumroc	OK	imported
	4	electricity, parameterized	OK	imported
1		methanol	OK	gas inputs corrected
	6	passenger car /DE	OK	rough assumption with fuel use
35		data biogas project 320	OK	Updated prices for allocation
1		vegetable oil, from waste cooking oil	OK	glyzerine changed also to waste input
16		operation datasets for transport	OK	import old KBOB datasets
1		zinc, primary, at regional storage	OK	zinc emissions to air, 4.4E-5 according to ecoinvent v3.6, ROW
4	12	electricity mixes, renewable RER and DE	OK	Newly modelled
2		biogas, production mix CH/RER	OK	Update of input mix for 2018
1	36	crude coconut oil, at plant/PH	OK	Import of 36 datasets from WFLDB and replace the old dataset with "Coconut oil, at oil mill (WFLDB 3.1)/GLO" also relinking former links. Delete the original dataset.
1		Lithium carbonate, at plant/GLO	OK	Input natural gas/JP relinked to GLO dataset
	1	aluminium chloride	OK	Modelled with v3 data
6	7	Several plastics data	OK	Import of PlasticsEurope data later than 2012 as system process with own assumptions on waste disposal. Implementation of emission factor for methane harmonized with new oil and gas data.
225	125	Photovoltaics Update 2020 by Treeze	OK	Import of new and replaced LCI data for the PV
6		fuel oil, burned in heating	OK	fuel oil, burned in heating, LHV korrgiert
210	36	crude oil and natural gas	OK	Update of oil and gas chains including additional data for GLO, GB, DE, ES, BE with reference year 2019, delete old LNG at freight ship
8	7	aluminium production	OK	Update with reference year 2018

2.4.3 Assumptions and limitations

The data for the agricultural production of the food products originates from different farms and production practices in Switzerland and for imported products from foreign countries. Switzerland imports about 50% of its products. In cases where data for foreign countries were not available, the same assumptions as for Switzerland are assumed. Although the data represents the major types of farms and production facilities, it has a limit and does not cover the whole spectrum of production agricultural products in all countries and production techniques relevant for the domestic consumption. This principle also applies on other non-food related background data.

Generic values for transport distances of the food products between location of production, distribution and supermarket are used in the data. This means, these distances derive from average distances for transportation from different countries of production to Switzerland and from production until supermarket in Switzerland.

Due to the great amount of background data, an ongoing, consistent update of the datasets is impossible. Especially changes in production techniques and efficiencies cannot always be updated in real time. However, the database is consistently updated as far as possible, especially concerning background data e.g. energy production and provision.

2.4.4 Data quality requirements

All life cycle inventory data in the ESU databases include quantitative information on uncertainties. But, these have not been evaluated in the course of the report. Generally, the uncertainty of data on foods is estimated in the range of 10-20% depending also on the indicator evaluated.

2.4.5 External critical review

No external critical review was carried out for this study.

3 Overview life cycle inventory analysis (LCI)

All data are documented electronically as part of the ESU world food database. The modelling approach for the different food groups is described in this chapter. The data can be purchased as part of the ESU food database. Life Cycle Impact Assessment (LCIA)

3.1 Total environmental impact of private consumption

3.1.1 Swiss balance

To get an idea of the environmental impact of a private person, Fig. 3.1 shows the environmental impact caused by a person living in Switzerland in one year. About half of the environmental impact of the consumed goods and services in the Swiss national economy come from imports (Frischknecht et al. 2018; Jungbluth et al. 2011). The total environmental impacts in 2005 measured with the ecological scarcity method 2021 is calculated here at about 30 million eco-points per person and year.

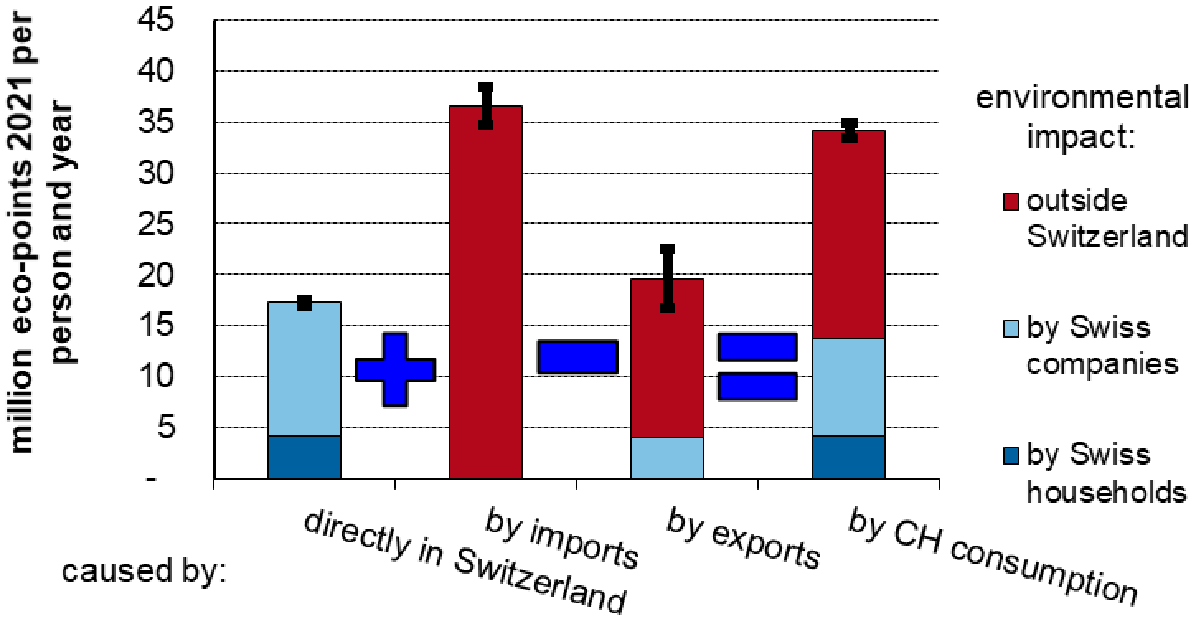


Fig. 3.1 Overview of the environmental impacts of consumption in the Swiss national economy assessed using the ecological scarcity method 2021 measured in million eco-points per person and year 2005.

3.1.2 Consumption areas

A big share of this total environmental impact of Swiss consumption can be attributed to the consumption of food (Jungbluth et al. 2011). Fig. 3.2 shows how the overall impact distributes on the different consumption areas. Depending on the method of data acquisition and assessment, those shares may variate. For a full assessment of environmental impacts food consumptions, energy use in households and mobility are the most relevant consumption areas (Jungbluth et al. 2012, updated calculation).

Nutrition is responsible for a significant share of environmental pollution. The greenhouse gases methane, nitrous oxide and ammonia come mainly from agriculture. In addition, there are emissions from the combustion of fuels for agriculture, in the food industry and in the transport of food. Thus, the share of food purchases in total consumption to about 16-20 % in terms of greenhouse gas emissions over 100 and 20 years, respectively (Fig. 3.2).

The pollution of soils and waters by the application of pesticides, artificial fertilisers and liquid manure with a variety of problematic substances (e.g. phosphate, nitrate, ammonia, heavy metals or medicinal agents) causes further considerable ecological problems, so that about 20% to 25 % of the total environmental impacts according to the European environmental footprint and the Swiss ecological scarcity method 2021, respectively, is caused by food (Jungbluth et al. 2011, updated calculation).

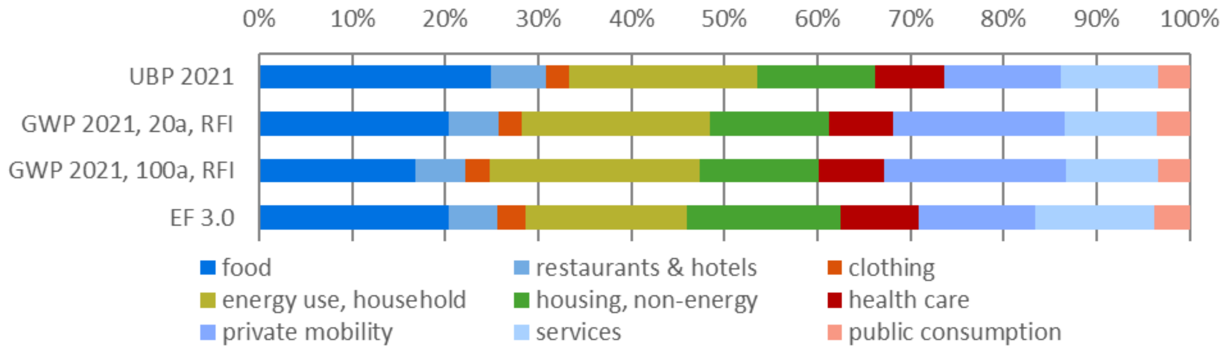


Fig. 3.2 Share of consumption areas of the total private consumption of a person in Switzerland per year, measured with the ecological scarcity method 2021.

3.1.3 Food consumption

The environmental impacts of food consumption in Switzerland were already investigated from different starting points (Fig. 3.3), such as: top-down splitting the overall environmental impacts to different consumption areas in an input-output analysis (Jungbluth et al. 2011), food availability on the Swiss market (Jungbluth et al. 2012), data from the Swiss household budget surveys on food purchases (Jungbluth et al. 2016d), meals consumed (Jungbluth et al. 2016d), nutritional recommendations (Eggenberger & Jungbluth 2015a) and nutrition styles based on food availability ((Jungbluth et al. 2016d). The impacts of single foods have been evaluated, e.g. for the food pyramid of the SGE (Freistil & Promotion Santé Suisse 2020).

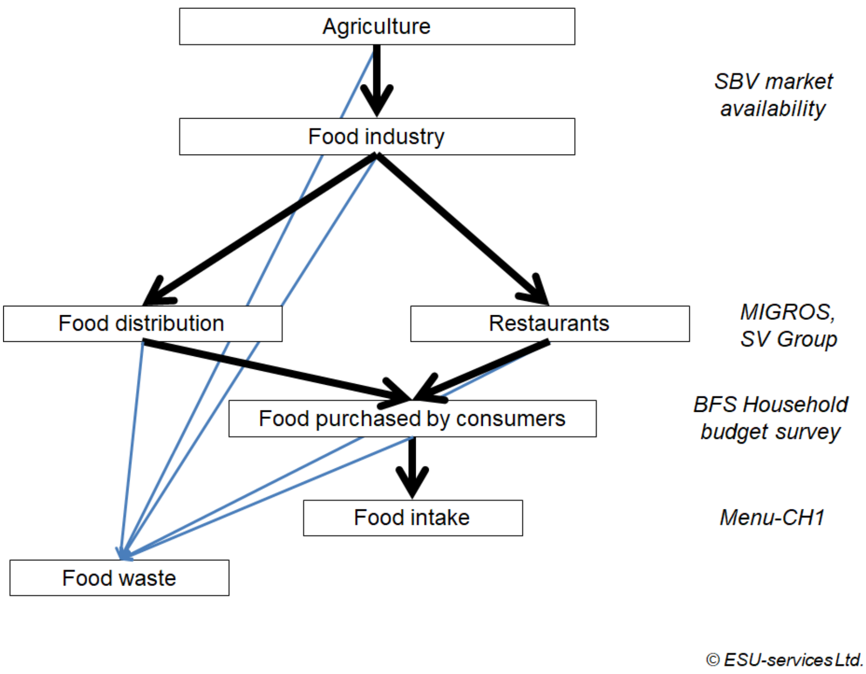


Fig. 3.3 Food flows and different points of investigation to estimate environmental impact

Different studies conducted so far in Switzerland show different results depending on the starting point of the analysis (Fig. 3.4 next page). The highest environmental impacts are those obtained with the top-down approach (input-output-analysis) followed by a modelling of the food availability. Estimates based on nutritional recommendations tend to underestimate the impacts, as they seem to miss parts of frequently consumed food (e.g. alcohol or sweets). Furthermore, food waste from field to fork must be considered for a full picture.

Each of these starting points has its advantages and disadvantages. For this project, where a list of 30-50 food items is investigated, the food availability on the market first seemed to best meet the expectations. For food purchased by consumers or food intake, the list of possible items would be in the range of several thousand products. To match the availability of food on the Swiss market, food waste and overconsumption must be subtracted to compare amounts with recommendations.

During the project, it was decided to take the purchases in the supermarket as the basis and to model therefore food items as described in chapter 1.4.

The environmental impacts per person and year amount to about 7-8 million eco-points 2021. Thus about 20’000 eco-points are caused per day and capita. This figure can be compared with the environmental impacts caused by the daily provision of various nutrients.

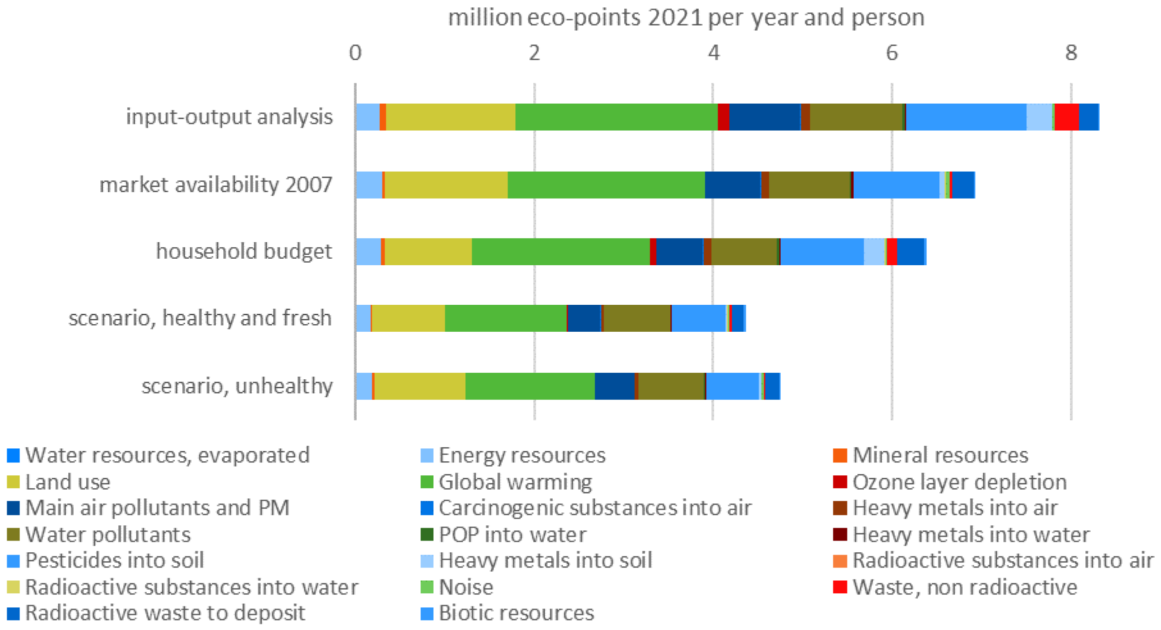


Fig. 3.4 Environmental impacts of food consumption calculated for Switzerland, measured with the ecological scarcity method 2021 (eco-points per person per year). Calculation with different statistics, accounting methods and scenarios as cited in the text.

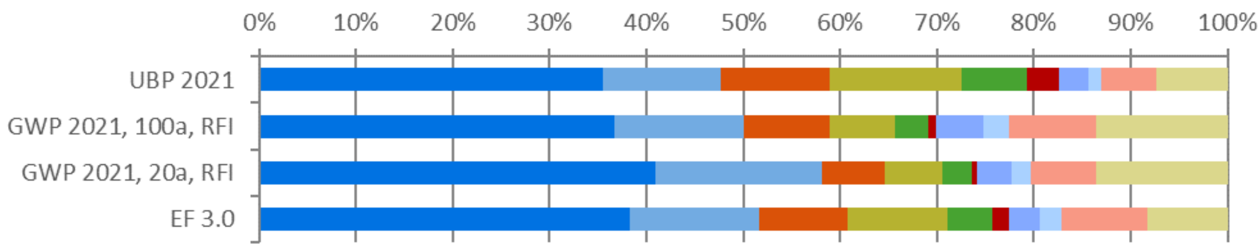
3.1.4 Importance of food groups within total impacts

This chapter provides an estimate of the share of certain food groups in the total environmental impact of food consumption. This is based on studies of the food consumed by the end consumer.

Foods of animal origin usually have higher impact per kg produced than plant-based foods. Dairy products (cheese and milk products) as well as meat and meat products (including meat, poultry, sausages or similar) represent the food groups with the largest environmental impacts. Meat and meat products contribute one quarter of the global warming effect of nutrition when taking the full production chain into consideration (Jungbluth et al. 2012), as seen in Fig. 3.5.

In terms of different product categories, meat, fish and dairy products account for nearly half of the total environmental impact of the provision of food products (Fig. 3.5). Beverages and stimulants are also important, especially alcoholic beverages and coffee, which together account for nearly 10% of the total impact. Transport, processing, and packaging are not of great importance from an environmental point of view.

If the focus is limited to greenhouse gases, animal products, processing and transport are more relevant. In the short-term perspective of the GWP for 20 years animal products count for 60% of the impacts. Thus, it is quite important to reduce these impacts as soon as possible to avoid the tipping points in climate change.



	EF 3.0	GWP 2021, 20a, RFI	GWP 2021, 100a, RFI	UBP 2021
meat	38%	41%	37%	35%
animal products	13%	17%	13%	12%
beverages	9%	7%	9%	11%
fats	10%	6%	7%	14%
cereals	5%	3%	3%	7%
fruits	2%	1%	1%	3%
vegetables	3%	4%	5%	3%
packaging	2%	2%	3%	1%
processing	9%	7%	9%	6%
transports	8%	14%	14%	7%

Fig. 3.5 Share of major food items and processes of the environmental impact of nutrition in Switzerland in the year 2017, measured with the ecological scarcity method 2021, the global warming potential for 20 and 100 years and the European environmental footprint

3.2 Impact assessment for food items

3.2.1 Environmental impacts per 100 g of food items

The environmental impacts of the food items were calculated per 100 g and per 100 kcal using the LCIA methods as described in Chapter 2.3.

Fig. 3.6 shows the environmental impacts of food items as defined in this project for the nutritional recommendations. The highest impacts are found for the food items with meat, fish, and oil products.

Results for the impacts for tea and coffee are not shown as they are recorded for the dry product and not the prepared beverage. Thus, they are not comparable with other beverages which show the volume for the product consumed.

Impacts of red meat are higher than for poultry and processed meat. The impacts of processed meat are dominated by dried meat, which is not a typical example in this group. Most processed meats are made from low-value by-products and thus show much lower impacts than the meats consumed without processing.

Vegan and vegetarian alternatives show always lower impacts per portion provided than animal products. An exemption is butter which shows lower or equal impacts as some of the vegan oils and fats.

Results for some food items are also influenced by the availability of data in the group and the weighting applied. Thus, e.g. minimally processed vegan meat substitutes show higher impact than the high processed ones, just because of the influence of seitan (which is approximated with highly processed wheat protein). For detailed recommendations this group is too diverse.

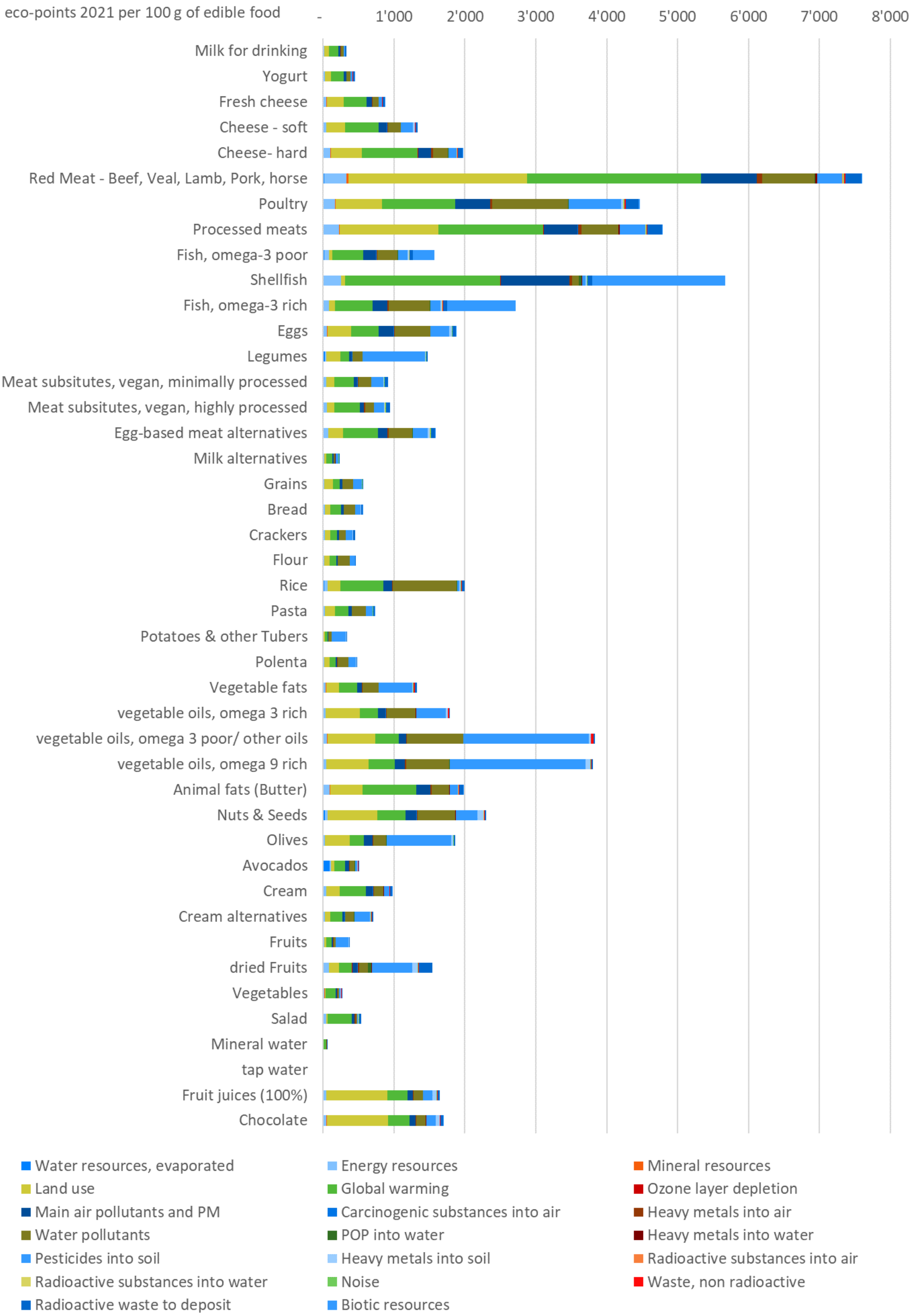


Fig. 3.6 Environmental impacts (ecological scarcity 2021) per 100 g edible food provided in the supermarket

3.2.2 Environmental impacts per 100 kcal of food items

Fig. 3.7 shows the environmental impacts per 100 kcal provided by a food item. To link the environmental impacts per kg sold in the supermarket to nutritional information, the share of inedible parts is considered in the calculations. This changes the picture. Food items with a low content of calories like e.g. salad now show much higher impacts compared to products with a high content of calories. All meat and fish products also show considerable high impacts in relation to the energy content.

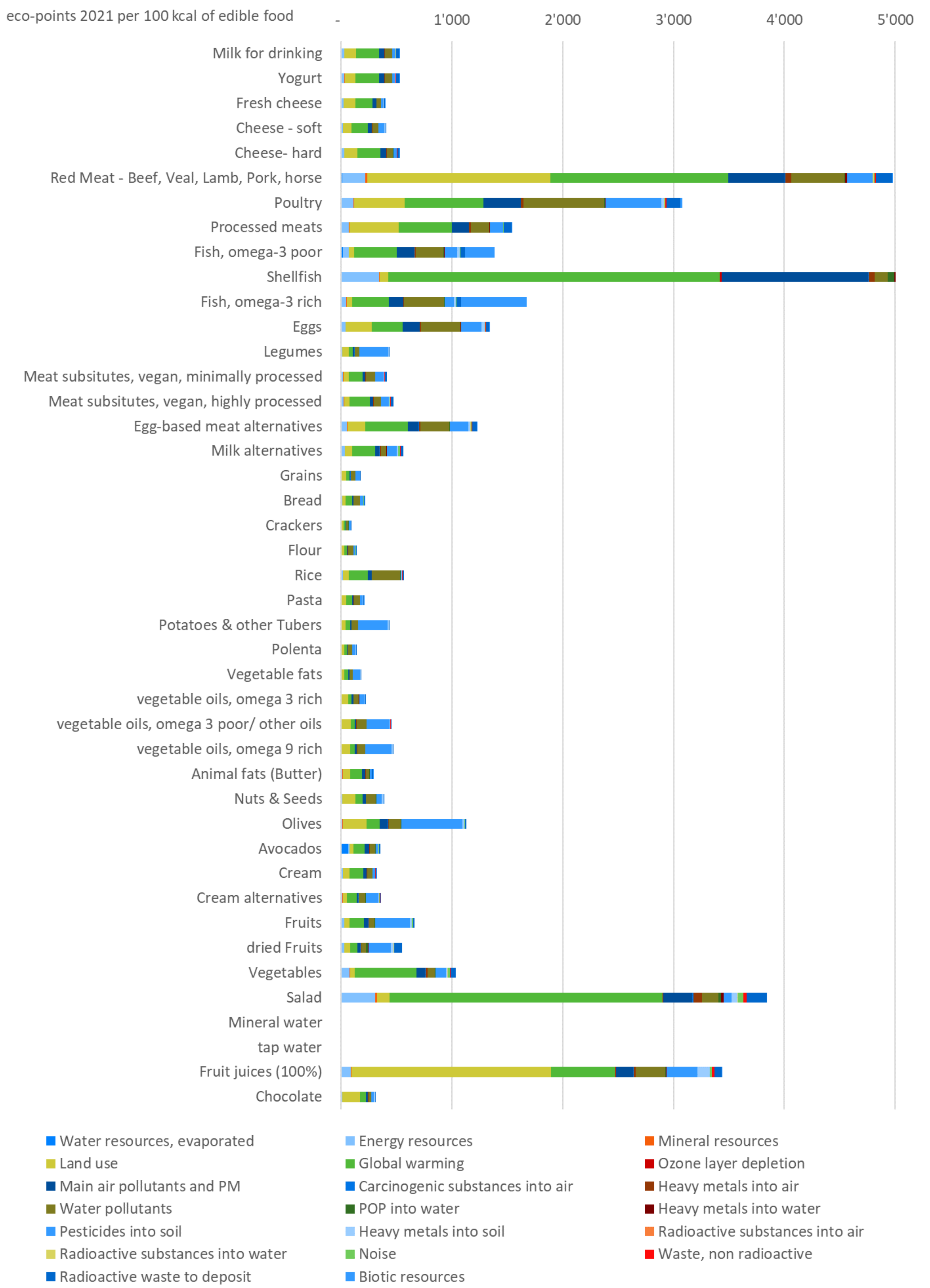


Fig. 3.7 Environmental impacts (ecological scarcity 2021) per 100 kcal food provided in the supermarket

3.2.3 Environmental impacts per nutritional value of food items

Tab. 3.1 shows the environmental impacts for the provision of the daily recommended amount of different nutrients. To link the environmental impacts per kg sold in the supermarket to nutritional information, the share of inedible parts is considered in the calculations.

Food items providing the nutrients in an eco-efficient manner are marked in green, while those with an inefficient provision are marked in yellow or red.

It must be noted that within the groups of food items there might be considerable differences concerning environmental impacts per portion and the nutrients per portion. For some plant-based alternatives there are products on the market with enrichments for certain nutrients. So far it is difficult to analyse the environmental impacts of such pure nutrients. This adds to the uncertainty of these evaluations.

The most eco-efficient food items for **protein** provision are grains, bread, flour, crackers, pasta, cheese, legumes, and meat substitutes. All meat and fish products show higher environmental impacts for the provision of proteins. Meat substitutes and legumes need less servings than the unprocessed grains and grain products to meet the daily demands.

Some sorts of fish are the most eco-efficient way to provide **Vitamin B12**. But high-sea fishing is an important threat to biodiversity. Furthermore, Swiss consumption is at the expense of fish availability in coast states living traditionally from marine resources. Thus, it cannot be recommended for a sustainable nutritional practice. Second best is the provision with milk products, processed meat substitutes and plant-based milk alternatives. Further alternatives like vitamin B12 supplements were not investigated in this study and need further evaluation.

Omega 3 fatty acids are best provided with vegetable oils and several other plant products. Especially cream alternatives can be an eco-efficient option. Many products allow to provide the necessary amount with a few servings per day. Thus, this nutrient does not seem to be critical.

The most eco-efficient way to provide **calcium** is tap water, but a huge amount of 15 litres would be needed, which is not feasible. The number of servings necessary to provide the daily amount of nutrients is shown in Tab. 3.2. Milk and hard cheese are the only food items providing the necessary amount with less than 5 servings a day. Plant-based milk alternatives can be a good option. Calcium supplements e.g. in milk alternatives might be an environmentally friendly way to meet the daily demands. A more detailed discussion on nutrients in plant-based milk alternatives can be found in literature (Bussa et al. 2020).

The most eco-efficient provision of **iron** can be achieved with grains. Also, legumes, bread, meat substitutes and flour can be good options. Several different servings are necessary to provide the recommended daily amount. Most efficient in this sense are legumes with only 4 servings necessary per day. Meat products like red meat which are also promoted for iron provision show considerable higher impacts.

The most eco-efficient way to provide **iodine** is omega 3 poor fish. As fish consumption in Switzerland is generally questionable, plant-based milk alternatives can be recommended from a sustainability point of view, but 7 servings per day would be necessary. Eggs can be an alternative with less servings per day. Salt enriched with iodine seems to be the most efficient way of provision but is not covered in this evaluation.

The most eco-efficient provision of **zinc** can be achieved with grains. Other good options are flour, legumes, and pasta. About 6-8 servings per day are necessary for these vegan products. With red meat only 3 servings are necessary, but environmental impacts are about 5 times higher to achieve the necessary intake.

Cow milk is most eco-efficient option for the provision of **vitamin B2**. Other good options are eggs and red meat. Also, other milk products provide B2 with low impacts. Grains, avocados, and bread can be vegan alternatives but would need a lot of servings per day.

Margarine would be most eco-efficient to provide **vitamin D** followed by omega 3 rich fish. With fish 2 servings per day would be needed, which is clearly not recommendable from a sustainability point of view. Thus, also for vitamin D supplements (or sunlight) might need further investigation.

The best option to provide **selenium** is pasta, and milk alternatives. Just 2 servings per day would be sufficient to meet the demand. Also, low processed meat substitutes are a good option.

In an overall point of view all meat products are not suitable to provide an eco-efficient provision of necessary nutrients. Rice is another product with high environmental impacts but low nutritional value.

The role of fruits and vegetables does not seem to be covered with the nutritional indicators covered so far. The same holds true for beverages.

So far, a detailed discussion on different plant-based alternatives with artificial nutrient supplements is not possible due to a lack of data to produce such ingredients.

It has to be noted that for some nutrients also an overconsumption can have negative effects.[17] This is not considered here and might be a problem if the number of daily portions is recorded as less than 1.

The detailed analysis for the different nutrients also shows that for some nutrients (e.g. zinc, vitamin D, iron) it seems to be impossible to achieve the daily intake with a sustainable provision of food items. Therefore, a more detailed explanation and recommendation by nutritional sciences seems to be necessary. Furthermore a differentiated viewpoint seems to be necessary for different groups in the population (children, pregnant women, elderly) seems to be necessary.

[17] E.g. maximum recommendations for fat are provided on https://www.who.int/news-room/fact-sheets/detail/healthy-diet

Tab. 3.1 Environmental impacts (ecological scarcity method 2021) per daily recommended intake of main nutrients for food items provided in the supermarket. Impacts above 10'000 eco-points per daily intake are marked red as such options would lead to a substantial rise of impacts.

eco-points 2021 per daily recommended intake	64 g protein	4 µg vitamin B12	1.5 g omega-3 fatty acids	1 g of calcium	15 mg iron	150 µg iodine	14 mg zinc[4]	1.4 mg riboflavin (vitamin B2)	15 µg vitamin D	70 µg selenium
Milk for drinking	6'625	5'761	602	2'760	na	5'136	11'594	2'290	99'373	19'734
Yogurt	7'417	5'249	1'042	3'615	68'234	9'347	13'895	3'860	62'030	na
Fresh cheese	3'932	4'679	309	3'354	112'036	9'718	10'517	3'571	72'616	na
Cheese - soft	4'384	3'666	307	3'020	99'675	11'726	8'457	4'327	49'838	na
Cheese- hard	4'995	5'435	431	2'398	98'758	11'429	7'789	6'987	54'127	na
Red Meat - Beef, Veal, Lamb, Pork, horse	19'111	5'323	3'564	716'028	46'030	414'971	24'561	28'512	60'212	60'038
Poultry	12'337	39'093	2'560	596'760	120'292	111'156	58'542	40'776	69'878	16'042
Processed meats	16'086	13'158	602	408'664	34'742	461'658	27'430	33'975	158'850	34'142
Fish, omega-3 poor	4'635	2'020	2'998	60'210	27'094	2'687	32'073	27'395	10'838	4'326
Shellfish	26'139	8'786	17'694	166'417	49'311	8'000	46'024	89'126	na	na
Fish, omega-3 rich	9'041	1'836	1'117	233'446	64'562	9'565	91'822	30'607	5'455	na
Eggs	8'939	5'587	713	36'665	14'666	6'769	20'533	7'948	14'666	5'866
Legumes	3'659	na	1'909	13'667	3'470	117'768	6'300	10'543	na	na
Meat subsitutes, vegan, minimally processed	2'545	916'681	822	15'477	5'927	49'820	14'103	58'334	na	2'020
Meat subsitutes, vegan, highly processed	3'426	5'891	227	20'802	5'068	na	na	na	na	na
Egg-based meat alternatives	7'446	10'601	1'325	33'127	24'845	na	2'929	na	na	na
Milk alternatives	9'666	5'447	1'021	2'699	17'872	3'220	16'680	33'360	8'410	834
Grains	2'907	na	478	13'645	1'729	35'918	1'894	5'318	na	na
Bread	3'909	74'931	843	19'379	5'620	31'221	6'556	7'868	84'297	13'565
Crackers	3'351	16'234	80	7'443	4'021	15'519	5'831	3'921	30'456	9'732
Flour	2'497	na	2'890	22'919	3'135	41'402	3'257	8'130	na	8'794
Rice	17'239	na	6'007	80'305	53'001	143'019	19'112	64'688	na	10'781
Pasta	3'618	na	4'081	27'552	3'887	56'291	5'254	12'697	na	741
Potatoes & other Tubers	8'854	na	na	46'117	10'376	10'376	12'913	7'748	na	na
Polenta	3'507	na	1'808	120'552	7'233	28'932	16'877	16'877	na	na
Vegetable fats	213'080	53'270	54	133'175	199'762	133'175	na	62'148	3'995	na
vegetable oils, omega 3 rich	na	na	71	6'044'796	na	na	761'644	na	na	na
vegetable oils, omega 3 poor/ other oils	613'643	na	341	2'645'011	1'150'580	na	na	na	na	na
vegetable oils, omega 9 rich	na	na	85	na	1'142'666	11'426'662	na	na	na	na
Animal fats (Butter)	83'870	56'097	163	51'243	na	78'201	104'919	104'919	22'205	419'677
Nuts & Seeds	6'394	na	136	12'790	7'449	50'640	7'194	11'308	na	4'466
Olives	88'403	na	263	27'025	6'430	86'065	261'064	na	na	na
Avocados	23'090	na	109	40'589	9'741	97'413	15'153	5'682	na	na
Cream	27'759	14'082	199	12'724	294'393	11'590	54'953	8'936	35'684	na
Cream alternatives	18'177	na	67	64'550	5'325	na	na	na	na	na
Fruits	37'974	na	na	27'689	20'767	51'918	58'148	29'074	na	na
dried Fruits	36'585	na	7'717	24'499	11'024	50'329	36'013	24'009	na	na
Vegetables	14'448	na	na	10'869	11'005	16'931	20'543	8'217	na	na
Salad	28'755	na	na	18'841	21'903	26'549	40'886	10'221	na	na
Mineral water	na	na	na	3'210	na	4'062	na	na	na	43'325
tap water	na	na	na	8	na	na	na	na	na	na
Tea	na	na	na	na	na	800'187	na	na	na	na
Coffee	38'678	na	na	39'815	23'075	50'765	189'522	86'146	na	na
Soft drinks	na	na	na	72'311	54'234	28'544	na	50'618	na	na
Fruit juices (100%)	116'641	na	na	61'780	41'006	40'006	76'545	30'618	na	na
Chocolate	15'837	34'204	230	8'796	9'212	34'702	16'306	8'296	379'985	na
Minimum	2'497	1'836	54	8	1'729	2'687	1'894	2'290	3'995	741

Tab. 3.2 Number of servings per food items to achieve the daily nutrient intake

Number of servings	64 g protein	4 µg vitamin B12	1.5 g omega-3 fatty acids	1 g of calcium	15 mg iron	150 µg iodine	14 mg zinc[4]	1.4 mg riboflavin (vitamin B2)	15 µg vitamin D	70 µg selenium
Milk for drinking, 200g	10,0	8,7	0,9	4,2	na	7,8	17,5	3,5	150,0	29,8
Yogurt, 100g	16,3	11,5	2,3	7,9	150,0	20,5	30,5	8,5	136,4	na
Fresh cheese, 30g	15,0	17,9	1,2	12,8	428,6	37,2	40,2	13,7	277,8	na
Cheese - soft, 30g	11,0	9,2	0,8	7,6	250,0	29,4	21,2	10,9	125,0	na
Cheese- hard, 30g	8,4	9,2	0,7	4,0	166,7	19,3	13,1	11,8	91,3	na
Red Meat - Beef, Veal, Lamb, Pork, horse, 110g	2,6	0,7	0,5	96,0	6,2	55,6	3,3	3,8	8,1	8,0
Poultry, 110g	2,5	7,9	0,5	120,5	24,3	22,4	11,8	8,2	14,1	3,2
Processed meats, 110g	3,1	2,5	0,1	77,6	6,6	87,7	5,2	6,5	30,2	6,5
Fish, omega-3 poor, 110g	2,7	1,2	1,7	35,0	15,7	1,6	18,6	15,9	6,3	2,5
Shellfish, 110g	4,1	1,4	2,8	26,4	7,8	1,3	7,3	14,1	na	na
Fish, omega-3 rich, 110g	3,0	0,6	0,4	77,0	21,3	3,2	30,3	10,1	1,8	na
Eggs, 110g	4,6	2,9	0,4	18,9	7,6	3,5	10,6	4,1	7,6	3,0
Legumes, 60g	4,1	na	2,2	15,4	3,9	133,0	7,1	11,9	na	na
Meat subsitutes, vegan, minimally processed, 110g	2,0	727,3	0,7	12,3	4,7	39,5	11,2	46,3	na	1,6
Meat subsitutes, vegan, highly processed, 110g	3,3	5,6	0,2	19,8	4,8	na	na	na	na	na
Egg-based meat alternatives, 110g	4,3	6,1	0,8	18,9	14,2	na	1,7	na	na	na
Milk alternatives, 200g	20,3	11,4	2,1	5,7	37,5	6,8	35,0	70,0	17,6	1,8
Grains, 60g	8,7	na	1,4	40,7	5,1	107,0	5,6	15,8	na	na
Bread, 100g	7,0	133,3	1,5	34,5	10,0	55,6	11,7	14,0	150,0	24,1
Crackers, 30g	24,8	119,9	0,6	55,0	29,7	114,6	43,1	29,0	225,0	71,9
Flour, 60g	8,8	na	10,2	80,5	11,0	145,5	11,4	28,6	na	30,9
Rice, 60g	14,3	na	5,0	66,8	44,1	119,0	15,9	53,8	na	9,0
Pasta, 60g	8,3	na	9,4	63,3	8,9	129,3	12,1	29,2	na	1,7
Potatoes & other Tubers, 240g	13,3	na	na	69,4	15,6	15,6	19,4	11,7	na	na
Polenta, 60g	12,1	na	6,3	416,7	25,0	100,0	58,3	58,3	na	na
Vegetable fats, 10g	1600,0	400,0	0,4	1000,0	1500,0	1000,0	na	466,7	30,0	na
vegetable oils, omega 3 rich, 10g	na	na	0,4	33333,3	na	na	4200,0	na	na	na
vegetable oils, omega 3 poor/ other oils, 10g	1600,0	na	0,9	6896,6	3000,0	na	na	na	na	na
vegetable oils, omega 9 rich, 10g	na	na	0,2	na	3000,0	30000,0	na	na	na	na
Animal fats (Butter), 10g	419,7	280,7	0,8	256,4	na	391,3	525,0	525,0	111,1	2100,0
Nuts & Seeds, 25g	13,6	na	0,3	27,1	15,8	107,3	15,2	24,0	na	9,5
Olives, 25g	189,6	na	0,6	58,0	13,8	184,6	560,0	na	na	na
Avocados, 120g	29,6	na	0,1	52,1	12,5	125,0	19,4	7,3	na	na
Cream, 30g	94,3	47,8	0,7	43,2	1000,0	39,4	186,7	30,4	121,2	na
Cream alternatives, 30g	85,3	na	0,3	303,0	25,0	na	na	na	na	na
Fruits, 120g	76,2	na	na	55,6	41,7	104,2	116,7	58,3	na	na
dried Fruits, 30g	79,0	na	16,7	52,9	23,8	108,7	77,8	51,9	na	na
Vegetables, 120g	41,0	na	na	30,9	31,3	48,1	58,3	23,3	na	na
Salad, 120g	41,0	na	na	26,9	31,3	37,9	58,3	14,6	na	na
Mineral water, 200g	na	na	na	25,9	na	32,8	na	na	na	350,0
tap water, 200g	na	na	na	71,4	na	na	na	na	na	na
Tea, 5g	na	na	na	na	na	3000,0	na	na	na	na
Coffee, 7g	81,6	na	na	84,0	48,7	107,1	400,0	181,8	na	na
Soft drinks, 200g	na	na	na	100,0	75,0	39,5	na	70,0	na	na
Fruit juices (100%), 100g	213,3	na	na	113,0	75,0	73,2	140,0	56,0	na	na
Chocolate, 20g	46,9	101,3	0,7	26,0	27,3	102,7	48,3	24,6	1125,0	na

3.2.4 Results

Results for the environmental impacts of different foods are shown in an Excel table, which can be bought from ESU-services. For quality control, the impacts of basic foods are compared with another fully aggregated indicator the European Environmental Footprint Method. In addition, results for the GHG emissions are calculated. A comparison and brief discussion of the results concerning all indicators and the product at supermarket is shown in this report. The environmental impact is also calculated per nutritional value (kcal) and quantity (e.g. 100 g).

The ESU-database proves to be a complete and reliable database for such assessments. During the LCIA it became obvious that it is difficult to mix LCI data from different sources and evaluate them with the Swiss ecological scarcity method. Other database as e.g. Agrybalyse to not include the full level of information e.g. on fish resources to allow an unbiased assessment.

3.3 Conflicts and synergies between health and environment

Improving health and environmental impact of nutrition may not always go hand in hand. Therefore, the following chapter depicts the main conflicts and synergies between the health and the environmental impact of the different product groups of nutrition.

3.3.1 Meat and alternatives

The following conflicts and synergies are identified for the consumption in this product group:

- Red meat, poultry, and processed meat lead to high environmental impacts per kilogram of product but also per nutritional group. From an environmental point of view, the consumption of meat is not recommended.
- Reduction of processed meat and low-quality meat in human nutrition leads to higher shares of food waste or non-human use of by-products. This would also increase the environmental impacts of high-quality meat if less processed meat were consumed.
- High-sea fish and fish fodder for aquaculture is not available on a global scale to provide a sustainable production. Switzerland is traditionally not consuming much fish and all high-sea fish consumed here goes at the expense of traditional fishing countries.
- For certain nutrients like vitamin B12, vitamin D or iodine, fish can be an environmentally friendly source to meet the nutritional demand. But, it has to be considered that not all sustainability aspects (such as overfishing and competition to traditional fishery) can be fully covered with the LCIA methods.
- Meat alternatives (and legumes which often are the base for meat alternatives) are an effective substitution to the consumption of meat. Comparing highly processed meat substitutes with red meat, the substitutes deliver all nutrients more environmentally friendly than meat. Particularly when it comes to protein and iron.

3.3.2 Dairy and egg products and alternatives

The following conflicts and synergies are identified for the consumption in this product group:

- Milk is a couple product in the production of beef and the breeding of calves. The ratio between beef, veal and milk can be varied, but it does not make sense to only use cow milk in a vegetarian diet and fully refrain from eating veal and beef. This would burden the milk with higher impacts.
- The same partly holds true for eggs and chicken. But here agricultural production technologies today separate the two production chains and lead to waste of non-used male or female chicks and used-ups hens. Initiatives are going on to implement again a double use breed for producing chicken and eggs which might avoid such wastage but might have lower feed to product efficiencies. Thus, it is not yet clear if this is really an improvement when considering environmental impacts.
- The consumption of this product group can deliver many nutrients in an environmentally friendly way. Dairy products have a relatively low impact for their content of vitamin B12, iodine and calcium and especially cheese is a good source of protein. However, the market for substitution

products (especially for dairy products) is growing constantly[18]. These alternatives cover many of the nutrients of dairy products. For vegetarians, consuming milk alternatives makes sense to prevent higher impacts from milk consumption without eating veal and beef. Besides that, further nutrients may be added (in new products) and by that, special nutritional demands could be satisfied.

3.3.3 Oils, vegetable fats and nuts

Some conflicts and synergies are identified for the consumption in this product group:

- Most of the products proposed from a nutritional point of view are traditionally not produced in Switzerland and thus imports are necessary.
- Oils like palm oil and sunflower oil have lower impacts than other plant oils with high nutritional values (e.g. olive oil). This might stand in conflict with nutritional goals in this project group.
- Olives and olive oil are promoted for healthy nutrition but show remarkably high environmental impacts and are more costly for consumers. A certain reduction of environmental impacts would at least be possible by using suitable packages (no heavy glass bottles but better low weight PET bottles) for such products.
- Vegetable oils, vegetable fats and nuts show synergies between health and environmental impact when it comes to the supply of omega-3 fatty acids. Here, nutritional demand can be met with relatively low environmental impact compared to other product groups.
- More focus might be laid on the intended use of oils. Some oils are not eaten because they are used for frying and roasting. Therefore, oils with low environmental impacts might be more suitable. High value products should only be used if fully consumed (e.g. for salads).

3.3.4 Vegetables and fruits

The nutrients investigated for the food items do not cover very well the positive properties of vegetables and fruits. Thus, the evaluations should not be misunderstood as an argument against an increased consumption of these products. With a recommendation for eating more fruits and vegetables the following possible conflicts and synergies are identified for the consumption in this product group:

- In winter and spring, a high consumption with a wide and attractive variety of fresh products cannot be supplied with the lowest environmental impacts. Therefore, heated greenhouse or long-distance transports are necessary and increase the environmental impact.
- In general, the cultivation, transport and seasonality influence the environmental impact of vegetables and fruits significantly and therefore may result in conflicting aspects. This topic will be discussed in the following chapters 3.4 and 4.5.3.
- Even though the environmental impacts of vegetables and fruits are high relative to their nutrient content, vegetables and fruits are considered one of the basic foodstuffs. They cover the major spectrum of vitamins, minerals, and fibre, and are elementary for nutrient supply and digestion which is not reflected in the above choice for nutrients selected.

[18] https://www.foodmanufacture.co.uk/Article/2022/01/05/Food-industry-trends-2022-from-COVID-19-to-climate-change, 11.01.2021

3.3.5 Grains, potatoes and legumes

The following synergies are identified for the consumption of this product group:

- This product group delivers the basic supply of energy for the human body. The impact assessment supports this principle, since it is the product group with the lowest environmental impact per calorific value. In addition, it also supplies protein, iron, and zinc with relatively low environmental impacts.
- Wholegrain products are recommended from both, a nutritional and an environmental point of view.

3.3.6 Beverages

Some conflicts and synergies are identified for the consumption in this product group.

- Not clear if mineral water is recommended from a nutritional health perspective when it comes to its mineralisation. There is a clear disadvantage of mineral water compared to tap water from an environmental perspective.
- The main purpose of beverages is to hydrate the body and for this, tap water is sufficient and leads to minimal environmental impact.
- Beverages can have other purposes like providing caffeine and sugar e.g. to increase performance. Since these are functional but not nutritional aspects, they are not regarded in this study.
- Alcohol is not recommended from environmental and nutritional point of view.

3.3.7 Sweet and savory

This product group is only of small nutritional value. Since it does not contribute to the nutritional demand it can be considered unnecessary. Therefore, it is also not recommended from an environmental point of view.

3.4 Importance of the production steps in the life cycle

An evaluation of myriad studies conducted by ESU-services in the last 25 years (some references are provided in chapter 2.4.1) shows that for low-processed products, agricultural production is the main source of pollution. For processed products, other production stages can dominate the total environmental impact. For many beverages (e.g. mineral water and beer), however, packaging and transport are of particular importance. The behaviour of consumers plays a key role when food is brought to the household by car, for example. Overall, the life cycle assessments show that recommendations for environmentally sound nutrition do not always have general validity and that it is often necessary to weigh up several factors. The results of such weighing and weighting of options for action based on life cycle assessments are discussed below.

3.4.1 Agriculture and fisheries

For most foods, the first production step takes place in agriculture. In life cycle assessments of agricultural production, various environmental impacts are important. The production of pesticides and fertilisers involves energy consumption. Their application leads to toxicological damage, overfertilization and acidification. The use of nitrogenous fertilisers also produces nitrous oxide emissions, which play a significant role in climate change. The use of land for agriculture has a direct influence on the species composition, i.e. the biodiversity present on an area.

In animal husbandry, the prior production of feed is particularly important. In addition, ruminant animals such as cows, sheep, and goats cause methane emissions, which in turn contribute to climate change. Manure and slurry from animal husbandry are brought back to the fields and cause similar problems as the application of artificial fertilisers. In some cases, emissions (e.g. ammonia, methane) are even higher than when artificial fertilisers are used.

Reducing the environmental impact of agriculture is extremely complex, as many factors, some of which are contradictory, must be optimised and at the same time there is a dependence on natural factors that cannot be influenced, such as the climate. When buying food, the production practice can practically only be assessed via labels such as IP or organic (see next chapter).

In the case of farmed fish, the production of the necessary feed is relevant. As far as possible, plant products should be used as feed. For wild catches in the sea, a high fuel input is usually necessary. Furthermore, there is a huge competition on natural fish resources which leads to overfishing, extinction of fish species, and malnutrition in traditional fishing countries.

For mineral water and sweet drinks, water is used in many cases, which must be extracted and possibly treated. Compared to fruit juices, however, the use of drinking water is associated with significantly lower environmental impacts.

3.4.2 Seasonality and greenhouse cultivation

For many fruits and vegetables, production during their natural main season has a significantly lower environmental impact than, for example, production in a greenhouse at a time when they cannot be grown outdoors. In the case of greenhouse products, it is above all the energy consumption for heating and lighting that causes a high impact.

In some cases, products are grown in the greenhouse and later harvested in the open or unheated greenhouse. Here, too, the proportional energy consumption must be considered.

Products grown in the greenhouse on artificial substrates are referred to as "hors-sol". Here, too, the decisive factor for the environmental assessment is whether the greenhouse is heated or lit. A general assessment of whether these products are better or worse than normal greenhouse products is not possible. Even if soil is used in the greenhouse, it must be sterilised, e.g. by steaming. With Hors-Sol production it is possible to control the addition of fertiliser relatively well and to operate an externally closed system.

Another possibility to offer fresh products out of season is the import from warmer countries by truck or plane. The latter in particular has a high environmental impact. (Chapter 3.4.4, Fig. 3.8).

Fruits and vegetables from seasonal production usually have the lowest environmental impact. Conserved products or outdoor products from southern countries have a lower environmental impact than products from heated greenhouses.

Tab. 3.3 shows the influence that purchasing behaviour can have. Vegetables that are consumed out of season cause many times more environmental pollution than domestic products grown in open fields. The environmental impact increases particularly strong when products are imported by air (e.g. asparagus in autumn/winter). A relevant increase is also caused by production in greenhouses or the further transport of products if they are purchased outside the regional growing season. It should be noted that in spring an increase in the environmental impact of products from the heated greenhouse can also be observed in the case of tomatoes. In this example, however, these are never flown in.

Tab. 3.3 Extract from the seasonality calendar for fruits and vegetables of ESU-services. In this case it shows the environmental impact of distinct types of origins of asparagus over the course of the year.

ESU-services fair consulting in sustainability			Switch:	Indicator	UBP 2021	per kg of good			Country	CH				
Product		**Origin**	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Green asparagus	IP	CH-lorry	n.a.	n.a.	n.a.	12'044	12'044	12'044	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Green asparagus	IP	ES-lorry	n.a.	n.a.	n.a.	13'497	13'497	13'497	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Green asparagus	IP	MX-air	n.a.	32'887	32'887	32'887	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Green asparagus	IP	PE-air	35'012	35'012	n.a.	n.a.	n.a.	n.a.	35'012	35'012	35'012	35'012	35'012	35'012
Green asparagus	IP	US-air	n.a.	28'849	28'849	28'849	28'849	28'849	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	IP	Regional	n.a.	n.a.	n.a.	n.a.	16'309	16'309	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	IP	CH-lorry	n.a.	n.a.	12'977	16'500	16'500	16'500	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	IP	DE-lorry	n.a.	n.a.	13'360	16'882	16'882	16'882	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus, heated	IP	DE-lorry	n.a.	n.a.	13'360	13'360	13'360	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	Bio	DE-lorry	n.a.	n.a.	n.a.	16'882	16'882	16'882	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	IP	ES-lorry	n.a.	n.a.	17'601	17'953	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	IP	FR-lorry	n.a.	n.a.	13'436	16'959	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	IP	MA-lorry	n.a.	n.a.	18'569	18'569	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	IP	NL-lorry	n.a.	n.a.	n.a.	17'035	17'035	17'035	17'035	n.a.	n.a.	n.a.	n.a.	n.a.
White asparagus	IP	PE-ship	n.a.	17'728	17'728	n.a.	n.a.	n.a.	17'728	17'728	17'728	17'728	17'728	n.a.
White asparagus	IP	PE-air	39'468	39'468	39'468	n.a.	n.a.	n.a.	n.a.	n.a.	39'468	39'468	39'468	39'468
White asparagus	IP	HU-lorry	n.a.	n.a.	n.a.	n.a.	17'188	17'188	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

3.4.3 Processing, conservation, packaging, freezing and storage

There are interdependencies in the environmental impacts caused by processing, preservation and storage of the food products that must be considered in the assessment.

3.4.3.1 Processing

Many agricultural products are processed before being distributed. For example, coffee and cocoa beans are roasted. Processing is usually relevant if a lot of heat is used for this, e.g. for cooking or roasting. However, general statements are relatively difficult.

3.4.3.2 Conservation

Food can be conserved to increase preservability of seasonal products, for example, or to enable longer storage in general. Possibilities for preservation are e.g. deep freezing or heating with subsequent airtight packaging.

When assessing environmental impacts, it must be considered that preservation causes additional impacts, but that on the other hand, lower impacts can occur during storage (canned foods) or during preparation (shorter cooking time). Furthermore, the losses due to spoilage on the way to the plate are generally lower with preserved products. The type of preservation in turn also has an influence on the packaging. These varied factors have to be weighed against each other, which is why it is difficult to make generally valid statements. For a precise assessment, the actual energy consumption in the household for storage and preparation for diverse types of preservation would have to be known as well.

3.4.3.3 Storage

Especially for chilled or frozen products, storage over a longer period is relevant. Apples or carrots, for example, are refrigerated for a long time so that they are available all year round.

Here, too, a range of factors (energy consumption of storage, transport routes, production in greenhouses, etc.) that influence the environmental impact must be considered.

Concerning frozen products, there are many qualitative discussions but few concrete figures comparing fresh and frozen products. There are only a few studies available that investigate this problem. Many of the studies conclude that freezing is positive because it minimises waste.

On the other hand, Garnett's (2007) statement that "just because we can keep something longer doesn't mean we will eat it" should be noted. Empirical studies on how much and whether really less waste is produced by deep freezing and cooling seem to be lacking so far. Only Fehr et al (2002) addresses this relationship in a supermarket.

From Büsser et al. (2008) and the study by Sonesson et al. (2005), it can be seen that the difference between fresh and frozen products mainly depends on the storage time in the household, whereby both studies do not take losses into account.

A clear answer to the question of whether frozen products are more environmentally friendly than fresh products is not yet possible. The various influencing factors have only been partially investigated so far. This reveals both advantages and disadvantages. Tab. 3.4 summarises the main factors influencing the assessment of frozen products.

Tab. 3.4 Comparison of positive (+) and negative (-) influencing factors in the assessment of frozen products

	Influence frozen products	Influence fresh products
Agricultural cultivation	+ Possibly cheaper, as farming does not have to take into account the storage or harvest time. + Harvest possible in the most optimal season.	- Higher requirements regarding harvest time and storage life
Processing and deep freezing	- Energy consumption, waste and wastewater generation	+ Low impact
Losses due to spoilage	+ Probably lower as soon as food is frozen. However, risk of total loss, e.g. in the event of a power failure.	- Higher as spoilage is more likely by the time it is processed in the household.
Packaging	- Possibly more elaborate packaging necessary.	+ Delivery also possible in reusable boxes.
Transports	- Higher expenses for additional cooling	+ Without freezing chain possible
Intermediate storage and storage	- Higher energy consumption for deep-freezing	+ Less high requirements
Preparation and processing	+ Less set-up and processing effort, shorter cooking times if already pre-cooked	- Higher expenses and losses

Frozen products do not make sense if the actual product is also available as a seasonal product or fresh product (meat) and/or longer storage at the buyer's is not necessary because it is consumed immediately.

The use of energy-efficient equipment at the producer's and in the company warehouse helps to minimise energy consumption. Freezing without refrigerants that damage the ozone layer and controlling refrigerant losses also contribute to climate protection, as does keeping storage as short as possible and minimising the storage capacity of frozen products.

Basically, the question arises why certain foods must be available all year round? A reduction of this requirement would in any case lead to less environmental impact.

3.4.3.4 Packaging

Most products are packaged to protect them during storage and transport. Packaging is mainly relevant when the actual product can be produced with relatively low environmental impact (e.g. mineral water, aerosol cans) or when unnecessarily costly packaging is used (e.g. gift packaging for chocolates, aluminium packaging for beverages). Here, the packaging production (mainly the raw materials) is usually more relevant than its proper disposal.

3.4.4 Transport

The environmental impact of transport is often measured primarily in terms of distance. However, this is not very helpful. The environmental impacts depend primarily on the means of transport. Air freight clearly causes the highest environmental impact per kilometre, followed by truck and rail transport. Ship transports, on the other hand, cause significantly less environmental pollution in relation to the distance. In the case of road transport, there are also major differences depending on the vehicle. The larger the vehicle, the lower the specific impact per transport kilometre. As a result, short transports by car or van are often similarly relevant in the life cycle as very long overseas transports by ship. The environmental impacts of different means of transport are compared in Fig. 3.8. Delivery vans cause the highest environmental impact per kilometre (and transported ton). However, in contrast to aircraft, they are only used over short distances. Due to the significant differences, a transport by ship over 10,000 km has a similar environmental impact as a transport by van over 100 km.

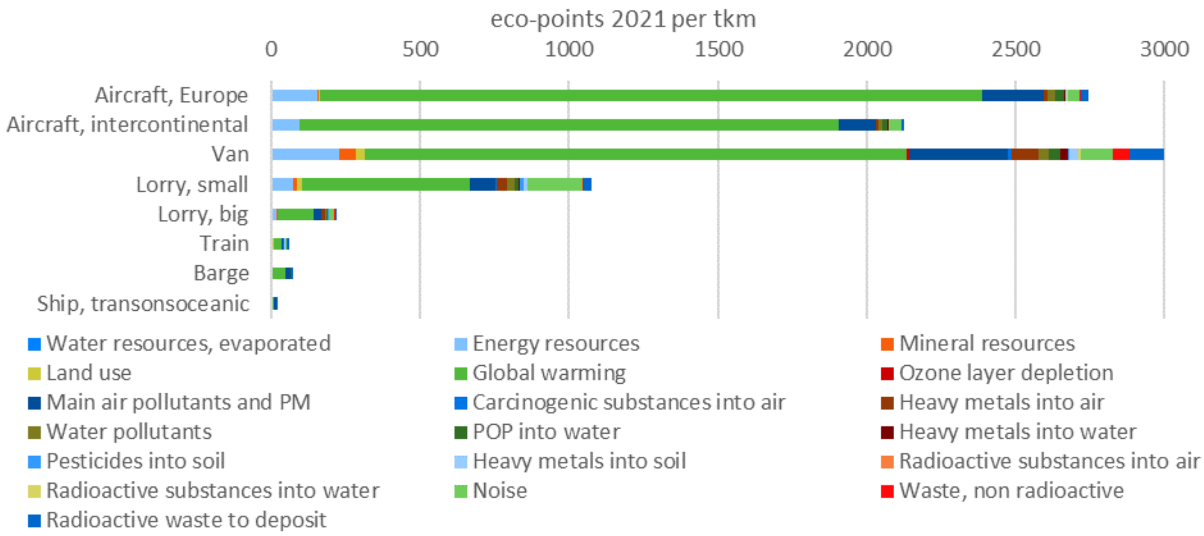


Fig. 3.8 Environmental impact of different means of transportation per ton and kilometre

The assessment of environmental impacts from the entire transport chain is therefore only possible if both the distances and the exact means of transport are known.

3.4.5 Interdependencies of the production steps

A separate assessment of individual production steps or product characteristics described above is often difficult because they influence each other. For example, a preserved product causes comparatively higher environmental impacts during processing than a fresh product. On the other hand, the expenses during preparation are lower and there are fewer losses. A returnable glass bottle is heavier than a disposable PET bottle and must also be transported back. Therefore, the packaging also has an influence on the environmental impact of the transport. With increasing transport distance, the impact of the returnable bottle rises compared to the impact of the one-way bottle. Thus, it is often not possible to give clear indications for individual criteria and an assessment is only possible for the product as a whole, taking into account all relevant criteria. However, such an assessment is then case-specific and associated with a relatively high level of effort.

3.4.6 Relevance matrix

The relevance for the total environmental impact is assessed qualitatively in a matrix for the different product groups. For this purpose, the relevance of different stations in the life cycle (see previous subchapters) for the overall environmental balance of a product from this group is first estimated within each product group. In the case of meat, for example, the main impact comes from agricultural production. In the case of beverages, on the other hand, packaging and transport are the relevant influencing factors (

Tab. 3.5). For the overall assessment of a product, at least the criteria rated 3-5 must usually be considered.

The proportion of the environmental impact caused by a product group in relation to total consumption is roughly estimated in the last line. This is based on the explanations in this chapter.

Tab. 3.5 shows the results of this expert assessment.

An addition across rows or columns does not make sense, as this is a purely qualitative assessment. In the following chapters, the main assessments for the individual product groups are explained in detail.

Tab. 3.5 Relevance matrix for assessing the environmental impacts of food in a life cycle assessment. Rating of the relevance of different sections in the life cycle with 5 (high) to 0 (none). The numbers cannot be summed up across rows or columns as no actual weighting is applied.

	Vegetables/fruits fresh	Vegetables/fruits fresh, prepared	Frozen products	Meat	Poultry	Fish	Dairy products	Egg products	Bread/small breads	Beverages	Coffee	Tea	Colonial products	Convenience	Sweets
Agriculture	4	4	3	5	5	5	5	5	3	1	5	4	4	4	4
Seasonality	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Food processing	1	2	3	1	1	1	3	1	3	2	3	3	2	2	3
Preservation	0	1	3	2	2	2	3	2	0	2	1	1	1	3	4
Storage	2	2	5	2	2	2	4	2	1	2	1	1	1	2	4
Packaging	1	1	1	1	1	1	1	1	1	5	2	2	2	1	2
Transportation	2	2	2	1	1	3	1	1	3	5	2	2	3	2	1
Preparation in the kitchen	3	3	3	3	3	3	1	3	0	0	4	4	3	3	0
Losses	5	5	1	2	2	2	3	2	4	0	3	3	1	1	2
Share of total consumption	3	3	4	5	4	3	5	2	2	1	4	2	3	2	1

4 Improvement potentials for food production and consumption

Based on the findings from chapter 0, suggestions for improvements in the consumption (and also production) of food are made in this chapter.

4.1 General measures for reduction of impacts

Environmental impacts from food production and preparation originate from different actors in the chain from food cultivation to waste disposal. All actors involved in the life cycle can contribute directly to "greening". The following main options are available, all of which should be used as far as possible:

- Greening of production processes: This includes, for example, minimizing the use of pesticides, fuels and fertilisers while at the same time maximizing the yield, energy savings in processing, cooling and preparation, as well as optimising transport and reducing processing losses and spoilage.
- Greening of consumer decisions: Consumers determine what is produced through their purchasing behaviour. They can, for example, buy regional products, avoid frozen products, or choose seasonally adapted fruit and vegetables.
- Greening the diet: Consumers can also contribute to greening by making fundamental decisions about their diet. This includes reducing the consumption of meat and other animal products.
- Greening of agricultural policy: Besides consumer and producer implemented measures, policy makers can have strong influence on both, production, and consumption of food products. By implementing laws and regulations they can push producers and consumers towards an ecological production and consumption of food. Furthermore, subsidies e.g. on promoting unsustainable foods as meat and milk, should be cut down. To sustainably change production and consumption, measures must be taken both on a national and international level of agricultural policy.

Only the simultaneous implementation of all four options is promising. Due to the large number of possible environmental impacts (e.g. greenhouse effect or over-fertilisation of water bodies), suitable analytical methods must be used to assess the environmental impacts. With the help of the life cycle assessment method, the environmental impacts during such life cycles have already been examined for hundreds of food products.

4.2 Reduction potentials in consumer behaviour

Several options of reducing environmental impacts are compared here within a general framework. Besides the consumption of food products also reduction potentials for impacts due to energy use in households and private mobility have been investigated (Jungbluth et al. 2012). The assessment has been made for average consumption patterns in Switzerland and the city of Zurich (Jungbluth & Itten 2012).

The method follows a stepwise approach (Jungbluth et al. 2012). In a first step, the total environmental impact of Swiss consumption was calculated (updated from Jungbluth et al. 2011; Jungbluth & Meili 2017). Then the share of the environmental impacts related to food consumption was assessed. Based on a more detailed analysis of this consumption sector, it was investigated by what percentage environmental impacts can be reduced by a certain change in the consumer behaviour. Finally, this estimation is used to evaluate the potential reduction of the total environmental impacts.

Consumers can aim to reduce the environmental impacts by decisions on different levels (Jungbluth et al. 2000). These range from the choice of packages for a product, preferences for certain labels, choices on ingredients for a meal, vegetarian or other diets to general considerations such as e.g. concerning household budgets. In this short chapter we present and compare the reduction potential in the total environmental impacts, if all consumers:

- Buy locally (no air-transported products)
- Buy seasonally (no fruits and vegetables from heated greenhouses)
- Vegan diet
- Buy organic food
- Resign on luxury food (chocolate, wine, coffee etc.)
- No food wastes in households
- Reduce obesity to normal weight
- Combine different changes towards a healthy and environmentally friendly diet

Fig. 4.1 shows the actual reduction potentials for the total environmental impacts. The most promising single change in behaviour is a vegan diet. The next best option is the reduction of food waste. A further important option is the resign on luxury products such as alcohol, coffee, and chocolate. A regional or seasonal choice of products only does however not show such a high potential for reducing environmental impacts. Different such measures can be combined to achieve an even higher reduction potential: For the modelling of the "healthy and environmentally friendly diet", it is assumed that meat consumption is reduced to two portions a week instead of six. Furthermore, air-transported products are not bought anymore, and fruits and vegetables are purchased seasonally. With this combination of measures, it would be possible to reduce the environmental impacts of total household consumption by more than 12% (and cut the impacts of the nutrition by 40%).

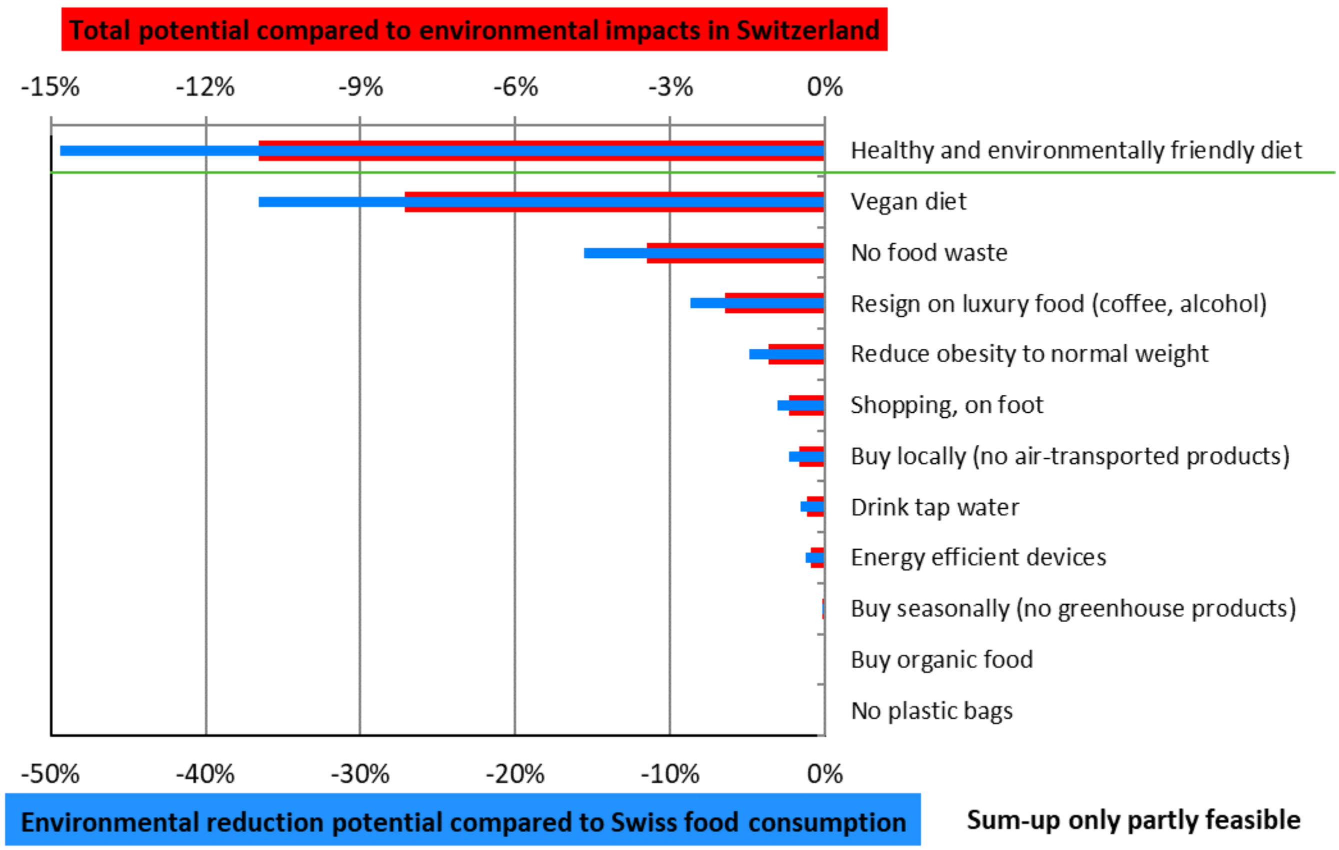


Fig. 4.1 Reduction potentials for total environmental impacts (ecological scarcity method 2021) due to behavioural changes in food consumption

The focus of Fig. 4.2 is the short-term reduction of the global warming potential (20a). The ranking changes a little bit. Thus, e.g. the reduction on transports by car and regional consumption becomes more relevant.

With this methodology, it has been shown that, the reduction of meat and animal products is the most critical issue from an environmental point of view. Also important is the reduction of luxury food and food wastes. The same methodological approach has also been applied on the consumption sectors energy and mobility and thus allows a consistent framework for the comparison of different changes in consumer behaviour.

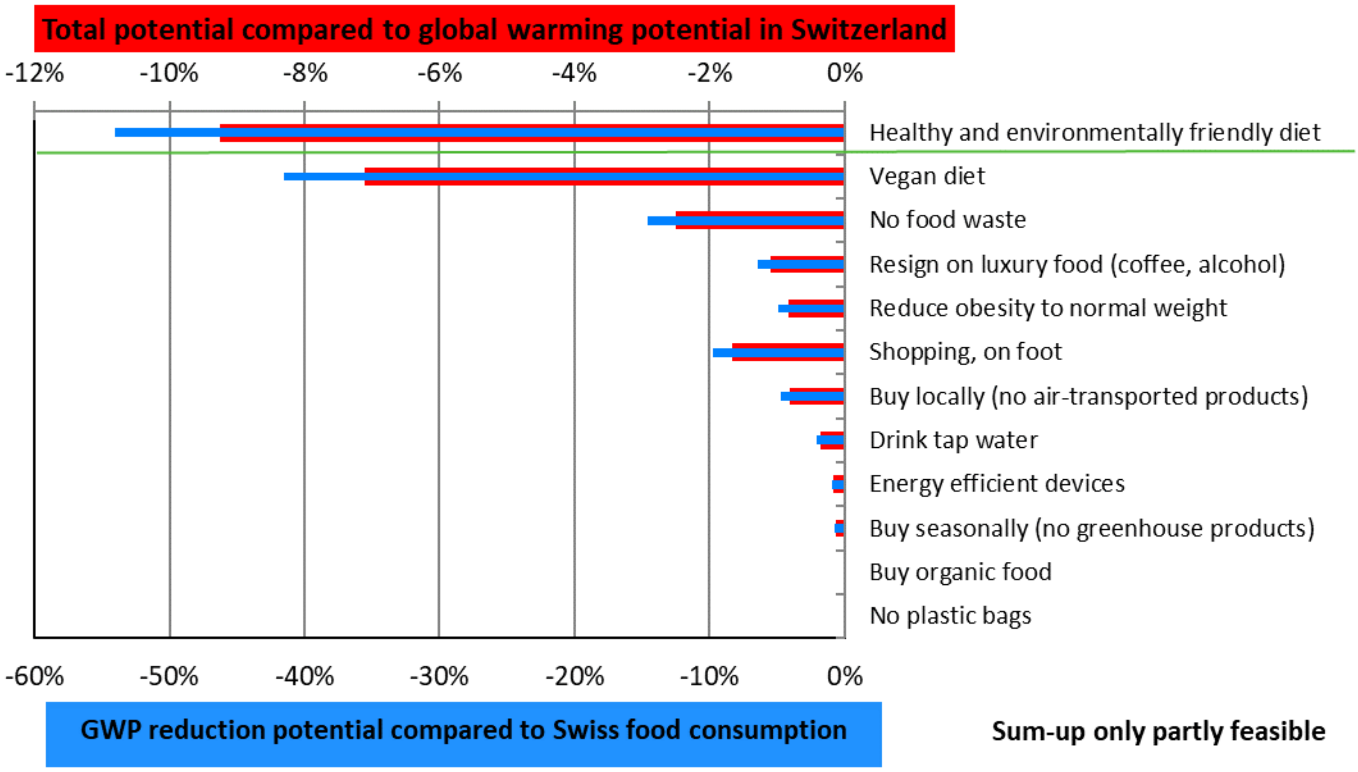


Fig. 4.2 Reduction potentials for global warming potential (20a, IPCC 2021) due to behavioural changes in food consumption

4.3 Reduction potentials in choice of diets and meals

Fundamental decisions on the type of food play a key role in the environmental impact caused. Fig. 4.3 shows the environmental impact of different diets in comparison. As already depicted before, the consumption of meat and other animal products contributes a major part to the environmental impact of the diet. Reducing meat (flexitarian diet) may already reduce the impact of the diet by one third compared to a meat- or protein-oriented diet. Completely dropping meat and animal products (vegan diet) reduces the environmental impact of the diet by more than half.

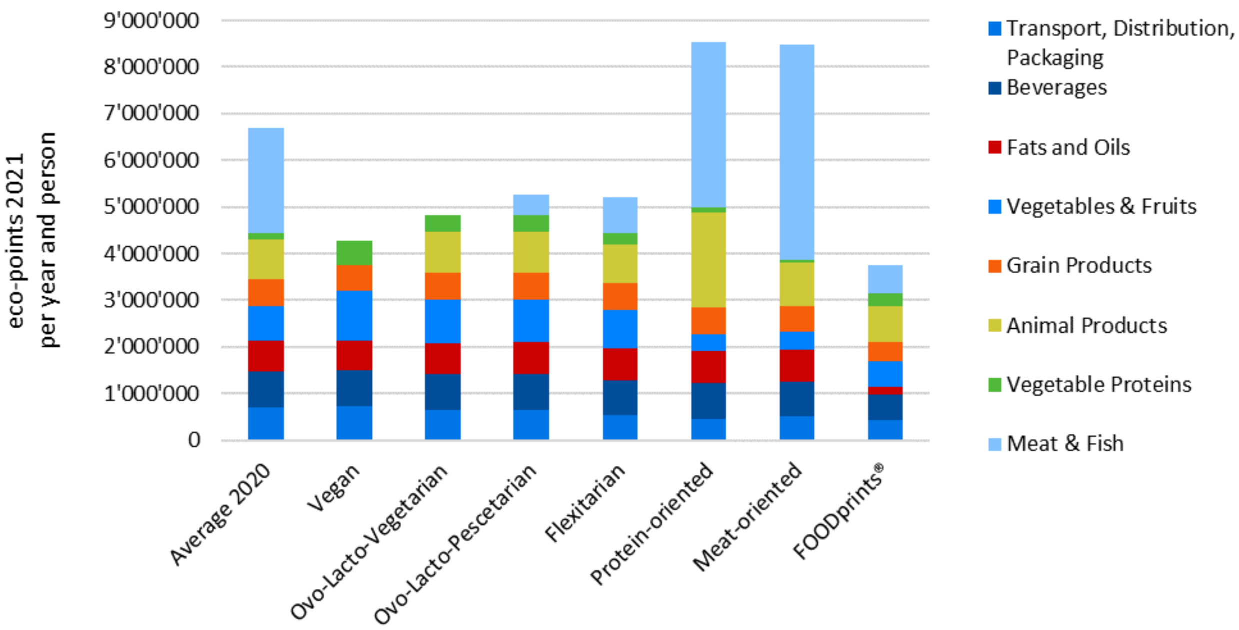


Fig. 4.3 Comparison of the environmental impact of different diets, showing the contribution of the different product groups in nutrition, measured with the ecological scarcity method 2021

If the environmental impacts of different canteen meals are compared, it becomes apparent that an average vegetarian meal causes about one third of the environmental impact compared to a meal containing meat (Fig. 4.4). The difference is mainly caused by the higher environmental impact per kilogramme of meat (Leuenberger & Jungbluth 2009).

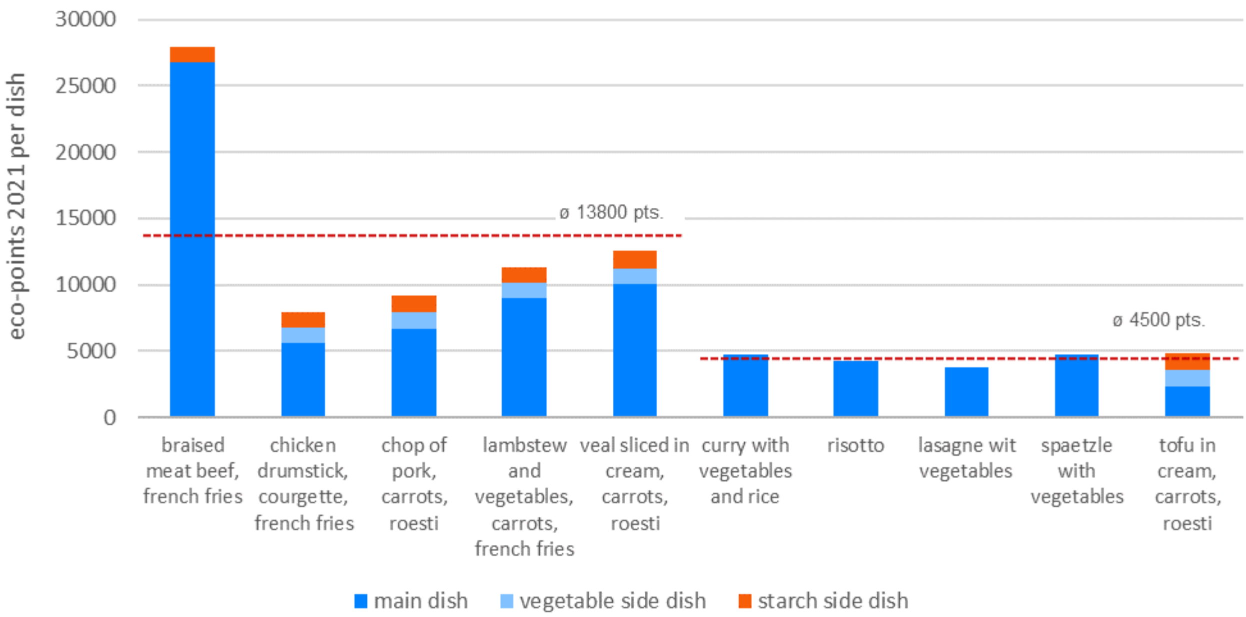


Fig. 4.4 Comparison of the environmental impacts of meat-based and vegetarian canteen meals.

4.4 Reduction potentials for daily nutrient intake

Tab. 4.1 shows the reduction potential for the total environmental impacts for the daily nutrient intake. The base line is the environmental impact due to the provision of nutrients with animal-based products. The reduction potential is investigated for the direct replacement with plant-based products (e.g. drinks instead of milk).

Proteins can be replaced very efficiently with several plant-based products and reductions of up to 90% for the environmental impacts can be achieved. It is more difficult to replace vitamin B12, which seems to be only possible with plant-based alternatives with added vitamin B12. For calcium and iron there also many good options.

Tab. 4.1 Reduction potential of the environmental impact (ecological scarcity method 2021) to achieve the daily nutrient intake for the replacement of animal-based food items with plant-based food items

Reduction potential of environmental impact	64 g protein	4 µg vitamin B12	1.5 g omega-3 fatty acids	1 g of calcium	15 mg iron	150 µg iodine	14 mg zinc[4]	1.4 mg riboflavin (vitamin B2)	15 µg vitamin D	70 µg selenium
Drink instead of cow milk	46%	-5%	70%	-2%	na	-37%	44%		-92%	-96%
Vegan cream instead cream	-35%	na	-67%	407%	-98%	na	na	na	na	na
Instead of red meat …										
Legumes	-81%	na	-46%	-98%	-96%	930%	-19%	51%	na	na
Meat subsitutes, vegan, minimally processed	-87%	17120%	-77%	-98%	-87%	-88%	-43%	105%	na	-97%
Meat subsitutes, vegan, highly processed	-82%	11%	-94%	-97%	-89%	na	na	na	na	na
Egg-based meat alternatives	-61%	99%	-63%	-95%	-46%	na	-88%	na	na	na
Instead of poultry …										
Legumes	-70%	na	-25%	-98%	-97%	6%	-89%	-74%	na	na
Meat subsitutes, vegan, minimally processed	-79%	2245%	-68%	-97%	-95%	-55%	-76%	43%	na	-87%
Meat subsitutes, vegan, highly processed	-72%	-85%	-91%	-97%	-96%	na	na	na	na	na
Egg-based meat alternatives	-40%	-73%	-48%	-94%	-79%	na	-95%	na	na	na
Instead of eggs …										
Legumes	-59%	na	168%	-63%	-76%	1640%	-69%	33%	na	na
Meat subsitutes, vegan, minimally processed	-72%	16307%	15%	-58%	-60%	636%	-31%	634%	na	-66%
Meat subsitutes, vegan, highly processed	-62%	5%	-68%	-43%	-65%	na	na	na	na	na
Egg-based meat alternatives	-17%	90%	86%	-10%	69%	na	-86%	na	na	na
vegetable oil instead of fish										
omega 3 rich	na	na	-94%	2489%	na	na	729%	na	na	na
omega 3 poor/ other oils	13140%	na	-89%	4293%	4147%	na	na	na	na	na
omega 9 rich	na	na	-100%	na	2217%	142734%	na	na	na	na

4.5 Reduction potentials for product groups

4.5.1 Meat and alternatives

As shown in Fig. 4.5, meat products, especially beef, veal, lamb, and fish (from fish-farming) lead to relatively high environmental impacts per kilogram. Insects or plant-based alternatives like tofu or Quorn can reduce that impact strongly. Reducing the demand for meat products and offering more meat-free meals, for example, therefore makes sense from an environmental point of view. Usually, plant-based alternatives generate less environmental impact than their animal-based equivalent. As already shown in Tab. 4.1, their consumption offers substantial reduction potential for environmental impacts.

Another problem with meat is the increased demand for particularly high-quality meat products (low-fat meat without bones, fat, etc.). Low-quality meat products can therefore no longer be used appropriately. Increasing the share of lower-quality meat products (e.g. whole poultry instead of just chicken breast) in the range of offered products could help to reduce the emissions associated with meat consumption. Transport, packaging, etc. are hardly relevant for meat products.

Concerning the total environmental impact, the situation for fish is similar to meat. Fishing respectively fish-farming are causing the main environmental impacts (Buchspies et al. 2011). In the case of wild catch, fuel consumption for ships and refrigeration is the most relevant factor. Also, the eco-factor for the use of biotic resources is an important contribution for the total environmental impact and should cover partly overfishing and damage on the marine ecosystems. For farmed fish, the production of feed and nutrient emissions from farming are important. As many fish products are purchased frozen, the storage time until consumption should be minimized to reduce environmental impacts.

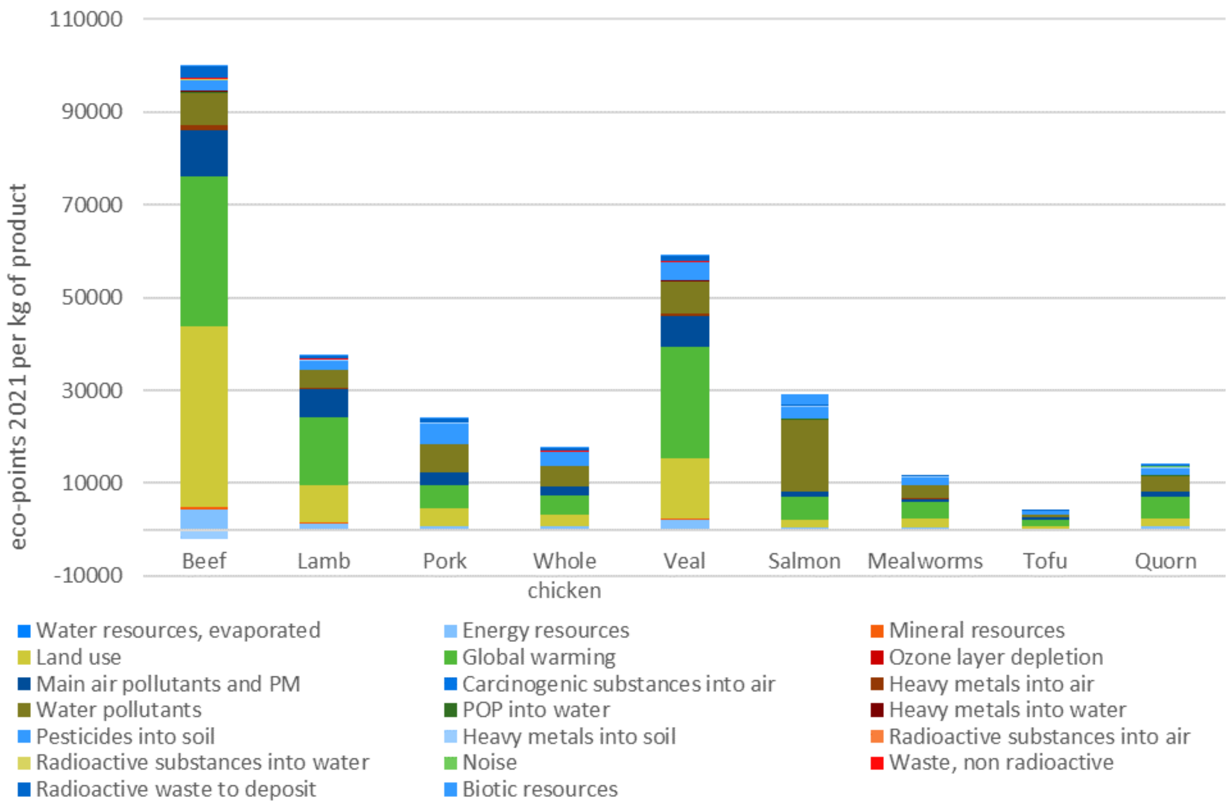


Fig. 4.5 Environmental impacts (ecological scarcity 2021 of different meats, fish, insects, and meat alternatives.

4.5.2 Dairy and egg products and alternatives

Alongside meat, dairy products are the group of foodstuffs consumed that account for a relatively high proportion of the total environmental impact. Here, too, agricultural production is in the foreground for many products, so that an influence seems possible primarily via labels.

Dairy products are often stored refrigerated, which is why this aspect must be considered when assessing environmental impacts. The use of non-refrigerated dairy products (e.g. UHT milk) could contribute to a reduction in greenhouse gas pollution.

In principle, the same applies to eggs as to meat products. As an animal product, agricultural production is the most key factor in terms of environmental impact.

For dairy and egg products, many substitutes are available. Same consequences as for meat alternatives apply here.

4.5.3 Vegetables and fruits

Overall vegetables and fruits are not a major issue for environmental impacts caused by food consumption. But, environmental impact can vary significantly between vegetables and fruits. The production steps, as described in chapter 3.4, like seasonality, cultivation type, transportation, processing, and packaging influence the environmental impact. Especially seasonality plays a significant role for fresh vegetables and fruits. If vegetables and fruits are purchased out of season, transport costs are generally higher, storage is necessary, or they are produced in heated greenhouses.

There are also huge differences between several types of vegetables. E.g. asparagus shows much higher impacts than carrots. A first hint may be given by the price. More expensive products often show lower yields in agriculture and thus need more efforts to be produced. On the other hand, for vegetables and fruits, a higher price can also come from organic production. However, no general conclusion can be given, and every type of vegetable or fruit must be considered individually.

4.5.4 Grains, potatoes, and legumes

This product group is supplying the energy in nutrition. Per calorific value, grains, potatoes and legumes have low environmental impacts compared to other product groups of food. By consuming wholegrain products (e.g. wholemeal wheat flour) environmental impact can be reduced compared to non-wholegrain products (e.g. white wheat flour). Generally, products which are less processed, which are produced in season, and which were transported only over short distances tend to have smaller impacts. Also, packaging should be reduced.

4.5.5 Oils, vegetable fats and nuts

This product group has high environmental impacts per kilogram and contribute an important share to the impact of food consumption. Especially oils of high nutritional value (e.g. olive oil or rapeseed oil) show high impacts. Reducing their consumption to a minimum and using cheaper oil like sunflower oil wherever else possible will reduce the impact of this group. Also, the use of plastic bottles instead of glass bottles (if not reused many times) reduces the impact of the oil products.

Nuts are high in nutrient content and deliver a lot of energy. On the other hand, they come with high environmental impact because of their elaborate production. Reducing their consumption to a minimum helps reducing the environmental impact.

4.5.6 Sweets and savoury treats

Quite different small items such as chocolate, potato chips, cookies, etc. belong to this product group. Due to relatively small packaging units, the packaging could be relevant in terms of environmental impact. Unnecessary secondary packaging or pure gift packaging should be avoided. However, the range of product types in this group is wide and therefore these products must be considered specifically to assess their environmental impact. Since this product group is of little or no nutritional value, reducing its consumption to a minimum would be most beneficial, from an environmental and a health perspective.

4.5.7 Beverages

The best option for provision of water is drinking tap water.

In the case of mineral water, transport and packaging are the most important criteria. As a rule, the smaller the bottle size, the higher the share of packaging in the total impact. Returnable bottles only make sense if the transport distance does not exceed 100 km.

In the case of fruit juices, wine and beer, the agricultural production required in each case is also important. Therefore, transport and bottle are less important for these products.

In the life cycle of coffee and tea the preparation by the heating of water is particularly important (Büsser & Jungbluth 2009d; Doublet & Jungbluth 2010). A critical point in the sale of filter coffee, can be the loss of undrunk product. From an environmental point of view, coffee cultivation is also important. Here, labels may be able to provide guidance. Transport and packaging are less relevant.

Conclusively, a reduction of consumption of alcohol, coffee and tea reduces the environmental impact from beverages and, when it comes to alcohol and coffee, is beneficial for health. With hydration being the main nutritional purpose of beverages, an increase of consumption of tap water as beverage and at the same time reducing other beverages, has great potential to reduce environmental impact.

4.6 Reduction potentials in preparation and consumption

Cooking (and baking) is a highly variable phase of the life cycle of food. Depending on the type of food and the form of cooking (e.g. at home or in a restaurant kitchen, in an oven or on the stove), the energy demand for cooking can contribute a remarkable share to the environmental impact of the dish. When cooking a vegetarian dish, the share of cooking will be bigger, since the environmental impact of vegetarian ingredients is smaller compared to a meat dish. However, the impact of cooking is highly variable. In general, it can be concluded, that cooking time should be reduced (as far as possible) and energy-efficient cooking devices should be used.

From comparisons of the amount of food produced with the amount consumed, it is known that considerable losses occur on the way from cultivation to the plate. Losses of food contribute significantly to the environmental impact caused, since the corresponding product was produced, transported and packaged around the clock. Losses occur when food spoils during storage, through waste during preparation and cooking, or when prepared food is not eaten because the portions are too large or too much has been prepared.

According to Beretta and Hellweg 2019, the amount of food spoiled by consumers in Western Europe is estimated to be about 92 kg per person per year. Over the entire life cycle, 330 kg/year are lost. This corresponds to about 37% of the amount of food produced, their study says. For Switzerland, a reduction potential of about 15 % would result if no more losses occur at the consumers. All actors in the life cycle can contribute to the reduction of this quantity and thus reduce the environmental impact. Unavoidable wet waste should be used as feed as far as possible. Where this is not possible, energetic use is preferable to composting, e.g. in sweeping incineration or in a biogas plant.

5 Conclusion

This report presents for the first time a detailed analysis and review on the environmental impacts of the Swiss nutrition system, food items and food groups. The report provides the scientific basis for revised nutritional recommendations related to the 3 pillars of sustainability - ecological, social and economic sustainability. This is done by assessing impacts on human health, ecosystems and resource depletion based on life cycle assessments.

In a global perspective, environmental impacts are a major driver of health impacts and premature deaths. Thus, possible advantages of a healthier diet must be confronted with recommendations that lead to higher environmental impacts. A compromise must be found which on the one side reduces health risks due to unhealthy consumption patterns and, on the other side, reduces risks for health, environment, and future perspectives from food production.

The study shows that the major conflict arises with the consumption of animal-based products. From an environmental perspective a replacement of animal-based products with plant-based products is necessary. Therefore, different options are analysed in this report.

Today, the Swiss population consumes more animal-based products than recommended. Thus, a reduction down to at least the recommended amounts could already provide a substantial reduction of environmental impacts. Therefore, it is also important to review the Swiss political incentives for an increased meat and milk consumptions (e.g. promotion via Proviande or Swissmilk, subsidies for animal-based agricultural systems). Such wrong incentives need to be avoided. The present policies of Swiss retailers to promote vegan or vegetarian products mainly/exclusively for the group of consumers with high environmental awareness and willingness to pay is also questionable. It would be very welcome if such products became mainstream and were no longer offered only to a certain target group.

Further improvements can be expected by substituting even more animal-based products with plant-based products. As diets might include many of these substitutes, it might be necessary to supplement such products with essential nutrients. So far, the environmental aspects of the production of such additives are not fully known and need further investigation.

In principle low-processed foods are often better from an environmental perspective than highly processed foods, but they often do not match the traditional choices of consumers. Therefore, processed plant-based products which imitate traditional animal-based products can be an important driver to achieve such a change in consumption habits.

Fish and marine products are not part of the traditional Swiss diet. Recommendations for an increased consumption are critical from an environmental and social perspective due to the present pressure on available fish stocks and the influence on poorer countries relying on fish in their traditional diet.

Other recommendations for a healthy diet e.g. for vegetables, fruits, beverages, grains and legumes are less critical from an environmental perspective. Recommendations for specific oil or fat-types should consider the intended application. For oils fully consumed (e.g. in salad, sauces or spread) it might be more justifiable to recommend high-quality, but also high-impact plant oils. For other applications e.g. in frying or roasting such a recommendation would be less appropriate as a relevant part of the oil stays uneaten. For such applications inexpensive, plant oils, produced with lower environmental impacts should be chosen.

The reduction of sugar, salt, alcohol, and fat in the diet, which seems most relevant from the health perspective, is also recommendable from an environmental point of view. Generally, preventing overconsumption of nutritionally unnecessary food reduces environmental impact and improves health.

Especially with regard to 42% of the Swiss population being considered overweight[19], reducing overconsumption may contain an important reduction potential. Sharply formulated, overconsumption can also be considered as food loss. However, this aspect is not further discussed in this study and needs additional research to quantify its potential.

The recommendations regarding a more sustainable diet presented in this study are mainly based on statistical production and processing data relevant for the Swiss situation. Therefore, the suggested prioritizations (e.g. plants instead of animals, less food waste, less products grown in greenhouses and no air-transport) are based on a solid foundation. However, for specific product-comparisons, there might be exceptions, e.g. if someone includes meat parts in the personal diet, which otherwise would be wasted (on a large scale, not just a one-time left-over filet in the store), the potential environmental impact of this choice might be lower than if a highly processed, plant-based product would have been chosen.

The proposed revisions for the Swiss recommendations according to this report are shown in Tab. 5.1.

While working on these recommendations we also recognized that it might be necessary to better address different target groups in the population with different nutritional demands. Especially for the single nutrients daily recommended intakes seem to be partly higher than what can be achieved with a normal diet. Thus, these recommendations need further revisions and adaptation to the needs of eg. Childs, women, men, elderly, active, or other groups of population.

19 https://www.bag.admin.ch/bag/de/home/gesund-leben/gesundheitsfoerderung-und-praevention/koerpergewicht/uebergewicht-und-adipositas.html, 09.03.2022

Tab. 5.1 Nutritional recommendations, including the sustainability aspects discussed in this report. Clarifications for better consideration of sustainability aspects marked in red.

Category	Portions/ day	Portion size	Preferred options
Sweets, sweetened beverages, luxury foods & alcohol	0	1 piece of sugar 10g chocolate 1 cup of coffee 3 dl Beer 1 dl wine	Enjoy only on special occasions and in moderation
Oils, fats & nuts		2-3 Tbsp vegetable oil 20-30g nuts / seeds 10g butter, margarine, cream	At least half the vegetable oil should be rape seed oil High value oils (olive, wheat germ, ..) should not be wasted for frying/roasting. Oils should be packed in environmentally friendly bottles (no heavy glass bottles).
Milk products, meat, fish, eggs & tofu	4	2dl plant drink / milk 150-200g yoghurt / quark/ cottage cheese 30g hard cheese / plant-based alternative 60g soft cheese/ plant-based alternative 150-200g quark /cottage cheese / plant-based alternative 2-3 eggs 100-120g seitan / tofu / meat / fish / Quorn / plant-based alternatives	3 milk products or plant-based drinks with calcium supplement 1 protein-rich food preferably with plant proteins (e.g. from soy, peas, whey). Balanced choice of all types of meat products (lean/low-fat, fatty, processed) to avoid food waste. Fish maximum once a month.
Grains, potatoes & legumes	3	75-125g bread / pastry 60-100g legumes 180-300g potatoes 45-75g crackers/ flour/ pasta/ rice / corn / grains	Wholemeal products
Vegetables & fruit	5	120g/ 2dl	3 vegetables, 2 fruit, juice can replace 1 portion Best choice seasonally grown fruits and vegetables If local seasonally grown, canned, or deep-frozen foods is not available food imported by ship, train, or truck should be preferred. No products from heated greenhouse or air-transported
Beverages		1-2 l	Tap water, herbal tea & in moderation: juices from seasonally grown fruits or concentrate

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A.Links

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More information about the Danish Dietary Guidelines: https://altomkost.dk/

B.Life cycle assessment methodology

B.1 General description

The International Organization for Standardization (ISO) standardised the general procedure for conducting an LCA in ISO 14040 (International Organization for Standardization (ISO) 2006a) and ISO 14044 (International Organization for Standardization (ISO) 2006b).

An LCA consists of four phases (Fig. 6.1):

- Goal and Scope Definition
- Inventory Analysis
- Impact Assessment
- Interpretation

Goal Definition includes describing the object of investigation. The environmental aspects to be considered in the interpretation are also defined here. *Scope Definition* includes describing modelling approaches, the identification and description of the key processes involved in the production of the object of investigation. The functional unit, which determines the basis for comparison, is also defined here.

The direct environmental impacts[20], the quantity of semi-finished products, auxiliary materials and energy required for the processes involved in the life cycle are determined and inventoried in the *Inventory Analysis*. These data are set in relation to the object of investigation, i.e. the functional unit. The outcome consists of the cumulative resource demands and emissions of pollutants.

The Inventory Analysis provides the basis for the *Impact Assessment*. Applying current evaluation methods to the inventory results in indicator values that are used for and referred to in the interpretation. ISO 14044 does not specify any specific methodology or support the underlying value choices used to group, normalise and weight the impact categories. The value-choices and judgements within these procedures are the sole responsibility of the authors and commissioner of the study.

Normalisation and weighting are introduced into ISO 14044 as optional elements of LCIA after classification and characterization. Weighting shall not be used in LCA studies intended to be used in comparative assertions[21] intended to be disclosed to the public. The draft ISO/TS 14074[22] shall provide further guidance for normalization, weighting, and interpretation. It states e.g. that weighting is based on value value-choices and is not scientifically based. Furthermore, all indicator results of the study, before weighting, shall be included in the LCA report.

In fully aggregating methods, different environmental influences are weighted, based e.g. on political interests. The authors of the ISO standards see this as an increased risk of misinterpretation. In our view, however, this is also possible when using non-aggregated results, as readers could possibly weight the different environmental impacts of e.g. 1 kg phosphate equivalent and 1 kg CO_2 equivalent equally.

Since most studies do not pursue this goal, a disclaimer can be used: "A comparative statement in the sense of the ISO standard, i.e. an environmental statement on the superiority or equivalence of a

20 Resource extraction and emission of pollutants

21 An environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function.

22 https://www.iso.org/standard/61117.html

product compared to a competing product with the same intended use, is not intended here. This eliminates the need for a review or a restriction regarding the use of fully aggregating indicators."[23]

The results of the inventory analysis and the impact assessment are analysed and discussed in the *Interpretation* according to the initially defined goal and scope of the LCA. Final conclusions are drawn and recommendations stated.

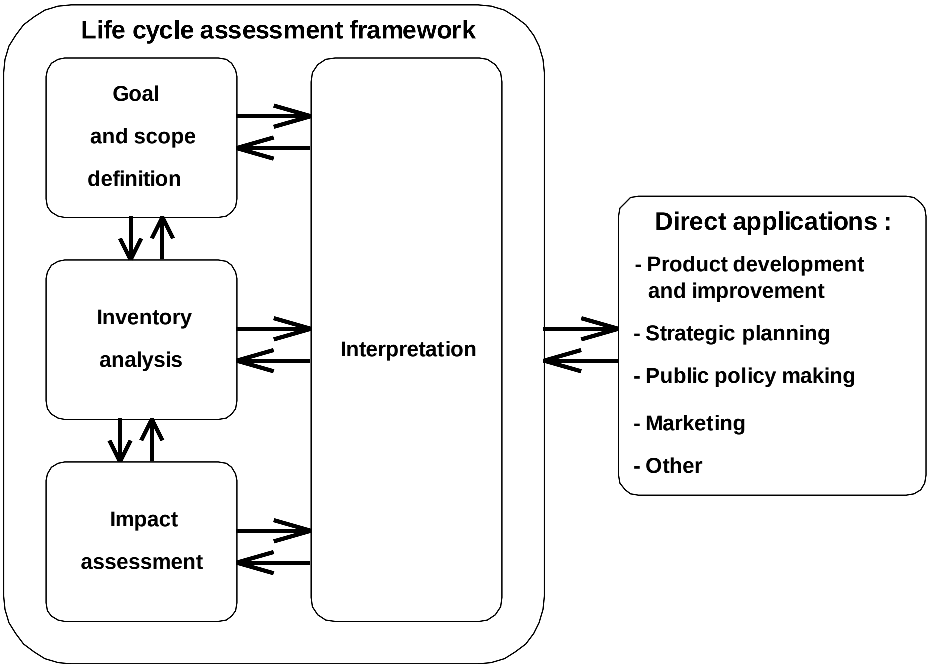

Fig. 6.1 Components of a life cycle assessment (LCA) according to the International Organization for Standardization

B.2 Swiss Ecological Scarcity Method 2021

The ecological scarcity method (BAFU 2021) evaluates the inventory results on a distance to target principle. The calculation of the eco-factors is based on one hand on the actual emissions (actual flow) and on the other hand on Swiss environmental policy and legislation (critical flow). These goals are:

- Ideally mandatory or at least defined as goals by the competent authorities,
- formulated by a democratic or legitimised authority, and
- preferably aligned with sustainability.

The weighting is based on the goals of the Swiss environmental policy; global and local impact categories are translated to Swiss conditions, i.e. normalised. The method is applicable to other regions as well. Eco-factors were also developed for the Netherlands, Norway, Sweden (Nordic Council of Ministers 1995, Tab. A22 / A23), Belgium (SGP 1994), Germany (Ahbe et al. 2014) and Japan (Miyazaki et al. 2004). The ecological scarcity method allows for an optimisation within the framework of a country's environmental goals.

[23] https://video.ethz.ch/events/lca/2019/autumn/72nd/e54eee95-f0dd-4915-84e7-18b7a8a47b7f.html
https://www.lcaforum.ch/portals/0/df72/DF72-02_Buxmann.pdf

The environmental and political relevance is essential for the choice of substances. The environmental policy does by far not define goals for all substances. Thus, the list of eco-factors is limited. This particularly applies to substances with low or unknown environmental relevance in Switzerland and Europe (e.g. sulphate emissions in water bodies).

The Method of ecological scarcity allows the weighting of the resource withdrawals and pollutant emissions recorded and calculated in a Life Cycle Inventory. The basic principles of the method were first developed in 1978 (Müller-Wenk 1978). The first update took place in 1998 (Brand et al. 1998). Another update took place between 2005, 2008 and 2013 (Frischknecht et al. 2008; Frischknecht et al. 2013). The most recent version was published in 2021 (BAFU 2021).

The method of ecological scarcity is based on the "distance-to-target" principle. It uses the total current fluxes of an environmental impact (e.g. nitrogen oxides) of a country on the one hand and the fluxes of the same environmental impact that are considered maximum permissible (critical) within the framework of the environmental policy objectives of the respective country on the other. Both critical and current fluxes are defined in relation to Swiss conditions.

Fig. 6.2 shows a simplified procedure for this assessment method. This shows that the classification and characterisation steps are only carried out for part of the environmental problems. Otherwise, the environmental impacts (emissions and resource consumption) and waste quantities from the Life Cycle Inventory are weighted directly.

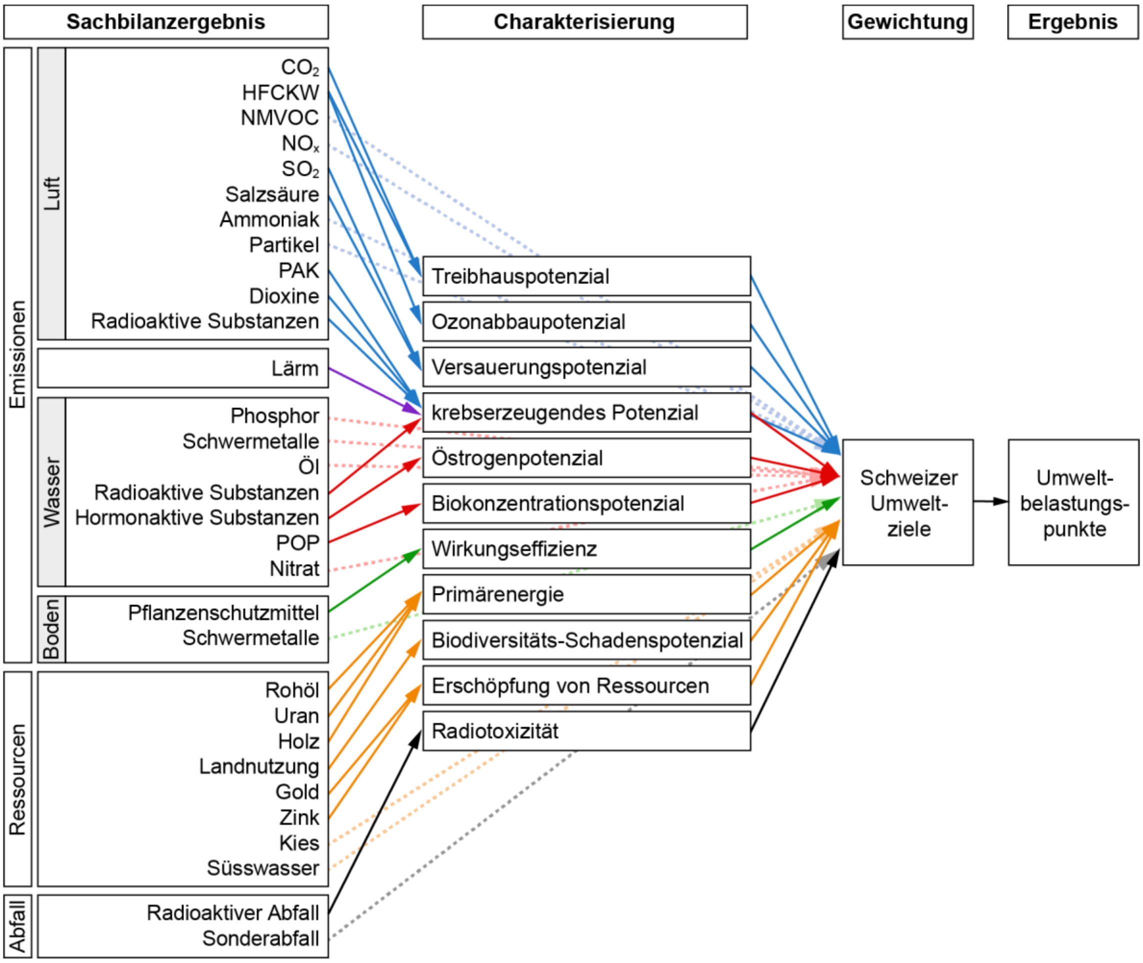

Fig. 6.2 Schematic illustration of the method of ecological scarcity 2013 (Frischknecht et al. 2013)

The evaluation is carried out using ecofactors which are defined as follows:

$$\text{Ecofactor} = \underbrace{K}_{\substack{\text{characterization}\\\text{(optional)}}} \cdot \underbrace{\frac{1 \cdot \text{UBP}}{F_n}}_{\text{normalization}} \cdot \underbrace{\left(\frac{F}{F_k}\right)^2}_{\text{weighting}} \cdot \underbrace{c}_{\text{constant}} \qquad (8.1)$$

with: **K** = **Characterisation factor** of a pollutant or resource

Flow = Cargo of a pollutant, consumption quantity of a resource or quantity of a characterised environmental impact

Fn = **Normalisation flow**: Current annual flow, relative to Switzerland

F = **Current flow**: Current annual flow, related to the reference area.

Fk = **Critical flow**: Critical annual flow relative to the reference area.

c = **Constant (1012/a)**

UBP = **Environmental Impact Point**: Unit of the evaluated result.

Factor c is identical for all ecofactors and serves to improve the manageability of the numbers. The first factor is used for characterisation and is applied to pollutants (or resources) that have the same environmental impact (e.g. climate change). The characterisation factor is optional in this method, i.e. not all pollutants are characterised in this method. The second term is used for standardization/normalization and contains the denominator of today's Swiss flux. This is either given in characterised form (e.g. tonnes of CO2 equivalents per year) if a characterisation factor is applied to the relevant pollutant, or in its original form (e.g. tonnes of PM10 per year) if the pollutant has no characterisation factor. The third term contains the weighting step. Here the current emissions on the one hand and the targeted emission goal on the other hand are put into proportion and squared.

The ratio of current to critical flow is taken into account as a square. This has the effect that strong overruns of the target value (critical flow) are weighted disproportionately and strong underruns are weighted disproportionately, i.e. an additional emission is weighted more strongly the higher the pollution situation already is.

According to the authors of the method, waste is assessed according to the precautionary principle. This procedure does not comply with the requirements of ISO 14044 for the definition of environmental indicators (International Organization for Standardization (ISO) 2006b). The derivation of eco-factors for individual pollutants also does not follow the specifications of the ISO standard, as these are only partially grouped according to environmental problems. These two indicators should therefore not be used for ISO-compliant life cycle assessments.

Thousands of eco-points (1000 UBP) correspond to the reference values shown in Tab. 6.1.

Tab. 6.1 Reference values for products and services causing 1000 eco-points

MoeK21	Thousand eco-points equal …
1'489.5	litres of tapwater from Switzerland
4.0	centimeters road, used for one year
1.0	kilograms of fossil CO2, directly emitted
0.033	kilograms of fossil methane, directly emitted
1.30	grams copper input into agricultural soil
0.73	litres crude oil produced, with transport to the refinery
35.7	kilograms of gravel mining
0.5	grams pesticide application in agriculture
1.4%	of a person's private daily consumption in Switzerland, 2018
1.3%	the daily consumption of a person in Switzerland
2.7	km transport of one person by plane
2.9	km transport of one person by car (occupancy 1.6 persons)
65.4	km transport of one person by bicycle
4%	of a vegetarian menu with 4 courses
3%	of a meaty 3-course menu
5%	of the daily food consumption of a person in Switzerland, 2018
20.3	plastic carrier bags (production, distribution and disposal)
0.043	cotton T-Shirts
0.17%	of the production of a laptop
23%	of daily consumption for hobbies/leisure activities in Switzerland, 2018
42%	of daily consumption of furniture and household appliances in Switzerland, 2018

B.3 Global Warming Potential 2021 (GWP)

Global Warming Potential (GWP), commonly referred to with the popular term carbon footprint (CF), calculates the radiative forcing over different time horizon. It assesses the potential impact of different gaseous emissions on climate change (IPCC 2021).

Climate change is a global problem that leads to several different direct and indirect effects on human health, man-made infrastructures and environmental damages such as:

- warmer or colder temperatures at certain places and times
- changes in the amount, annual distribution and magnitude of rainfalls and snowfalls
- changes in the magnitude of wind velocities
- melting of glaciers leading to disappearance of permafrost areas, higher sea level and changes in salinity
- acidification of oceans due to higher concentration of carbonic acid
- changes in local or global climate phenomena such as the gulf stream, monsoon seasons, etc.

There is no mechanism to clean up this damage and these emissions. Emissions today will lead to long lasting changes in the climate system of the earth.

The residence time of the substances in the atmosphere and the expected immission design are considered to determine the global warming potentials. The potential impact of the emission of one kilogram of a greenhouse gas is compared to the potential impact of the emission of one kilogram CO_2 resulting in kg CO_2-equivalents (kg CO_2-eq).

The gases with the greatest global warming impact are CO_2, CH_4 (methane) and N_2O (nitrous oxide). In addition, various chlorinated and fluorinated hydrocarbons (CFCs, HCFCs, HFCs, PFCs) and SF6 have a direct radiative forcing effect. While the global warming impact of the latter substances per kilogram can be several thousand times greater than that of CO_2, their contribution to the overall emissions inventory is often small.

Global warming potentials can be determined applying different time horizons (20, 100 and 500 years). The short integration period of 20 years is relevant because a limitation of the gradient of change in temperature is required to secure the adaptation ability of terrestrial ecosystems. The long integration time of 500 years is about equivalent with the integration until infinity. This allows monitoring of the overall change in temperature and thus the overall sea level rise, etc.

Most studies present results for a time horizon of 100 years. For our studies, we show results for time horizon of 20 and 100 years is chosen. This seems to be necessary as there are urging challenges in the short time perspective to avoid irreversible damage to the climate system on the earth.

There are specific effects of emissions in high altitude, which lead to a higher contribution of aviation to climate change than just due to the emission of CO_2 from burning aviation fuels. The exact relevance is subject to scientific debate, but there is a consensus that aircrafts have an impact that is higher than just their contribution due to the direct CO_2. The gap between this scientific knowledge on the one side and the absence of applicable GWP (global warming potential) factors on the other side is an important shortcoming for life cycle assessment or carbon footprint studies which aim to cover all relevant environmental impacts of the services or products investigated (Jungbluth 2013). As transportation by aircraft has high relevance in this assessment, some sensitivity analyses with an adaptation of the IPCC methodology are included in the assessment. Therefore a factor for the RFI (radiative forcing index) is included. This better represents the state of the art concerning the accounting of specific aircraft emissions. For the time being an RFI of 2 on total aircraft CO_2 (or 5.2 for the CO_2 emissions in the higher atmosphere) is the best-practice approach because it is based on recent scientific publications, this basic literature cannot be misinterpreted. Furthermore it is also recommend by some political institutions (Jungbluth 2013).

Tab. 6.2 shows typical reference values for products and services causing an global warming potential of 1 kg CO_2-eq. The IPCC Method with the RFI Factor was used.

Tab. 6.2 Reference values for products and services causing 1kg CO_2-eq

GWP 20a	GWP 100a	1 kg CO2-eq equals...
3'131.2	3'594.7	litres of tapwater from Switzerland
6.5	8.7	centimeters road, used for one year
1.0	1.0	kilograms of fossil CO2, directly emitted
0.012	0.034	kilograms of fossil methane, directly emitted
0.93	1.76	litres crude oil produced, with transport to the refinery
2.9%	3.4%	of a person's private daily consumption in Switzerland, 2018
2.8%	3.3%	the daily consumption of a person in Switzerland
3.3	3.7	km transport of one person by plane
4.2	5.1	km transport of one person by car (occupancy 1.6 persons)
104.9	124.6	km transport of one person by bicycle
8.2%	10.2%	of a vegetarian menu with 4 courses
4.9%	6.4%	of a meaty 3-course menu
12.0%	18.6%	of the daily food consumption of a person in Switzerland, 2018
26.8	26.8	plastic carrier bags (production, distribution and disposal)
0.109	0.109	cotton T-Shirts
0.47%	0.47%	of the production of a laptop
41%	53%	of daily consumption for hobbies/leisure activities in Switzerland, 2018
77%	97%	of daily consumption of furniture and household appliances in Switzerland, 2018

B.4 PEF - European environmental footprint method (2018)

The PEF (Product Environmental Footprint) method is the impact assessment method of the Environmental Footprint initiative. The implementation is based on EF method 2.0.[24] The approach is a further development of the ILCD method (European Commission et al. 2011). It contains some updates and includes normalization and weighting.

Sources:

- Characterization (Andreasi Bassi et al. 2023)
- Normalization and weighting sets from Annex 2 of the Product Environmental Footprint Category Rules Guidance.
- Normalization: World population used to calculate the NF per person: 6895889018 people; Source: United Nations, Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision, DVD Edition – Extended Dataset (United Nations publication, Sales No. E.11.XIII.7).
- Weighting: Sala S., Cerutti A.K., Pant R., Development of a weighting approach for the Environmental Footprint (Sala et al. 2018).

A description of the impact categories considered can be found in Tab. 6.3

24 https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

Tab. 6.3 Midpoint impact categories used in this study (European Commission 2010; Fazio et al. 2018)

Impact category	Impact assessment model	Indicator unit	Source
Acidification	Accumulated Exceed-ance model	mol H+ eq	Posch et al. 2008 Seppälä et al. 2006
Climate change	Radiative forcing as global warming potential over a time horizon of 100 years	kg CO_2 eq	IPCC 2013 + JRC adap-tions
Ecotoxicity freshwater	USEtox® 2.1	CTUe	Rosenbaum et al. 2008
Particulate matters	Disease incidence model	Disease incidence	Fantke et al. 2016
Eutrophication terrestrial	Accumulated Exceed-ance model	mol N eq	Posch et al. 2008 Seppälä et al. 2006
Eutrophication freshwater	EUTREND model	kg P eq	Struijs et al. 2009 as ap-plied in ReCiPe
Eutrophication marine	EUTREND model	kg N eq	Struijs et al. 2009 as ap-plied in ReCiPe
Human toxicity, cancer effects	USEtox® 2.1	CTUh	Rosenbaum et al. 2008
Human toxicity, non-cancer effects	USEtox® 2.1	CTUh	Rosenbaum et al. 2008
Ionizing radiation	Human Health effect model	kg U^{235} eq (to air)	Frischknecht et al. 2000
Land use	Soil quality index as in LANCA model	Pt	Horn et al. 2018
Ozone depletion	EDIP model based on the ODPs of the World Mete-orological Organization (WMO) over a time hori-zon of 100 years	kg CFC-11 eq	WMO 2014 + integrations from other sources
Photochemical ozone for-mation	LOTOS-EUROS model	kg NMVOC eq	Van Zelm et al. 2008 as applied in ReCiPe
Resource use, fossils	CML model	MJ eq	van Oers et al. 2002
Resource use, minerals and metals	Ultimate reserves model	kg Sb eq	van Oers et al. 2002
Water scarcity	AWARE model	m^3 deprived	Boulay et al. 2018

Tab. 6.4 shows typical reference values for this impact assessment method.

Tab. 6.4 Reference values for products and services causing one thousandth EF point

EF3.0	One milli-eco-point equals …
20'076.2	litres of tapwater from Switzerland
0.8	centimeters road, used for one year
38.4	kilograms of fossil CO2, directly emitted
1.0	kilograms of fossil methane, directly emitted
0.04	grams copper input into agricultural soil
8.9	litres crude oil produced, with transport to the refinery
0.13	grams pesticide application in agriculture
24%	of a person's private daily consumption in Switzerland, 2018
23%	the daily consumption of a person in Switzerland
95.9	km transport of one person by plane
59.1	km transport of one person by car (occupancy 1.6 persons)
1'368.4	km transport of one person by bicycle
92%	of a vegetarian menu with 4 courses
65%	of a meaty 3-course menu
129%	of the daily food consumption of a person in Switzerland, 2018
2.2	plastic carrier bags (production, distribution and disposal)
0.18	cotton T-Shirts
1.1%	of the production of a laptop
318%	of daily consumption for hobbies/leisure activities in Switzerland, 2018
567%	of daily consumption of furniture and household appliances in Switzerland, 2018

B.4.1 Climate Change

Impact indicator: Global Warming Potential 100 years

Baseline model of the IPCC 2013 (IPCC 2013) and some additional factors calculated by the JRC.

Ozone depletion

Impact indicator: Ozone Depletion Potential (ODP) calculating the destructive effects on the stratospheric ozone layer over a time horizon of 100 years.

Ionising radiation - human health

Impact indicator: Ionizing Radiation Potentials: Quantification of the impact of ionizing radiation on the population, in comparison to Uranium 235.

Photochemical ozone formation - human health

Ozone and other reactive oxygen compounds are formed as secondary contaminants in the troposphere (close to the ground). Ozone is formed by the oxidation of the primary contaminants VOC (Volatile Organic Compounds) or CO (carbon monoxide) in the presence of NOx (nitrogen oxides) under the influence of light.

Impact indicator: Photochemical ozone creation potential (POCP): Expression of the potential contribution to photochemical ozone formation.

The method used includes spatial differentiation and is only valid for Europe. Considering a marginal increase in ozone formation, the LOTOS-EUROS spatially differentiated model averages over 14000 grid cells to define European factors.

B.4.2 Respiratory inorganics

Impact indicator: Disease incidence due to kg of PM2.5 emitted

The indicator is calculated applying the average slope between the Emission Response Function (ERF) working point and the theoretical minimum-risk level. Exposure model based on archetypes that include urban environments, rural environments, and indoor environments within urban and rural areas.

B.4.3 Non-cancer human health effects

Impact indicator: Comparative Toxic Unit for human (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogramme).

USEtox consensus model (multimedia model). No spatial differentiation beyond continent and world compartments. Specific groups of chemicals require further works (cf. details in other sections).

B.4.4 Cancer human health effects

Impact indicator: Comparative Toxic Unit for human (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogramme).

USEtox consensus model (multimedia model). No spatial differentiation beyond continent and world compartments. Specific groups of chemicals require further works (cf. details in other sections).

B.4.5 Acidification terrestrial and freshwater

Impact indicator: Accumulated Exceedance (AE) characterizing the change in critical load exceedance of the sensitive area in terrestrial and main freshwater ecosystems, to which acidifying substances deposit.

B.4.6 Eutrophication freshwater

Impact indicator: Phosphorus equivalents: Expression of the degree to which the emitted nutrients reaches the freshwater end compartment (phosphorus considered as limiting factor in freshwater).

European validity. Averaged characterization factors from country dependent characterization factors.

B.4.7 Eutrophication marine

Impact indicator: Nitrogen equivalents: Expression of the degree to which the emitted nutrients reaches the marine end compartment (nitrogen considered as limiting factor in marine water).

B.4.8 Eutrophication terrestrial

Impact indicator: Accumulated Exceedance (AE) characterizing the change in critical load exceedance of the sensitive area, to which eutrophying substances deposit.

B.4.9 Ecotoxicity freshwater

Impact indicator: Comparative Toxic Unit for ecosystems (CTUe) expressing an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a chemical emitted (PAF m3 year/kg).

USEtox consensus model (multimedia model). No spatial differentiation beyond continent and world compartments. Specific groups of chemicals requires further works (cf. details in other sections).

B.4.10 Land Use

Impact indicator: Soil quality index

CFs set was re-Calculated by JRC starting from LANCA® v 2.2 as baseline model. Out of 5 original indicators only 4 have been included in the aggregation (physico-chemical filtration was excluded due to the high correlation with the mechanical filtration).

B.4.11 Water scarcity

Impact indicator: m3 water eq. deprived.

Relative Available WAter REmaining (AWARE) per area in a watershed, after the demand of humans and aquatic ecosystems has been met (Boulay et al. 2018).

B.4.12 Resource use, energy carriers

Impact indicator: Abiotic resource depletion fossil fuels (ADP-fossil); based on lower heating value

ADP for energy carriers, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). Depletion model based on use-to-availability ratio. Full substitution among fossil energy carriers is assumed.

B.4.13 Resource use, mineral and metals

Impact indicator: Abiotic resource depletion (ADP ultimate reserve)

ADP for mineral and metal resources, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). Depletion model based on use-to-availability ratio. Full substitution among fossil energy carriers is assumed.

B.4.14 Long-term emissions

Environmental impacts from long-term emissions are generally not taken into account by ESU. The assessment including long-term emissions showed high impacts in the category eutrophication, freshwater due to phosphates from coal mining spoil heaps. It can be assumed that there is a high degree of uncertainty in the background database here, which cannot be corrected within the framework of individual studies. In the authors' view, other aspects also speak against assigning a high weight to long-term emissions in the LCA assessment (cf. the detailed discussion in Frischknecht et al. 2007b).

